BIM-MATURITY MEASUREMENT WITHIN THE METAL FAÇADE INDUSTRY

Positioning the current BIM-maturity level of the metal façade industry to provide practical and valuable insights for improvements

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PREFACE

The final stage of the master program Construction Management and Engineering at the University of Twente requires an academic research. For the purpose of this academic study, research is conducted in this field and is documented in this report.

The research topic was easily chosen due to my high interest in Building Information Modeling (BIM). BIM has emerged as a new construction management method in the construction industry in the last decade. Therefore, a considerable increase in the use of BIM has been witnessed in the construction industry globally, but also in the Netherlands. Different sub sectors have been implementing BIM in the Netherlands, including the manufacturing sector. Due to limited academical research of BIM developments, its implementation and therefore performance measurements within this sub sector, the interest to study this grew. Based on the research interest of the VMRG, an association for manufacturing organizations of metal (aluminum and steel) façade elements, the research area was narrowed down to the metal façade industry. Preliminary research revealed that at the current moment manufacturing organizations of the metal façade industry lack the knowledge of their own BIM competences and performances Therefore, it was of interest of the VMRG to have a research conducted that positioned the BIM-maturity level of the metal façade industry by measuring the BIM-maturity level of their members. Additionally, the association was also curious on how the current maturity level of the industry could be improved.

This research begins with acquiring some background information of the association accompanied with field exploration to elaborate on the motive of the research and problem-oriented theory. This followingly lead to the problem statement, research objective and question(s). To answer the research question(s) a multiple case study design was utilized with a qualitative data collection approach, in the form of in-depth interviews. The results provide a comprehensive view of the BIM-maturity level of the metal façade industry, but also give an indication of the extent of BIM use and implementation problems within the industry. These findings are then used to provide practical and valuable insights on how the metal façade industry can implement BIM properly to increase their current BIM-maturity level.

To achieve these results the help of several persons was required. My first acknowledgement of gratitude goes to the supervisors of the University of Twente: Hans Voordijk, Bram Entrop and Sander Siebelink. I am grateful to them for the provision of necessary expertise and guidance to complete this academical research. I would also like to thank the VMRG and their employees for their helpfulness and support. In particular I would like to thank Stingo Huurdeman for his practical guidance, support and expertise as an external supervisor. Finally, I am the many organizations grateful for their willingness to participate in this research.

Raysha Ramautarsing

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CONTENTS

SUMMARY

Motive and problem description
The adoption of Building Information Modeling (BIM) has increased enormously during the last two decades in the construction industry due to the many recognized benefits it is supposed to yield during different project lifecycle stages. BIM has also emerged as a new construction management method in the construction industry in the last decade. These developments have also not ignored the Netherlands and its different sub sectors. According to the VMRG, an association for manufacturers of metal (steel and aluminum) façade elements, the urge to implement BIM within this specific domain of the manufacturing sector has also emerged. However, at the current moment, organizations belonging to the metal façade industry lack the knowledge of their own BIM competences and performances which is required for successful BIM implementation. Without the knowledge of own competences and performances, no meaningful performance improvements may be achieved, financial investments may be misplaced and much efficiency may be lost.

Objective
Based on the problem statement, this study aims to position the BIM-maturity level of the metal façade industry by measuring the BIM-maturity level of the members of the VMRG, to provide practical and valuable insights on how the industry can improve its current BIM-maturity level.

Research sample and strategy
It was of main interest of the VMRG to have the members of their BIM work group included in the research sample. The BIM work group is founded by the VMRG to establish uniformed agreements on the implementation of BIM and therefore, to facilitate BIM developments within the façade industry. In total 11 organizations of the BIM work group (n=11) showed interest and were willing to cooperate for the purpose of this research. For generalizability of the findings also members outside the BIM work group were approached for participation. Two organizations that were willing to participate, were added as a separate group, the non-BIM work group (n=2), to the research sample (n=13). To measure the BIM-maturity level of the research sample, a multiple case study research design was utilized with a qualitative data collection approach, in the form of in-depth interviews.

Methodology
In order to measure the BIM-maturity of each organization of the research sample it was needed to determine a BIM measurement tool for assessment. Therefore the emphasis had been put on the demands of the VMRG and the following data quality dimensions: (1) the reliability of the tool, (2) its validation within the construction industry and (3) the completeness. The point of departure here was the measurement tool developed by Siebelink (2017). The tool was assessed as appropriate to measure the BIM-maturity level of the members of the VMRG.

The tool of Siebelink itself consists of two parts: the best practices and maturity model. The best practices includes several questions to identify the extent of BIM use and the drivers and barriers regarding the implementation of BIM. This part of the measurement tool is necessary to consider the findings within the right context and therefore, to justify and comprehend the obtained scores. The maturity model itself is consisting of six criteria, eighteen sub criteria, six maturity levels and a set of follow up questions per sub criteria to actually measure the BIM-maturity level

of each member. To collect the data, the best practices and maturity model were translated into a format to interview representatives of each organization.

Results

According to the collected data, the maturity level of the manufacturing organizations fluctuates between 1.6 and 4.0. These individual organization scores equal an average BIM-maturity of 2.5 for the metal façade industry. Findings also show that organizations that participate within the BIM work group score higher than organizations that do not participate within the BIM workgroup. However, due to the small sample size of the non-BIM work group the reliability of this finding is limited.
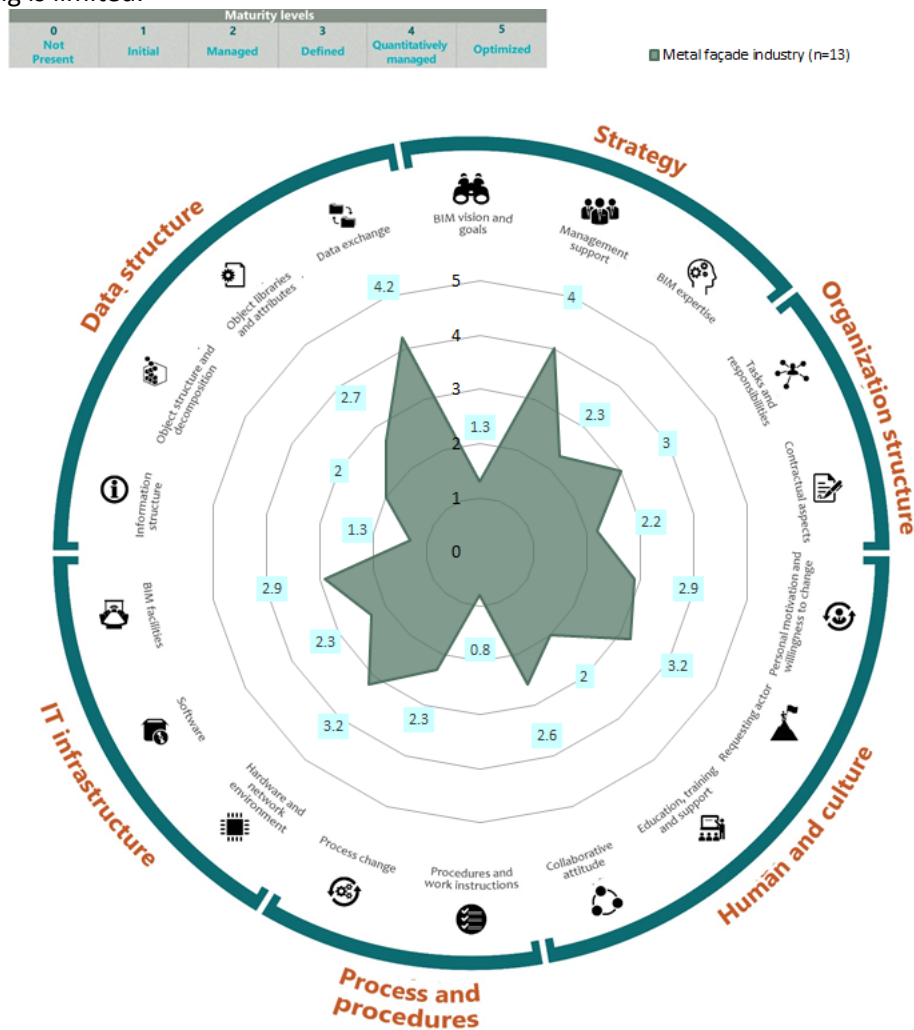
Figure 1 Representation BIM-maturity scores metal façade industry

Furthermore, the results also show some remarkable measurements. According to the peaks illustrated in Figure 1, the industry scores remarkably high on the sub criteria management support and data exchange. However, the drops implicate that currently within the industry BIM visions and goals and BIM-related work instructions are lacking or defined to a limited extent, and that the use of a document management system is usually limited or not enforced into work instructions.

In comparison with sector analysis held in 2014 and 2016 (University of Twente, 2014; Siebelink, 2017) BIM developments have grown within the manufacturing sector. However, these developments are limited to a maturity assessment within a specific domain of the manufacturing sector, the metal façade industry.

Findings also show that the metal façade industry is mainly driven by client request or market demand to implement BIM. Otherwise, industry organizations are driven to implement BIM to take the lead within the industry and therefore point out several drivers such as: the reduction of errors and failure costs, efficient data streams and communication, efficient manufacturing process and a better end product for the client with possibilities for maintenance.

However, several barriers are also found that hamper the implementation of BIM and affect the current BIM-maturity level negatively. Currently, there is a **lack of client request** which mainly occurs due to the fact that the industry is driven by market demand. In order to keep track on fast BIM developments, the manufacturing organizations only implement what is requested by the client. This is also substantiated by the barrier that involves the **lack of time to implement BIM** and specific BIM uses**.** Therefore, the definition of BIM goals and BIM-related procedures and work instructions might often be lacking or defined to a limited extent. Furthermore, **projects are not regarded complex enough** by industry organizations to implement BIM and therefore, executed traditionally, since this happens to be easier and faster. The initial investments to implement BIM also seem to impede the implementation of BIM, which is substantiated by **the lack of skilled personnel and education** and **high software and hardware costs**. At the current moment, general BIM guidance and support is lacking within the industry and BIM software can often not execute advanced BIM uses. Moreover, **not all project partners with whom industry organizations collaborate with are perceived to have the same BIM competences** which is expressed through limited application of contractual guidelines in practice and the lack of quality and detail of delivered models to execute certain BIM uses. Lastly, **software shortcomings** and incompatibility hinder the implementation of several BIM uses.

Conclusion and recommendations

Based on the drops illustrated in Figure 1, abovementioned barriers and certain lower than average BIM-maturity scoring sub criteria, several areas of improvement are defined. Therefore, in order to increase the BIM-maturity level of the metal façade industry, it is important for each manufacturing organization to develop a detailed BIM execution plan to effectively integrate BIM into their organizational or project delivery processes. It is necessary for the execution plan to firstly include the definition of BIM value for each organization in order to establish BIM visions and goals. Additionally, at the beginning of the implementation process within a project or the organization itself, it is recommended for each organization to align the BIM uses they wish to implement with their resources and available infrastructure. Therefore, organizations need to determine which software platforms and hardware are appropriate for the majority of BIM uses they wish to implement. By outlining their current capabilities against the required or desired capabilities, industry organizations can also get an idea when additional staff will need to be acquired or when staff will need to trained on new BIM technologies. It is recommended for organizations to have multidisciplinary work groups or experts supporting the implementation process of BIM. Furthermore, it is also recommended for industry organizations to document uniformed BIM-related work instructions and procedures. When implementing BIM in a project, ideally more integrated contracts and delivery methods are preferred to facilitate information and risk sharing and therefore, collaboration. Also, for the purpose of collaboration and information exchange is it of great essence to have object decompositions aligned with project partners and sector standards. Lastly, also for the purpose of smooth collaboration, it is of great importance for each organization to define a document management system. The VMRG can also encourage the implementation of BIM within the metal façade industry by enforcing implementation stimulating requirements in their Quality Mark.

1. INTRODUCTION

This report covers a research that regards the BIM-maturity measurement within a specific domain of the manufacturing sector in the Dutch construction industry, the metal façade industry. This research is executed on behalf of the guest organization, the VMRG (Verenging Metalen Ramen en Gevelbranche) and under supervision of the University of Twente. This introductory chapter explicitly describes the developments around the subject and therefore the motive if this research. Based on this, the problem, the research objective, question(s) and relevance are described.

1.1 Motive

The motive of this research is substantiated by the emergence of BIM due to its many recognized benefits in the last two decades in the (Dutch) construction industry and thus, the metal façade industry, and therefore, the need to execute BIM performance measurements

1.1.1 Emergence of BIM

In today's global construction industry, the drive for faster, more efficient delivery of building projects has never been more challenging and complex. Efforts to improve efficiency are usually difficult in a market that is frequently characterized by low margins, skills shortages, uncertain work pipelines, and especially complex supply chains and dependencies between different stakeholders. To mitigate the increasing complexity of projects, information and communication technology (ICT) has been developing at a very fast pace (Bryde, et al., 2013). Digitising the process of the design, build and operation of built assets for the purpose of a faster and more efficient delivery of building projects, therefore isn't a new concept (NBS, 2017). Especially, during the last decade this shift in ICT which regards the proliferation of Building Information Modelling (BIM) has been witnessed throughout the construction industry. BIM is to be known as the new Computer Aided Design (CAD) paradigm and is currently the most common denomination for approaching the design, construction and maintenance of buildings (Bryde, et al., 2013).

1.1.2 BIM benefits throughout construction projects lifecycle

Furthermore, BIM is to be known as one of the most promising developments in the architecture, engineering and construction (AEC) industries. With BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer - generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building (Eastman, et al., 2008). BIM has evolved as an construction management method in the last decade. When properly implemented, BIM can provide many benefits to a project. The value of BIM has been illustrated through well planned projects which yield: increased design quality through effective analysis cycles; greater prefabrication due to predictable field conditions; improved field efficiency by visualizing the planned construction schedule; increased innovation through the use of digital design applications; and many more (The Computer Integrated Construction Research Group, 2010). Moreover Eastman et al (2008) have provided several benefits belonging to the different project lifecycle stages such as, pre-construction, design, construction and fabrication, and post construction which are presented in Table 1.

Table 1 BIM benefits across project lifecycle stages (Eastman, et al., 2008)

Pre-construction benefits to owner	Design benefits	Construction and fabrication benefits	Post construction benefits
Concept, feasibility and design benefits	Earlier and more accurate visualizations of a design	Synchronize design and construction planning	Better manage and operate facilities
Increased building performance and quality	Automatic low - level corrections when changes are made to design	Discover design errors and omissions before construction (Clash detection)	Integrate with facility operation and management systems
	Generate accurate and consistent 2D drawings at any stage of the design	React quickly to design or site problems	
	Earlier collaboration of multiple design disciplines	Use design model as basis for fabricated components	
	Easily check against the design intent	Better implementation and Lean construction Techniques	
	Extract cost estimates during the design stage	Synchronize procurement with design and construction	
	Improve energy efficiency and sustainability		

1.1.3   BIM developments in the Dutch construction industry

Due to the prosperities which can be achieved by using BIM, the construction industry has become inconceivable without the use of BIM. These developments have also certainly not ignored the Netherlands. Different types of architects and engineering bureaus are actively involved in implementing BIM. When reading annual reports of big Dutch construction companies, we might also come across the term BIM quite often. Also smaller construction companies have become involved with BIM. Moreover, large public clients such as the Dutch Government Buildings Agency and the Dutch Ministry of Infrastructure and the Environment have started mandating the use of BIM towards contractors, and thus are giving further impulse to the implement BIM into the Dutch construction sector. Contractors on their turn also mandate the use BIM more often to the parties they contract, such as subcontractors and suppliers (Adriaanse, 2014) . The urge to implement BIM has also emerged in the metal façade industry as according to the VMRG. The sector analysis held in 2014 and 2016 created a view of BIM developments in the Dutch construction industry by measuring the BIM-maturity level of several organizations belonging to different sub sectors (Siebelink, 2017). However, the participation of manufacturers of metal façade elements was limited. The urge to implement BIM properly within this specific domain of the manufacturing sector, but also the need to execute BIM performance measurements to capture the BIM developments within the metal façade industry leads to the motive of this research and the VMRG.

1.2   The VMRG and the façade industry

1.2.1   The association VMRG

The VMRG is an association for metal façade builders that strives for maximum comfort for the end user through cooperation with its members and partners in the industry. The members of the VMRG are the manufacturers of aluminum and steel façade elements and carry the VMRG Quality Mark. They are responsible for engineering, production and assembly activities of a façade building process. The partners of the VMRG are organizations that supply products or services to VMRG members. Approximately 200 members and partners are associated with the VMRG and the VMRG itself represents around 95% of the total metal façade construction market in the Netherlands.

Although most of the members manufacture certain façade elements such as windows, doors and curtain elements, a distinction between these members can be made based on the different types projects they execute (Beers van, 2016) which is presented in Figure 2.
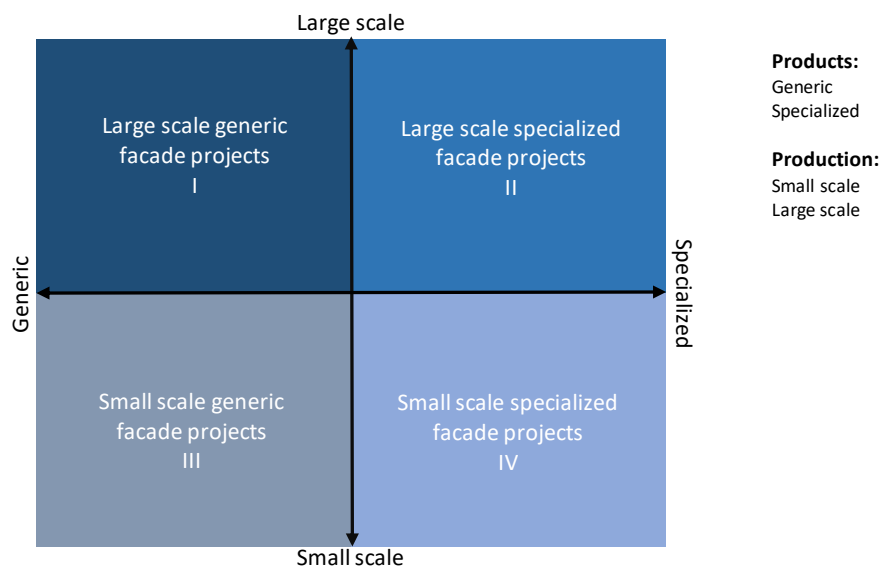
Figure 2 Distinction between members based on project execution types (Beers van, 2016)

1.2.2   The Quality Mark VMRG

The VMRG Quality Requirements and Recommendations are fundamental for the VMRG Quality Mark. It includes a set of quality requirements and agreements, which every organization involved in the production chain must comply with. Therefore, the members of the VMRG are obliged to deliver in accordance with these requirements and in line with the VMRG Quality Mark. The quality is verified by an external organization named SKG-IKOB on a regular basis. The VMRG Quality Requirements and Recommendations are furthermore a collection of several documents, such as assessment guidelines, arranged in a propriate manner and translated into comprehensible language and is available at the website http://www.vmrgkwaliteitseisen.nl .

1.2.3   Main pillars of the VMRG

According to the VMRG, the long term value of a building is guaranteed through continuous product and process improvement, innovation, training and service. Therefore, the main pillars of the VMRG are listed as followed:

> ➢ To devote itself to the interests of its members, which are the manufacturers of aluminum and steel façade elements. But also to ensure commitment to its partners who deliver products or services to the VMRG members *(Belangenbehartiging)*.
> ➢ To provide necessary information to and ensure continuous innovation and promotion of the façade industry *(Voorlichting en promotie)*.
> ➢ To offer further training and commitment of specific knowledge transfer and other types of information provision *(Scholing, onderzoek, opleiding en kennisoverdracht)*.
> ➢ To guarantee the quality of the products and services provided by the VMRG members, which is assessed through the VMRG quality mark, a comprehensive package of quality requirements *(Beheer van het VMRG-Keurmerk)*.

In order for VMRG to sustain its pillars based on the BIM developments pointed in Section 1.1, implementing and utilizing BIM in a mature and proper way will be mandatory in the near future.

1.3   Problem description

Currently, within the metal façade industry specific agreements with projects partners are missing regarding the implementation of BIM. Therefore, to establish uniformed agreements regarding the implementation of BIM and facilitate BIM developments within the industry, initially the VMRG has established a BIM workgroup. The BIM work group consists of a group of manufacturers that operate within Europe. Along with the members of the BIM workgroup a BIM protocol and BIM implementation plan have been made up to now and a start has been to specify the information requirements regarding specific façade elements. Furthermore, the VMRG has also facilitated the creation of an object decomposition through an intern student and internal research within their branch.

However, the implementation of BIM generally requires detailed planning and fundamental process modifications for the project team members to successfully achieve the value from the available model information (The Computer Integrated Construction Research Group, 2010). An effective use of BIM requires changes that should be made to almost every aspect of a firms business. Additionally, it also requires a thorough understanding and a plan for implementation before the conversion can begin (Eastman, et al., 2008). However, there is quite some ambiguity regarding what BIM is and what it means or involves for managing the members of the VMRG. According to Eastman et al (2008) BIM has its roots in computer-aided design research from decades ago, yet it still has no single, widely-accepted definition.

The complexity, required investment and time to implement BIM may serve as barriers to the implementation of BIM. According to the VMRG, members might lack knowledge and expertise to properly exploit the full benefits of BIM. While BIM is expected to provide significant benefits it requires significant costs related to specific software's, data storage and training and education. According to van Beers (2016), members of the VMRG are also of the opinion that BIM costs time and money, and therefore may hamper the implementation of BIM.

Moreover, practice also shows that shows that projects cannot always take full advantage of promised BIM benefits. Differing levels of BIM readiness between various disciplines within the Dutch construction industry serve as a serious implementation barrier to BIM . It appears that these inconsistent levels of BIM readiness across collaborating parties in construction projects limit the degree to which BIM goals and accompanying expectations can be realized, especially regarding BIM uses with extensive data exchange between parties (Siebelink, 2017). Lack of standards and agreements between collaborating parties or insufficiently complying with these standards impedes information exchange, but is also detrimental for product suppliers (Beers van, 2016). This difference in BIM-use and maturity levels between different domains and disciplines can therefore lead to communication issues, design errors and increased risks related to scheduling and budget costs. These aforementioned issues lastly lead to an inefficient BIM process with little to no added value, making the returns for utilizing BIM less profitable

According to literature, a thorough understanding of current BIM operations and therefore, effective, advanced, and high-performing measurements are also required to successfully implement BIM (Wu, et al., 2017). This is substantiated by Succar et al. (2012), who believes that BIM performance metrics are pre-requisite for BIM performance improvement. Without metrics, teams and organisations are unable to consistently measure their own successes or failures. Moreover, without these measurements no meaningful performance improvements may be achieved, financial investments may be misplaced and much efficiency may be lost. Therefore, measurement metrics enable teams and organisations to assess their own BIM competencies, and eventually compare them against an industry benchmark (Succar, et al., 2012). Therefore, it is essential for the organizations of the metal façade industry to identify their performance regarding BIM to determine priorities for improving their BIM implementation processes.

Based on the previous, the following problem definition is stated:

The organizations belonging to the metal façade industry currently lack the knowledge of their own BIM competences and performances.

1.4   Research objective

Based on the problem stated in Section 1.3, the VMRG is curious in a BIM-maturity measurement of the metal façade industry by measuring the BIM-maturity level of their branch members. This is essential for them to achieve a proper understanding of how the industry can implement BIM properly to increase their current BIM-maturity level. Therefore, the research objective is stated as followed:

Position the current BIM-maturity level of the members of the VMRG to provide practical and valuable insights on how the metal façade industry can increase its BIM-maturity level.

1.5   Research questions

In order to guide and support the research objective and further clarify the problem to be solved, the research objective is translated into a main research question. This main research question is sequentially divided into research questions for which sub questions are formulated. The questions will furthermore also give an indication of what kind of specific data, data collection approach and data analyzing method is needed.

Main question

> How can the metal façade industry implement BIM properly to increase their current level of BIM-maturity?

Research questions and sub questions:

1. **How can the current BIM-maturity level of the metal façade industry be measured?**
   a. Which standards or requirements should the BIM measurement tool comply with?
   b. Which measurement tool fits to assess the BIM-maturity level of the members of the VMRG?
   c. Which (sub)criteria and maturity levels is the measurement tool composed of?
   d. How can the associated level of BIM-maturity be defined for a measuring spectrum?

2. **What is the current BIM-maturity level of the metal façade industry?**
   a. What is the average BIM-maturity level of the metal façade industry ?
   b. How does the industry score on each (sub)criteria?
   c. What do these score implicate for the industry?

3. **Which implementation problems exist when trying to implement BIM within the industry?**
   a. How are the implementation problems characterized as?
   b. Why do they occur?
   c. How do these problems affect the current BIM-maturity level of the industry?

1.6   Relevance of research

1.6.1   Managerial relevance

As mentioned before, the VMRG's interest lies in a BIM-maturity measurement of the metal façade industry by measuring the BIM-maturity level of their members. By measuring the current BIM maturity level, the association also aims to get an indication of several implementation barriers (and drivers). Using these findings as a base, they finally aim to achieve a proper understanding of how the industry can implement BIM properly to increase its current BIM-maturity level. Therefore, this research will initially lead to a detailed inquiry of BIM developments of aluminum and steel manufacturers that operate within the façade industry. Furthermore, it will also lead to practical and valuable insights necessary for the VMRG to increase the BIM maturity level of their and the industry, but also to structure its service provision better towards their members.

1.6.2   **Academical relevance**

Other than its relevance from a managerial perspective, this research is also relevant from an academical perspective. The PDEng report of Sander Siebelink, *"Ontwerp en implementatie van een BIM-maturity model & best practices voor de Nederlandse bouwsector"* (Siebelink, 2017) has contributed to a BIM-maturity measurement of the Dutch construction industry on sectoral level. After an elaborated assessment on BIM measurement tools, Siebelink (2017) explains the lack of sufficiency of each existing tool to measure the BIM-maturity of the construction industry within the context of the research. He, therefore, developed a new measurement tool based on a set of criteria and sub criteria for measuring the BIM-maturity of several organizations belonging to different subsectors within the Dutch construction industry. A total of 105 organizations were assessed on their level of BIM-maturity. The subsectors involved project clients or owners, contractors, architectural firms, engineering firms, installation companies and suppliers (Siebelink, 2017). However, the participation the manufacturers of metal façade elements was limited. Therefore, this research is of academical value by testing the BIM measurement tool once again within the Dutch construction sector, but within a more specific domain of the manufacturing sector, the metal façade industry. Moreover, the results of this research can be used to benchmark the earlier obtained results if the same maturity model that is developed and used by Siebelink (2017) is utilized during this research. Lastly, the applicability of this tool for the façade industry can also be discussed.

2. RESEARCH DESIGN

In order to answer the earlier defined research questions and to be able to arrive at a solution for the problem that catalyzes the research project, specific procedures are followed and techniques are used which are elaborated in the research design and presented in this chapter. Therefore, the research design incorporates the research sample and strategy, data collection method, research phases and the associating research model.

2.1   Research sample and strategy

It was of main interest of the VMRG to include the organizations that belong to the BIM work group to the research sample due to the fact that already implement BIM to a certain extent within the façade industry. Therefore, they are able to give us an indication of BIM developments within this specific industry and to carry out an actual measurement. A total of 11 companies (n=11) that are a part of the BIM work group, showed interest in this particular research and were able to cooperate, and therefore, added to research sample.

To measure the BIM-maturity level of the research sample, a multiple case study design has been utilized. This, to ensure that a clear picture of the real-life (BIM) situation of each company has been obtained. To identify where and why eventual BIM implementation problems or barriers exist, determine the drivers and motivation for the implementation of BIM and sequentially measure the level of BIM-maturity, a qualitative data collection approach, through in-depth interviews, has been utilized. This was necessary to primarily explore and try to understand the underlying reasons, opinions, and motivations regarding the problem-oriented theory and to dive deeper into the problem.

However, when generalizing findings for the metal façade industry, the risk of generalizing incorrect findings may occur, since only the organizations associated with the BIM work group of the VMRG are included in the research sample. In order to ensure that characteristic BIM developments in this sector have not been neglected, manufacturing organizations that are associated with the VMRG quality mark, had a considerable turnover compared to the organizations of the BIM work group and were expected to perform BIM-related activities, were approached for cooperation of this research. In total 2 organizations appeared willing to cooperate and were added as a separate group, the non-BIM work group (n=2), to the design sample. Thus, the sample of the metal façade industry was broadened to 13 companies (n=13) which was necessary to assure validation to a certain extent. Due to the willingness of participators and the size of the non-BIM work group, validation cannot be assured to its full extent and is considered to be a limitation of this research.

2.2   Research phases and model

2.2.1   Preliminary phase

Before the start of the first phase, preliminary research was conducted (see Figure 3) to gain a better understanding of the problem, to narrow it down and translate it into a feasible research topic. Therefore, background information of the organization, The VMRG, was acquired through interviews to describe the motive and to elaborate on the problem-oriented theory. Some field exploration was done through an interview and meetings with organizations of the BIM work group to get familiar with the BIM processes and workflows that were currently being utilized by

the manufacturing organizations. Furthermore, specific literature was reviewed in order to obtain a thorough understanding of both the problem-oriented theory and the BIM processes and uses related to this specific sector. These aforementioned steps sequentially led to stating the research problem, objective and question(s). The product of this phase then used as a base and was meant to guide the thesis accordingly.

2.2.2   Phase 1: Methodology - Determine BIM measurement tool for assessment
After having set the base of the research during the preliminary stage, this stage focused on the selection of a BIM measurement tool to assess the level of BIM-maturity of each organization of the research sample (see Figure 3). When determining the appropriateness of the tool, emphasis had been put on the demands of the VMRG and the following data quality dimensions: (1) the reliability of the tool, (2) its validation within the construction industry and (3) the completeness. The point of departure here was the BIM measurement tool developed by Siebelink (2017), which was consulted to determine its appropriateness for measuring the BIM-maturity level of the façade industry. Additionally, several existing tools that had been developed over the past two decades were criticized about their shortcomings based on the reviews provided by Siebelink (2017) and Chengke Wu et al. (2017).

2.2.3   Phase 2: BIM-maturity assessment
In this stage the BIM-maturity level of each company of the research sample is measured by utilizing the BIM measurement tool chosen in the previous stage, in this case the measurement tool developed by Siebelink (2017). This was done by translating the tool into an interview instrument. During this stage, it was not only important to measure the BIM-maturity level of each company, but also to identify main barriers (and drivers) regarding the implementation of BIM processes and uses in this specific industry (see Figure 3).

To ensure generalizable findings and an external valid research, representatives of each company that cover the elements of interest of this research were interviewed. Therefore several representatives associated with the implementation and utilization of BIM were consulted, such as a BIM engineer, a BIM coordinator, an engineering head, a project manager or the director. Data was collected qualitatively through face-to-face structured interviews. By conducting face-to-face interviews, questions could be made adaptable when necessary and doubts could be clarified if needed. This data collection method also ensured that the responses were properly understood by repeating or rephrasing the questions. The interview format consisted mostly of fully open questions to allow more in-depth information of the problem-oriented theory and thus, to identify the main barriers (and drivers) regarding the implementation of BIM and specific BIM uses.

2.2.4   Phase 3: Insights for improving the BIM-maturity
This final stage is meant to provide valuable insights on how to improve the current BIM-maturity level of the metal façade industry and therefore, to facilitate the implementation of BIM within the industry (see Figure 3). The results presented at the end of phase 2 are primarily used and analysed to prepare the solution that is required in this phase. Additionally, literature is reviewed to support or extend the provided solution. The product of this last phase is meant to an adequate answer to the main research question.

2.2.5   Research model

The aforementioned research phases are illustrated in Figure 3. This research model also defines the chapters in which each phase and research question is described and therefore, also functions as a research guide.
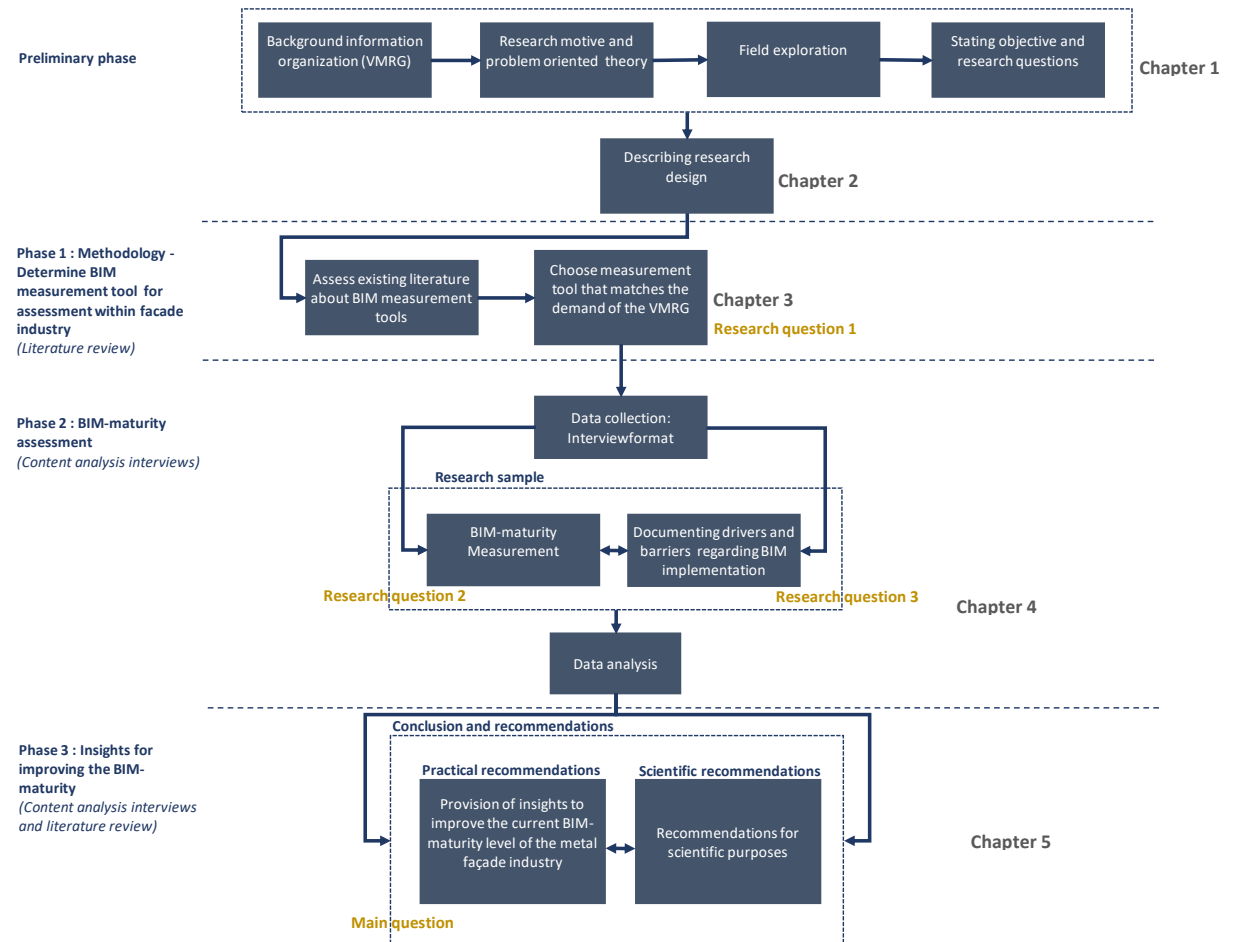
Figure 3 Research model

3. METHODOLOGY

This chapter is meant to provide an answer for the first research question. Therefore, it aims to describe how the BIM-maturity level of the members of the VMRG can be measured. This is done by initially elaborating on the definition of a maturity level and how this can be measured. Furthermore, several existing measurement tools are listed and criticized on their shortcomings based on available literature reviews. The recent developed measurement tool by Siebelink (2017) is then assessed for its appropriateness for measuring the BIM-maturity of the façade industry. The tool is consequently refined to a certain extent for research purposes and it is also made comprehendible how the maturity level is measured using the measurement tool.

3.1   BIM performance characterization and measurement

Building Information Modelling has experienced rapid development in recent years. Various organizations and stakeholders have begun to implement BIM due to the numerous recognized benefits. As mentioned before, the successful implementation of BIM requires a thorough understanding of current situation of BIM operations as well as effective, advanced, and high-performing measurements (Wu, et al., 2017).

The BIM-maturity level of an organization provides a way to characterize its performance. A maturity level consists of related specific and generic practices for a predefined set of process areas that improve the organization's overall performance. A maturity level is therefore a defined evolutionary plateau for organizational process improvement (Software Engineering Institute, 2010).

BIM Maturity benchmarks are performance improvement milestones that teams and organisations aim to or work towards. The progression from low to higher levels of maturity indicate: (i) better control through minimising variations between performance targets and actual results, (ii) better predictability and forecasting by lowering variability in competency, performance and costs, and (iii) greater effectiveness in reaching defined goals and setting new more ambitious ones (Succar, et al., 2012).

The BIM-maturity level of an organization is normally measured through a BIM measurement tool or maturity model which typically is composed of several (sub)criteria and multiple maturity levels. The maturity levels are measured by the achievement of the specific and generic goals associated with each predefined set of process areas (Software Engineering Institute, 2010). When the requirements of each level are satisfied, implementers can then build on top of established components to attempt 'higher' maturity. A higher level of maturity is certainly better than a lower level of BIM-maturity. However, each individual organization can value a maturity score differently. It is therefore of great importance to interpret the scores within the context of that specific organization according to the BIM goals they have set and then to determine whether or whether not the achieved scores are in line with the maturity level desired of the organization (Siebelink, 2017).

3.2 Overview BIM maturity measurement tools

Throughout the years several BIM measurement tools have been developed. Some well recognized tools with available detailed literature information and reviews are summarized in Figure 4.
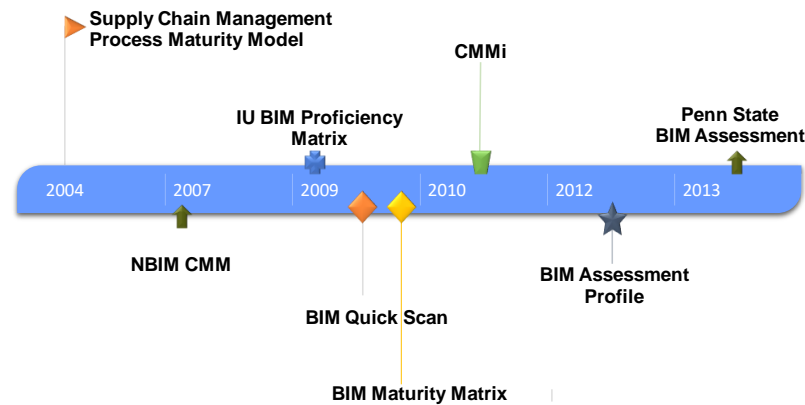
Figure 4 Timeline maturity models

The supply Chain Management Process Maturity Model developed by Lockamy and McCormack is focussed on organizational processes. The model is based on the Business Process Orientation maturity model, which builds on the fact that when processes rise to a higher level of maturity when their focus is shifted from internally to externally, towards the supply chain (Siebelink, 2017)

The NBIMS CMM proposed by the National Institute of Building Science as part of its famous National BIM Standard, evaluates BIM implementation in 11 areas using a 10-level scale (Wu, et al., 2017).

IU BIM Proficiency Index developed by the Indiana University aims to assess the individual skills of respondents to work within a BIM environment. It consists of 8 categories and on the basis of the scores per category insights for opportunities of improvement can be gained (Siebelink, 2017) (Wu, et al., 2017).

The BIM Maturity Matrix consists of three capability stages, five maturity levels, twelve organizational scales and a number of competency areas. The number of competence areas depend on the level of detail of the BIM analysis; the granulation level. Based on one of the four granulation levels chosen, the areas of competence are distinguished and further developed within the matrix (Siebelink, 2017).

The CMMi model is a 'classic' maturity model, developed to improve process improvement within the entire organization. As a successor to the Capability Maturity Model (CMM), the CMMi has been developed with a multidisciplinary approach to prevent the use of multiple CMMs. Best practices are incorporated in the maturity model for activities that include the total lifecycle of a product (planning up to delivery and maintenance). The model is made up of process each containing a set of best practices. If the model and best practices are applied together, they make a significant contribution to achieving improvement objectives within that process area (Siebelink,2017; Wu, etal., 2017).

The 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. The assessment profile consists of 6 areas, 20 measures, and 5 maturity levels to evaluate the BIM maturity of facility owners. By utilizing the tool and guideline, facility owners can understand current BIM maturity levels and identify correct paths to initiate or improve BIM implementations (Wu, et al., 2017).

The basis of the Penn State BIM Assessment is the Capability Maturity Model integration (CMMi). The model has been specifically developed for owners of assets. The underlying theory is elaborated in a "BIM planning guide for facility owners". All components and sub-components in the maturity model are defined and scaled on one five-part maturity scale (Siebelink, 2017).

3.3   Review existing maturity models

After having reviewed the existing tools, it appeared that throughout the years the focus while developing these tools has shifted from generic to a more specific sector or domain.

Furthermore, Wu et al (2017) and Siebelink (2017) have also reviewed several of the BIM measurement tools mentioned in Section 3.2. Wu et al (2017) has reviewed tools such as: the NBIM CMM, the IU BIM Proficiency Index, the BIM Maturity Matrix and the BIM Assessment Profile. According to Wu et al (2017) there are no standards yet for establishing a BIM maturity model and thus, no universal applicable tool exists. Therefore, each of the reviewed tools has unique emphasis, contains different strengths and weaknesses and matches different users.

Siebelink (2017) has also reviewed several of these tools in his PDEng report, such as the NBIM CMM, IU BIM Proficiency Index, the Supply Chain Management Process Maturity model, the BIM Maturity Matrix, Capability Maturity Model integration and Penn State Maturity model. In his assessment four categories of requirements for design-orientated research had been applied e.g.: functional requirements, contextual requirements, user requirements and structural requirements (Verschuren & Doorewaard, 2010). However, according to Siebelink (2017) the existing BIM measurement tools fell short on several aspects related these requirements when measuring the BIM-maturity level.

The arguments and discussions of Wu et al (2017) and Siebelink (2017) can be summarized as followed:

- According to Siebelink (2017) collaboration aspects, especially within the supply chain are insufficiently addressed in the current models. The Supply Chain Management Process Maturity Model is the only model that addresses this aspect, but is not capable of assessing the BIM-maturity because BIM is not part of the model.
- Complex frameworks are being utilized in the models, of which the BIM Maturity Matrix is an example of. Unambiguous scores and lacking literature-based foundations eventually result in assessments that are unclear, not transparent and, thus not suitable for mutual comparison. This reduces the usability of the BIM-maturity models as supportive tools for organizations and sectoral associations (Siebelink, 2017).
- The description of the criteria and maturity levels are often poorly defined with limited scientific substantiation. Therefore the ranking in the maturity model, for example when determining the gradual maturity increase, becomes quite challenging (Siebelink, 2017).

- According to Siebelink (2017) existing models focus less on facilitating a maturity measurement of organizational processes, but more on the presence technical aspects in BIM. Wu et al (2017) also support this statement by pointing out the fact that the IU BIM Proficiency Index only addresses the technical aspects within BIM.
- According to Siebelink (2017) many of the maturity models that were evaluated focused on a specific discipline. This limited their flexibility and applicability by different disciplines within the construction industry. The BIM Assessment Profile and Penn State BIM Assessment for example are specifically developed for the owners of assets (Siebelink,2017; Wu, etal., 2017).
- Some of the maturity models reviewed lacked field tests, empirical studies and practical data collections for validation and optimization, such as the IU BIM Proficiency Matrix, BIM Maturity Matrix, and BIM Assessment Profile (Shengke Wu et al., 2017).

3.4   Development of a new BIM-maturity measurement tool

3.4.1   Requirements for development of tool

Based on the aforementioned shortcomings, Siebelink (2017) decided to develop a new BIM-maturity model for the purpose of his PDEng research. As mentioned before in his assessment four categories of requirements for design-orientated research had been applied (Verschuren & Doorewaard, 2010):

- **Functional requirements**, which indicates that the maturity model is capable of measuring the BIM-maturity level of different-scaled companies belonging to various sub sectors (disciplines) within the Dutch construction industry. Furthermore, the maturity levels of the model need to be defined in a distinguishable way. The model should also be representable for BIM uses during different project lifecycle stages and should be applicable on organizational, sectoral and project level.
- **Contextual requirements**, which primarily concerns the fact that the model is able to cover the collaboration dynamic between chain partners.
- **User requirements**, which implicates that the model generates results that are comprehendible and transparent for users with limited knowledge regarding BIM-maturity models. It should also be able to identify barriers within the BIM implementation process and to give insights which aspects should be improved to grow towards a higher maturity level.
- **Structural requirements**, which means that the model should be built on the existing scientific knowledge with a strong emphasis on the usability for the target users.
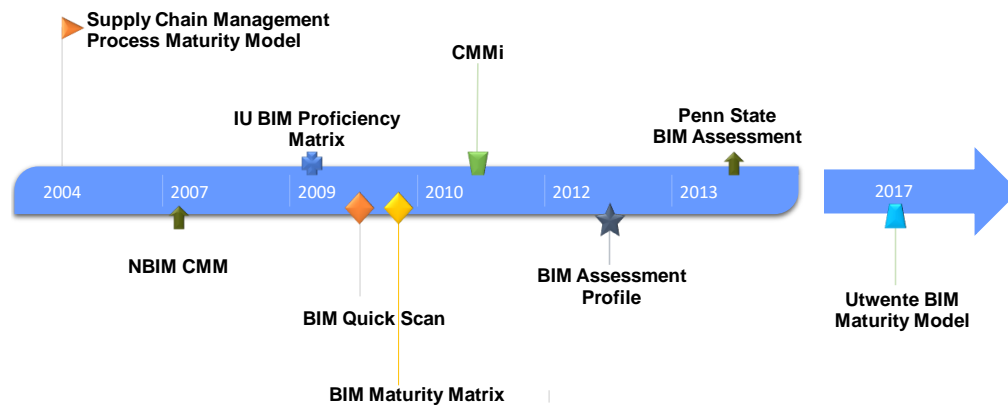
Figure 5 Updated timeline maturity models

3.4.2   Design of the tool

According to Siebelink (2017) existing maturity models did not qualify for measuring the BIM-maturity based on the objectives and requirements of the research. Therefore, in order to comply with the requirements mentioned in Section 3.4.1 a new measurement tool was developed. However, several valuable elements of existing maturity models have been taken into consideration when developing the BIM-maturity model. The measurement tool mainly consisted of two parts:

1. Best practices, consisting of several questions to identify the extent of BIM use, implementation steps and, the drivers and barriers regarding the implementation of BIM.
2. Maturity model, consisting of 6 criteria, 18 sub criteria and 6 maturity levels to measure the BIM-maturity level of the construction industry.

According to Siebelink (2017) a maturity level is more valuable when its considered within the right context. To implement a specific BIM use, quite often a certain level of BIM-maturity is needed. Furthermore, during the implementation process several barriers might hamper the utilization of specific BIM uses. Therefore, a link was made between the best practices and the maturity model to justify and comprehend certain findings and scores. The best practices and maturity model were then finally translated to an interview format for measuring purposes.

3.4.3   Best practices

The best practices is consisting of several questions to gain insights about the role that BIM plays within the organization and their specific subsector as mentioned before. Additionally, questions are composed to create an overview of which BIM uses are being utilized within each organization and to which extent. If not or not completely being utilized, the barriers hampering the specific BIM use and its implementation are also mapped. Sequentially, questions are formulated to point out how the organization is driven to implement BIM and how their future regarding BIM is set.

3.4.4   Maturity model

Horizontal axis

The maturity model consists of a horizontal and vertical axis. The horizontal axis of the model presents the maturity levels. In total six maturity levels are defined. These are mainly employed from the Capability Maturity Model integration and other scientific literature reviewed. The levels are distinguished as followed (Siebelink, 2017): (0) Not present, (1) Initial, (2) Managed, (3) Defined, (4) Quantitively managed and (5) Optimized. An elaborated description of the maturity levels is presented in Appendix 1.

Vertical axis

The vertical axis of the model presents the criteria of measurement. The criteria established by Siebelink (2017) to measure the BIM-maturity level are based on the findings of Silver et al. (1995) and is substantiated by the fact that a Building Information Model can be thought of as an information system, that is part of an organizational context. Therefore, the information system is not self-contained, but forms a part of a larger whole, such as business processes, strategies, people, culture, structure and IT infrastructure, which interact with the information system (Siebelink, 2017). Based on the previous, the following six main criteria are developed by Siebelink (2017): (1) strategy, (2) organization structure, (3) human and culture, (4) process and procedures, (5) IT infrastructure and (6) data structure.

Each main criteria is then divided into sub-criteria to assess specific processes within the criterion, as illustrated in Figure 6. The sub-criteria have been taken from the descriptions of criteria in the literature (Silver, et al., 1995) and criteria of existing maturity models, with important contributions from the Penn State BIM Assessment (Computer Integrated Construction Research Program, 2013) and the Supply Chain Management Maturity Model (Lockamy & McCormack, 2004). A description of the six main criteria and corresponding sub criteria is presented in Appendix 3.
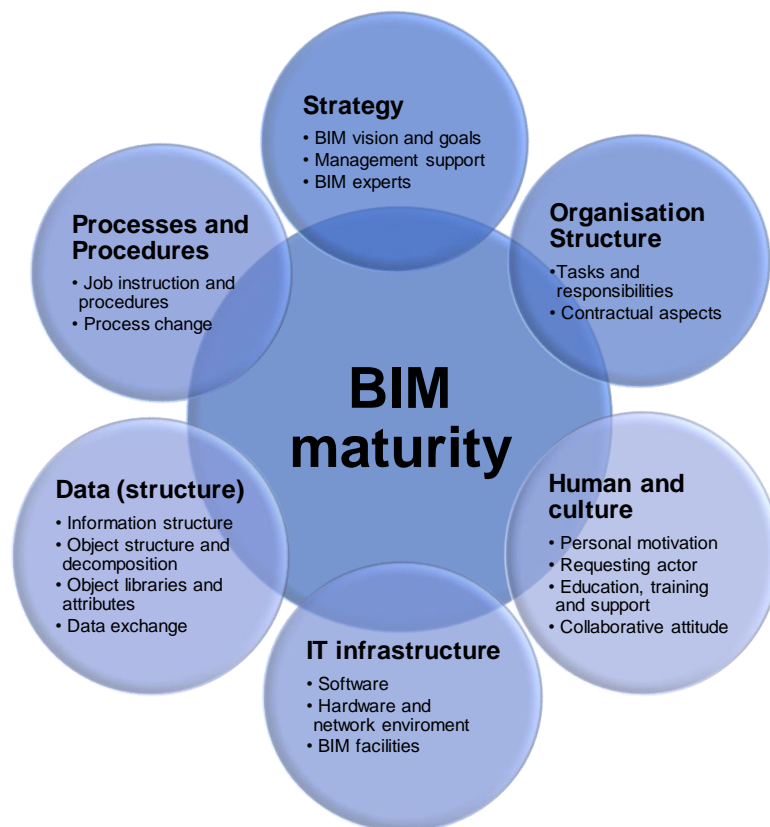
Figure 6 BIM-maturity model (Siebelink, 2017)

Interview format

In order the measure the actual maturity level of the organizations, the maturity descriptions per sub criterion are defined using the generic descriptions presented in Appendix 1 as a guide. Additionally, a set of question are formulated for each sub criterion. The structure of the questions are chosen in such a way, that the answers of the respondent determine which follow-up questions for the measuring spectrum have yet to be asked (Siebelink, 2017). The measurement tool uses a principle when determining the maturity level of each sub criterion which implicates that all the elements of a certain maturity level description must be met before moving on to the subsequent level (Siebelink, et al., 2018). In this way it is possible that after one or two questions it is sufficiently clear to which maturity scale the organization can be scaled, necessary for the interviewer to know to continue with the questions for the next sub criterion. After the interview the respondents their answers can be analysed and thus, can the appropriate level of BIM-maturity be determined for each sub criterion and eventually the whole organization.

BIM visie en doelstellingen

De strategie op organisatieniveau kan worden geconcretiseerd voor BIM door hierin een BIM visie en bijbehorende doelstellingen op te nemen.

Maturity levels voor subcriterium

0 Not present	1 Initial	2 Managed	3 Defined	4 Quantitatively managed	5 Optimized	Score
No visions or goals for BIM formulated	A basic vision for BIM is defined, but there are no concrete goals associated with it.	There are general BIM goals, but a BIM vision is lacking or not kept in line with the broader strategy.	The BIM vision fits within the broader organizational vision/ strategy and is aligned with partners.	SMART BIM goals are defined.	The BIM vision and goals are actively monitored (e.g., by means of periodic reporting) and, if necessary, updated.	

1. Is there a certain BIM vision formulated? Is this translated to a BIM goal?

....

2. Does the development of BIM fit within the broader strategic policy of the organization? Is this vision coordinated with other project partners in the (sub) sector?

....

3. How specific are the objectives for development and implementation of BIM formulated?

....

4. Are the BIM targets specific and measurable? Is there a period included in which the objectives should be realized? How realistic is that?

....

5. How do new BIM developments or technologies affect the vision and objectives?

....

Figure 7 Illustrative example of maturity model: sub criterion BIM vision and goals

3.5   Determining appropriateness of BIM measurement tool

3.5.1   Lacking standards for development maturity models

As mentioned before, industries have yet to establish standards for developing BIM measurement tools. Therefore, it can be quite confusing for BIM users to select a tool for evaluation (Wu, et al., 2017). For this reason, when determining the appropriateness of a tool for the purpose of this research, the demands of the VMRG concerning this research need to be taken into consideration.

3.5.2   Demands of the VMRG

The VMRG is interested in a BIM-maturity assessment of a specific domain within the manufacturing sector, the metal façade industry, by measuring the BIM-maturity level of their members. This concerns a measurement on organizational level. This assessment, should not only provide insights regarding the BIM-maturity level of each organization, but should also identify

the main barriers (and drivers) related to the implementation of BIM and several BIM uses. After having determined the aforementioned, the association aims to achieve valuable insights on how BIM can implemented properly within the industry to improve the current BIM-maturity level.

3.5.3   Assessment maturity model

To assess the appropriateness of the BIM measurement tool developed by Siebelink (2017),Section 4.6.2 is used as a point for departure. The tool is then tested on various data quality dimensions such as, reliability, validity and completeness to elaborate on the appropriateness of the model to measure the BIM-maturity level of the organizations of the façade industry.

1. RELIABILITY

Reliability is the ability of an instrument to measure the attributes of a variable or construct consistently (Hartmann, 2017). According to Succar et al. (2012), in order to increase the reliability and thus, the adoptability and usability by different stakeholders the metric should be applicable, consistent, flexible, informative, specific and usable.

- *Applicability within façade industry*
  The metric should be applicable, in a sense that can be utilized by all stakeholders across all project lifecycle phases. Due to the fact that this measurement tool is developed on the basis of those requirements, has a proven successful application within the Dutch construction industry and thus, enables a BIM-maturity measurement of organizations belonging to different sub sectors, including manufacturers, this model qualifies. However, to which extent this tool is applicable for the façade industry is rather a point for discussion and will result from the findings of this research.

- *Consistent*
  To guarantee consistency, the instrument should still yield the same results when conducted by different assessors. This measurement tool is built on specific user requirements and therefore ensures that the tool is comprehendible for users with limited knowledge regarding maturity models. Therefore, it assures consistency.

- *Flexible*
  The metric should be flexible in a way that assessments can be performed across markets, organizational scales and their subdivisions. The measurement tool qualifies due to the fact that it is based on a functional requirements that ensure that the model is suitable for application organizational, sectoral and project level.

- *Informative*
  The metric should also be informative, meaning that they provide feedback for improvement and guidance for next steps. This tool is able to identify the barriers hampering the BIM implementation process and therefore is able to give insights on areas that need to be improved to grow towards a higher maturity level.

- *Specific*
  Metrics should be well defined and serve industry-specific assessment purposes. This measurement tool has an underlying substance that is based on scientific literature and is developed to serve a specific industry thus, the Dutch construction industry,

- *Usable*
  At last, metrics should be intuitive and be easily employed to assess BIM performance. This is ensured by the user requirement that allows comprehensibility for users with limited knowledge related to BIM-maturity models.

2. VALIDITY

Validity is the extent to which the instrument measures the attributes of a concept accurately (Hartmann, 2017). Therefore, the content and suitability of the tool, including interview questions, were first tested by submitting the tool to members of a supervisory group on maturity. After processing the feedback, the tool was reviewed through some test interviews at organizations in different sub sectors. The comments by the respondents were then processed in the "final test" interview format for wider testing. To ensure and to evaluate the accuracy of the measurement tool during the interview round, also questions were asked about any missing aspects. Some respondents advocated a stronger anchoring of contractual aspects. Additionally, the research team believed that BIM could be a driver of change and improvements in processes and that this effect on process change could be included in the further development of the BIM maturity model. The maturity model was therefore revised and the two sub criteria were added to their corresponding main criteria for further implementation. The validation and thus, accuracy of this model can be ensured by the multiple review rounds for refinement steered by a construction-wide supervisory group.

Reliability

Validity

100 % **Completeness**

Measurement tool
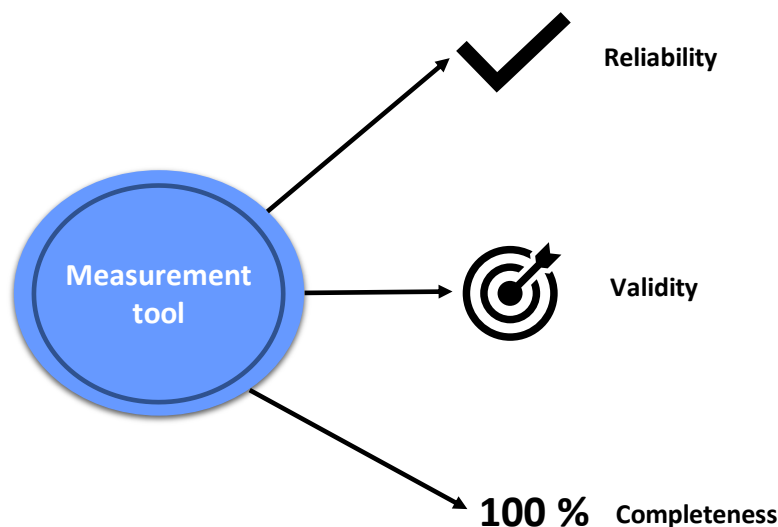
Figure 8 Data quality dimensions

3. COMPLETENESS

Completeness is the extent to which the instrument can record all data sets and items (DAMA UK Working Group, 2013). Various aspects from previous developed maturity models that are essential for measurement such as, organizational and collaboration aspects are taken into consideration while developing the maturity model and therefore, strengthen the data quality dimension completeness.

- *Organizational aspects*
  The model is developed to not only measure the technical aspects in BIM, but rather takes into account the larger whole, the organizational context. The criteria were developed based on the fact that the information system not self-contained, but forms a

part of a larger whole, such as business processes, strategies, people, culture, structure and IT infrastructure, which interact with the information system. Therefore, it enables a BIM-maturity measurement of organization level. This is type of maturity measurement the VMRG is interested in, which makes the maturity model suitable for the purpose of this research.

- ***Collaboration aspects***
  BIM enables inter-disciplinary collaborations within the construction industry. The Building Model is not only used for visualization purposes and does not only represent the geometry of the building, but also contains data supportive for other disciplines related to construction, fabrication, and procurement activities (Eastman et al., 2008). This model is able to cover the collaboration dynamic between chain partners, due to it is built on the fact that processes rise to a higher level of maturity when their focus is shifted from internally to externally, towards the supply chain.

3.6   Adjusted interview format

Due to the fact that the initial format was meant to cover different sub sectors within the Dutch construction industry, this format has been refined and adjusted, especially in the first part, the best practices, to gain specific and necessary data within the façade industry.

Distinction between organizations
During this trajectory various organizations will be interviewed. In order to consider the results in a valuable way a distinction between the organizations is made based on the total FTE (fulltime-equivalent) operating within each organization, the type of projects they execute grounded on the classification in Section 1.1 and the investments made to implement BIM by providing training and education (per FTE) and acquiring software on a yearly basis. Therefore, several questions are summed up in order to obtain relevant data for the aforementioned distinction.

Separate overview of BIM uses for the manufacturers of façade elements
The initial format included an overview of general and specific BIM uses for each sub sector in order for respondents to mark down which BIM uses are being utilized and if not what barriers are hampering the successful implementation of a particular BIM use. The manufacturing sub sector was initially integrated with the supplying sector. Therefore, for the context of this research, a separate overview of BIM uses was created for the manufacturers of façade elements. The overview consisted of the initial general BIM uses as defined by Sieblink (2017). It also consisted of the initial specific BIM uses that were listed under the integrated subsector "suppliers and manufacturers", due to the fact that these BIM uses were quite in line with several specific manufacturer's BIM uses as described in the BIM handbook (Eastman, et al., 2008). Furthermore, several BIM uses that were being utilized by the members of the VMRG according to previous research within the branch (Beers van, 2016) were added to the overview of BIM uses. An elaborated description of the BIM uses is presented in Appendix 2.

Verification from developer
Moreover, in the second part of the measurement tool, the BIM maturity model, two sub criteria were added to the interview format. The sub criterion contractual aspects was added to the main criterion organization structure and the sub criterion process change was added to the main

criterion process and procedures, as suggested by the group of experts that were in charge of verification and validation of this model in 2016. Therefore, the follow-up questions for these sub criteria were formulated in a way to enable an appropriate measurement of BIM maturity. These questions were also verified by the initial developer of the maturity model. The adjusted interview format that has been utilized during this research is presented in Appendix 8.

3.7   Interview preparation

For conducting an entire interview a duration of approximately 90 minutes (one and a half hour) was selected based on a test interview conducted with the director of the VMRG. The duration could however, vary depending on the knowledge, experience and detail of answers from the respondents.

Therefore, in order to facilitate an effective, continuous and flowing interview within time, the interview format was mailed to the respondents representing each organization, usually a week before the interview date. By doing this, the respondents could prepare their selves for the interview which could save them time during the interview, especially during the first part (best practices) of the interview. However, this was not mandatory. The email also stated that it was not required to answer the questions in the second part (maturity model) beforehand, but rather to use it as an indication and to think about them in advance.

For the first two interviews the interview format presented in Appendix 8 was sent to the respondents for preparing purposes. However, it soon became obvious that respondents tried to measure their self indirectly and prepared answers to scale their self beneficially. Therefore, for the following interviews, the interview format that was sent to the respondents was changed and was not consisting of the description of the maturity levels for each sub criteria in order to prevent the aforementioned effect from occurring.

3.8   Preliminary conclusion

There are currently no standards established for developing BIM measurement tools. Therefore, the requirements and demands of the VMRG were taken into consideration when needed to determine a tool that is appropriate for measuring the BIM-maturity level of the façade industry. The BIM measurement tool developed by Siebelink (2017) was found to fit these requirements and also qualified on several data quality measures such as, reliability, validity and completeness. The tool is consisting of two parts, the best practices and maturity model. The best practices enables us to identify the extent of BIM use and the drivers and barriers regarding the implementation of BIM, which is necessary to consider the findings within the right context. Furthermore, the maturity model is consisting of six criteria, eighteen sub criteria and six maturity levels. In order the measure the actual maturity level of the manufacturing organizations, the maturity descriptions per sub criterion are defined. Additionally, a set of question are formulated for each sub criterion. The structure of the questions are chosen in such a way, that the answers of the respondent determine which follow-up questions for the measuring spectrum have yet to be asked (Siebelink, 2017). The measurement tool also uses a principle when determining the maturity level of each sub criterion which implicates that all the elements of a certain maturity level description must be met before moving on to the subsequent level (Siebelink, et al., 2018).

4.   BIM-MATURITY ASSESSMENT FAÇADE INDUSTRY

This chapter is meant to provide an answer for the second and third research question. This regards the positioning of the current BIM-maturity level of the façade industry and the identification of BIM implementation problems. Therefore, this chapter is divided into 3 sections. The first section is introductory and describes the data set of assessment. The last two sections (Section 4.2 and 4.3) define the core of this chapter by each covering one of the abovementioned research question topics. Therefore, in each of these sections, the results and analysis concerning the research question are presented in a brief and comprehensive manner.

4.1   Data set of assessment

The research sample consisted of thirteen manufacturing organizations representing the façade industry (n=13). These organizations manufactured mainly aluminum, but also steel façade elements. Each of these organizations were usually represented by a BIM engineer, a BIM coordinator, an engineering head, a project manager or the director. In order to consider the results presented in the next two sections within the right context, a distinction of the data set is made based on the organization size and thus, the fulltime-equivalent operating within each organization. As presented in Figure 9, the data set mainly consists of organizations that have an organizational size that fluctuates between 51 and 200 fulltime employees.
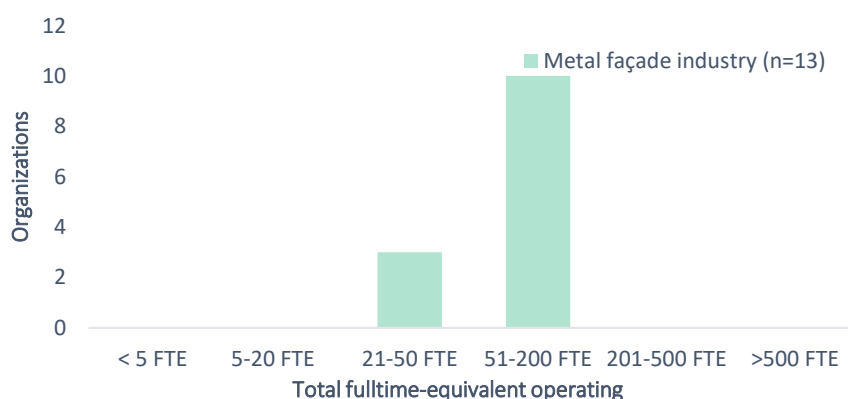
Figure 9 Classification organizations based on organization size

4.2   BIM-maturity measurement

This section is meant to cover the BIM-maturity measurement by capturing the BIM developments within the façade industry. Therefore, the extent to which BIM is implemented and how the industry its performance is characterized as, in terms of BIM-maturity, is presented. Additionally, the results are analysed and discussed. Lastly, the impact of the BIM investments on the maturity level is also analysed and discussed.

4.2.1   Results BIM-maturity measurement

I BIM implementation

Figure 10 illustrates a mixed pattern of the extent to which BIM is being implemented into projects within the industry. According to data retrieved by respondents, 70% of the industry implements BIM for less van 60% of their projects. Furthermore, 30 % of the industry implements BIM within more than half of their projects (60-80%) of which 15% to its nearly full project extent (80-100%). Additionally, it should also be mentioned that some of these numbers are based on organizational turnover instead of the actual amount of projects, since necessary data to determine the needed percentage was not available at the moment of interview. A distinction of the type of projects executed by the manufacturing organizations is presented in Appendix 4.
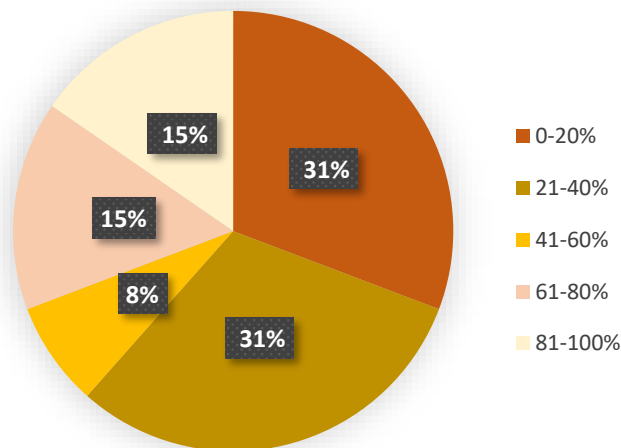
Figure 10 Percentage of projects executed with BIM

II Average BIM-maturity level manufacturing organizations and metal façade industry

The results, as shown in Figure 11, indicate that the BIM-maturity level of the manufacturing organizations that represent the façade industry (n=13) fluctuates between 1.6 and 4.0. These organizational scores equal an average BIM-maturity of 2.5 for the metal façade industry
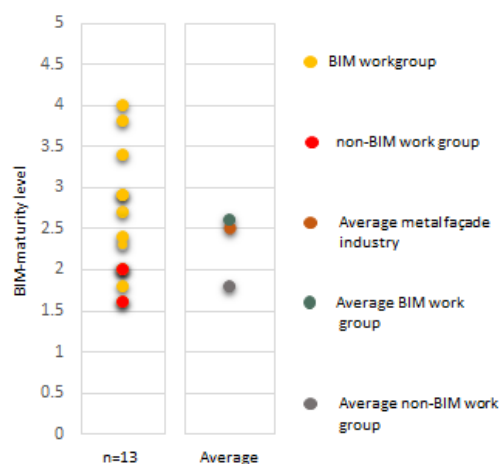
Figure 11 BIM-maturity overview

The figure also illustrates three outliers, representing a higher BIM-maturity level than the average maturity level of the industry. These are the organizations that score an average BIM maturity level of 3.4, 3.8 and 4.0. Therefore, they are characterized as the front runners of the industry. It is also apparent from the figure that these frontrunners belong to the BIM work group. The average maturity level of the BIM work group of the VMRG (n=11) is therefore, as expected, higher than the average BIM-maturity level of the façade industry (n=13) and calculated to be 2.6. The average maturity level of the non-BIM work group is calculated to be 1.8.

III Average sub criteria level façade industry

In order to get a closer look into the BIM developments, Figure 12 zooms in on the maturity measurement per sub criteria. The results of this measurement are summarized as followed:

- *Strategy*
  Figure 12 illustrates that BIM visions and goals are lacking or defined to a limited extent within industry organizations. Moreover, most organizations have a BIM expert or work group operating, that is not always accountable for all operational divisions within the organizations, with just enough time and priority to support the BIM implementation process. However, most of the organizations are supported sufficiently by their management to implement BIM accordingly which often also regards the further development of new BIM uses.

- *Organization structure*
  The figure also implicates that the definition of BIM-related tasks and responsibilities are often project-oriented and integrated within job descriptions of regular tasks per project, but not uniformly defined across the organizations. Furthermore, organizations often use specific guidelines and standards to anchor BIM in contracts and protocols. However, these guidelines are not always applied in practice.

- *Human and culture*
  The figure also indicates that the organizations of the metal façade industry are motivated and willing to change their organizational culture to support the implementation process of BIM. Moreover, industry organizations have several requesting actors active within different organizational departments that steer and support the implementation of BIM within their organization. Furthermore, structured education, training and support is usually given to those employees that specifically work with BIM, while general guidance across the entire organization is limited or not available. Nevertheless, collaboration between (chain)partners is being recognized within the industry and is anchored in contracts. Moreover, some of these organizations also jointly align structures, tasks and processes with (chain)partners for the benefit of collaboration.

- *Process and procedures*
  Furthermore, the figure also shows that BIM-related procedures and work instructions are currently lacking, limited defined or not consistently used. Furthermore, BIM leads to fundamental process change and improvement within industry organizations, but is currently rolled out limited throughout the entire organization.

- *IT infrastructure*

  Figure 12 also illustrates that the hardware of industry organizations are capable of running basic BIM software and that advanced systems are only available in specific workplaces, dependent on the necessity of specific BIM uses. Furthermore, the BIM software that are being utilized within the industry usually do not support advanced BIM uses. However, most of organizations consist of working areas or spaces that are specially equipped for the purpose of collaboration with BIM.
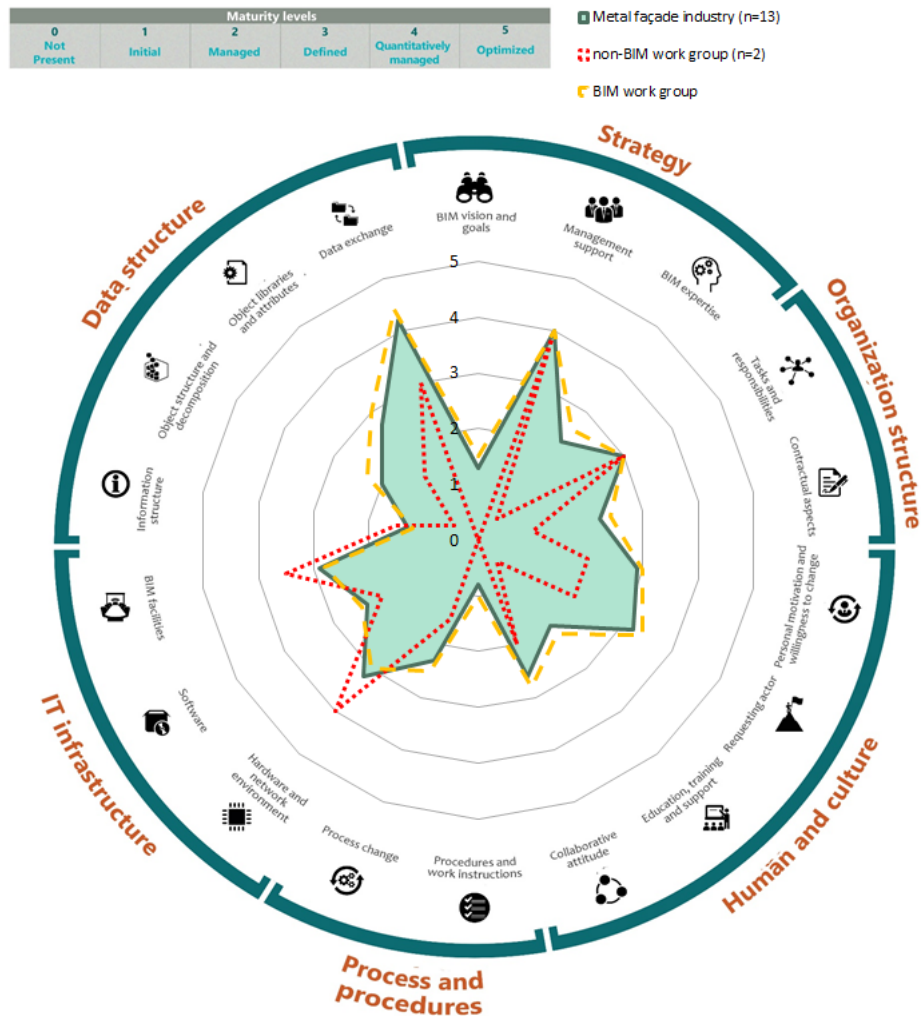
Figure 12 Radar chart BIM-maturity criteria metal façade industry

- *Data structure*

  The use of a document management system is unstructured, not defined in prescribed work procedures and is usually dependent on individual competences within a project team, as shown in the figure. Furthermore, uniformed object decompositions are utilized within the different companies, but are not always shared or aligned with (chain)partners or sector standards. Moreover, uniformed object libraries are being utilized for which non-geometric data is being linked to and is often, but not always aligned with sector standards. Lastly, data exchange is mostly enforced in contracts and takes place on the basis of open standards (IFC). This supports the exchange of information between (chain)partners.

Figure 12 also substantiates the higher average maturity score of the BIM work group (n=11). The yellow dotted line which represents the BIM work group (n=11) lies for most sub criteria right above the green line that represents the metal façade industry (n=13), indicating a higher BIM-maturity level. The red dotted line which represents the non-BIM work group (n=2) however, appears to be more below the line of the metal façade industry and into the inner of the figure, resulting in a much lower maturity score. There are two outliers in this case which regard the sub criteria hardware and network environment and BIM facilities.

4.2.2   Analysis and discussion: BIM-maturity assessment

I Evolution BIM implementation within the metal façade industry
According to previous research done within the metal façade industry, approximately 95.8 % of the industry utilized BIM for 75 % or less of their projects, while only 4.2 % implemented BIM for more than 75% of their projects (Beers van, 2016). When comparing these findings with the current BIM implementation pattern as presented in Section 4.2.1 a certain increase is noticed. This indicates that BIM is being implemented more into projects within the industry in comparison with two years ago.

II Maturity comparison with sector analysis (2014 and 2016)
According to the sector analysis done in 2016, the average BIM-maturity level of the supplying and manufacturing sector fluctuated between 0 and 2.1 and were apparent to be lowest when compared with the other sub sectors such as, clients, architectures, engineering consultants, etc (Siebelink, 2017). This also accords with the findings of the sector analysis held in 2014 (University of Twente, 2014) However, the outcomes of this research differs remarkable from earlier obtained findings.

This can be explained by the following:
- The research sample of the supplying and manufacturing sub sector of the sector analysis (2016) consisted of seven companies, of which only two were manufacturers of steel and aluminum elements. The sample size limits the generalizability of findings but also a fair comparison, since remarkable BIM developments within the sub sector and specific domain may been neglected or ignored during the sector analysis.
- The sample has not only been extended (n=13), but also differentiated from the integrated sub sector "suppliers and manufacturers" of which a specific domain within the manufacturing sector, the metal façade industry, was investigated. This may have led to more explicit, but also deviating findings in comparison with the sector analysis.
- The BIM developments may have evolved within the sub sector and domain over the past two and four years due to a dynamic evolving construction industry.
- The majority of organizations interviewed are part of the BIM work group of the VMRG and are known to implement BIM to a certain extent. Along with the VMRG, members of the BIM work group have already established a BIM execution plan and protocol and created an object decomposition for BIM facilitating the implementation of BIM.

III Sub criteria comparison with sector analysis (2014)
The results of the sector analysis held in 2014 allow us to make a comparison on sub criterion level. The results of the sector analysis (University of Twente, 2014) are consistent with the data obtained in this research when considering the sub criteria BIM visions and goals, work instructions and procedures and information structure. Both the sector and industry analysis indicate the low and limited scores for these sub criteria.

However, the comparison also shows that management support has increased throughout the years. This is also substantiated by the growing number of requesting actors within the sub sector and more physical facilities to stimulate BIM processes within organizations. Lastly, it should be mentioned that collaboration between project partners has been acknowledged by the sector throughout the years and is becoming a focus point for many organizations in order to implement BIM successfully.

4.2.3   Analysis and discussion: BIM investments

In order to determine how the BIM investments influence the maturity level, the correlation between the BIM investments done and the average BIM-maturity level is analysed for each manufacturing organization. The BIM investment patterns of the façade industry itself are presented in Appendix 5.

The correlation is measured by a correlation coefficient[1] (r) that represents the strength of the putative linear association between the variables in question (Mukaka, 2012). A neglectable correlation of 0.01 is found between the variables BIM-maturity and education and training investments. The correlation coefficient indicates that a higher maturity is not necessary characterized with greater education and training costs, nor less. As shown in Figure 13, organizations with the highest scoring BIM-maturity level invest relative little in the education and training of their employees compared to other manufacturing organizations. However, the correlation between the variables is interesting, due to the fact that there is one front runner that invests a great amount in the education and training of their employees in comparison with other organizations. Therefore, to explain the ironic correlation coefficient, the scores of the front runners on the sub criteria education, training and support are analysed. It appears that all front runners score above than average on this sub criteria, meaning that education and training within these organizations is given in a structured way, on regular basis, across the entire way and is aligned with personal requirements along with guidance and support in practice (training on the job). These organizations also have the highest score on this sub criteria in comparison other organizations of the sample. The correlation coefficient can furthermore also be explained by the existing capabilities of an organization if required data is available. If organizations have existing personnel with necessary BIM-related knowledge and competences, structured education and training on a regular and yearly basis would cost them less in comparison to those that lack these competences. However, the coefficient can also be explained by inefficient (high) investments and therefore, financial misplacement of other manufacturing organizations.

A low positive correlation of 0.44 was found between the variables BIM-maturity and software investments. This implicates that that greater investments made to acquire BIM software licenses and therefore, execute and implement specific BIM uses lead to a higher BIM-maturity level. This is illustrated in Figure 14 and demonstrated by the front runners of the industry. However, a higher maturity doesn't specifically have to accompanied by higher investments, since organizations vary in size and smaller organizations need to acquire less software licenses to operate and implement BIM uses. Furthermore, the cost of purchasing new software also depends on the firm's existing IT facility (Liu, et al., 2015). This may therefore, explain the low positive correlation.

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[1] $R = \dfrac{\Sigma (x-X)(y-\bar{y})}{\sqrt{(x-X)^2}\sqrt{(y-\bar{y})^2}}$ x= each sample value of variable x; X=mean of variable x; y=each sample value of variable y; ȳ= mean of variable y
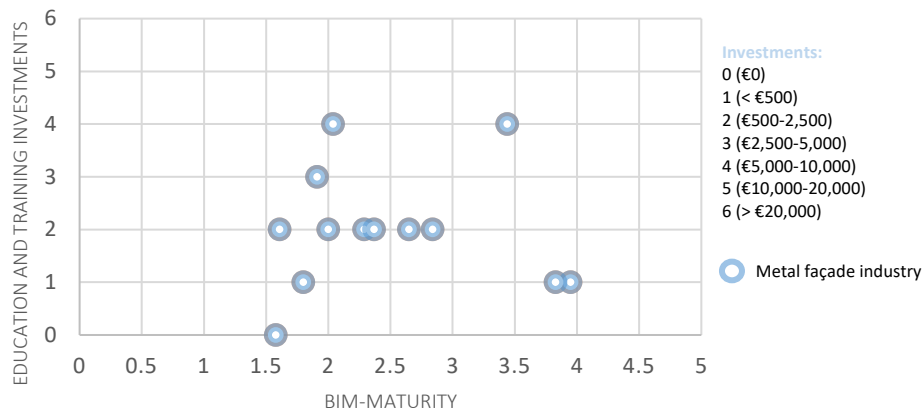
Figure 13 Correlation BIM-maturity and education and training investments
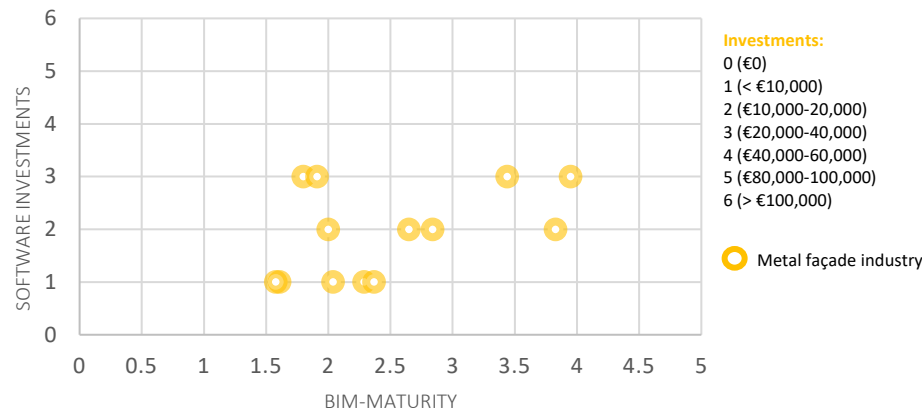
Figure 14 Correlation BIM-maturity and software investments

4.2.4   Preliminary conclusion

This research has shown that the metal façade industry scores an average BIM-maturity level of 2.5. The scores of the industry on each sub criteria itself is presented in Figure 15. These scores implicate that the BIM developments within manufacturing sector have grown in comparison with the sector analysis (University of Twente, 2014; Siebelink, 2017). This is also substantiated by a certain growth of BIM implementation into projects within the industry. However, these developments are limited to a BIM-maturity assessment within a specific domain of the manufacturing sector, the metal façade industry. The figure also illustrates some remarkable peaks and drops. The peaks indicate the façade industry scoring remarkably high on the sun criteria management support and data exchange. Therefore, research shows that organizational managers are willing to support and invest in the implementation of BIM and that data exchange is often facilitated through open standards (IFC) which is usually enforced in contracts. However, the drops implicate that currently within the industry BIM visions and goals and BIM-related work instructions are lacking or defined to a limited extent and that the use of a document management system is usually limited or not enforced into work instructions. The correlational analysis also shows that strategic and structured BIM investments, especially related to software, stimulate the implementation process and thus, can lead to a higher BIM-maturity level.

Maturity levels					
0 Not Present	**1** Initial	**2** Managed	**3** Defined	**4** Quantitatively managed	**5** Optimized

☐ Metal façade industry (n=13)
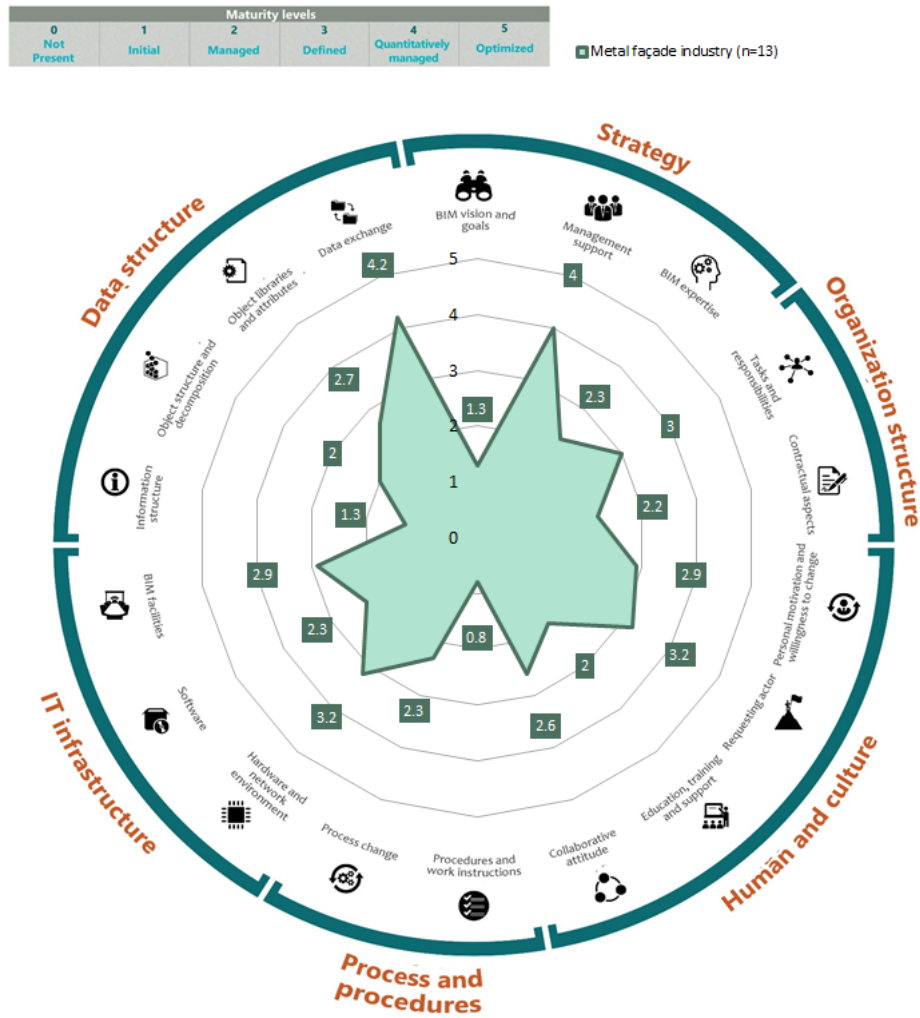
Figure 15 Sub criteria measurement metal façade industry

4.3   Drivers and barriers BIM implementation process

This section aims to identify the BIM implementation problems by investigating both the drivers and barriers for implementing BIM in the façade industry. Additionally, the way the identified implementation problems affect the current BIM-maturity is also analysed and discussed

4.3.1   Results drivers

Several organizations are driven by various factors to implement BIM. The most common and likely driver to implement BIM within the industry is according to nine respondents the market demand and the fact that the use of BIM is being requested or mandated by the client .

However, some organizations are also driven to implement BIM to take the lead within the industry. Below, some drivers specified by the respondents are listed in the order of most common to less common.

- According to eight respondents, an important driver to implement BIM is the reduction of errors and costs of failure. Therefore, 3D modelling and engineering has become of technical necessity for many organizations, especially when needed to solve complex issues.
- According to three respondents, BIM also allows efficient data streams and communication. It therefore also allows better alignment and collaboration between (chain)partners whereby organizations are driven to implement BIM.
- As stated by two respondent, organizations are also driven by the fact that utilizing BIM facilitates a more efficient manufacturing processes.
- Two organizations also state that they are driven by the fact that the use of BIM creates a better end product for the client, and also one that can be maintained using BIM due to infinite possibilities of BIM.
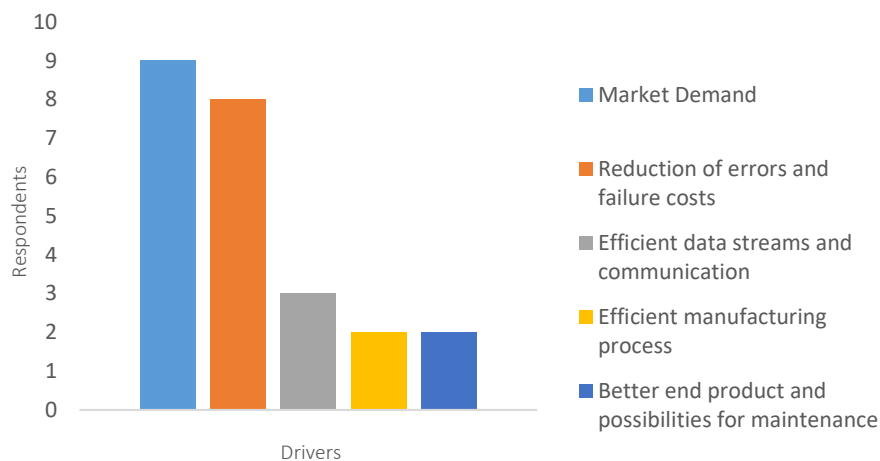
Figure 16 Industry drivers for implementing BIM

4.3.2   Results barriers

During the interview trajectory a diverse and great amount of barriers have been recognized. These barriers which have been identified per BIM use are presented in Appendix 6. In order to present these barriers in a comprehensive way these barriers have been clustered to seven main barriers and are presented in Figure 17.

Client request

The most common barrier to the implementation of a specific BIM use is the fact that it is not requested or mandated by the client. This is self-evident since most of the manufacturers of the industry are driven by the market demand to implement BIM. This is also substantiated by the fact that respondents often explicitly mention that the implementation of specific BIM uses have no added value for their organization and are therefore not implemented.

Lack of skilled personnel and education

Another common barrier to the implementation of BIM appears to be the lack of skilled personnel and thus, the lack of training and education. According to the respondents, this barrier is mostly recognized when it regards the implementation of specific BIM uses such as, 3D detail engineering, but also more advanced BIM uses such as, structural analysis, physical building analysis, cost estimation (5D modeling), steering manufacturing process, etc.

Lack of time to implement BIM

As according to the respondents, the lack of time to implement a specific BIM use is also perceived as a severe bottleneck to the implementation of BIM. Many organizations experience the implementation of certain BIM uses to be time-consuming. Therefore, they are often not given priority to implement yet or they are being implemented in a non-BIM environment which eventually hinders the implementation of BIM within their organization.

Less mature project partners

In order for the industry to benefit of the implementation of BIM and specific BIM uses it is necessary that collaborating project partners have implemented BIM to at least the same extent as the manufacturing organizations. However, according to the respondents, not all project partners are perceived to have the same BIM competences and BIM-maturity which hampers the implementation of BIM. According to two respondents, not all project partners model 3D, which create a lot of insufficiency when data needs to be exchanged between project partners. According to one respondent this also impedes clash detection between various aspect models. Moreover, not all suppliers are capable of extracting information stored in a 3D model for the purpose of purchase management. Furthermore, the quality and level of detail of the delivered 3D models often prove to be insufficient to execute a cost estimation (5D model) based on the 3D model or to use it for the purpose of purchase management

Software shortcomings

Software most often has several shortcomings hindering the successful implementation of particular BIM uses. According to several manufacturers, software such as HiCAD and Revit do not support specific BIM uses, such as structural and physical building analysis. Therefore, these BIM uses are often executed using simplistic methods, usually in a non-BIM environment or outsourced, as stated by respondents. Moreover, according to two respondents, Revit does not facilitate sufficient 3D-detailengineering. Large files with a high level of detailing are proven to be unworkable due to shortcomings of the software. This also hinders the planning of production

and supply. Furthermore, software such as Revit, do not support the steering of the manufacturing process directly from a BIM environment. Due to incompatibility a lot of re-work is created, additional intermediate links are used and sometimes the manufacturing process is steered from a non-BIM environment. The lack of a uniform and compatible software to steer the manufacturing process is also expressed by the use of different BIM software by many of the manufacturing organizations which is presented Appendix 7.

Non-complex projects
According to three respondents, not all project require the execution of specific BIM uses due to their non-complex nature. For example, 3D modelling, 3D detail engineering and the generation of 2D drawings from 3D drawings is not always necessary. Simple and non-complex projects are therefore still modelled traditionally and two-dimensional, since this happens to be easier and faster for some manufacturers. Also, two respondents are of opinion that several advanced BIM uses, such as locating through laser and machine guidance techniques are not necessary for non-complex projects, and are solely executed for mega and complex projects.

Hardware and software costs
The costs of the acquisition of new software licenses and hardware to support the implementation of BIM is also experienced to be a barrier. Also, two manufacturers are of the opinion that the costs of software and hardware for the implementation for specific BIM uses, such as structural and physical building analysis do not weigh up against the benefits. Therefore, these are executed in a non-BIM environment or outsourced as mentioned before.
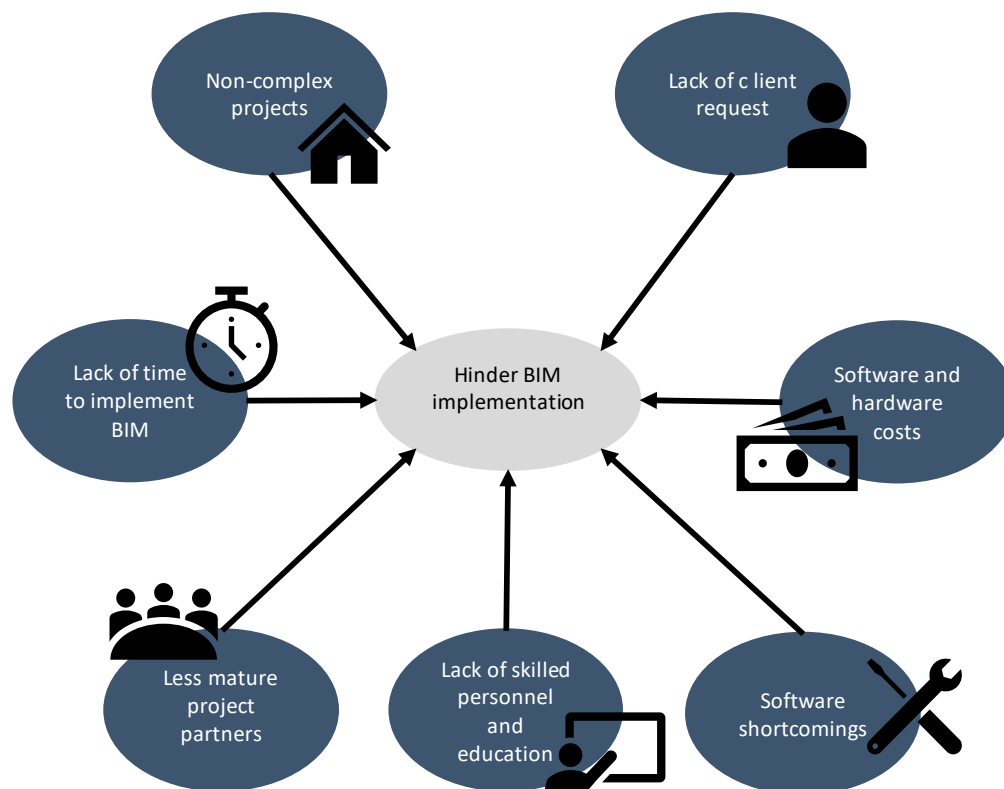
Figure 17 Barriers BIM implementation process

4.3.3   **Analysis and discussion findings**

Strategy

The fact that the BIM visions and goals within the industry are lacking or defined to a limited extent can possibly be explained by the lack of client request and the fact that the industry is driven by market demand. Therefore, most organizations experience the lack of time as a severe bottleneck for implementing BIM. In order to keep track on the pace, to not get left behind with BIM developments and subsequently satisfy the market demand, manufacturing organizations only implement what is requested by the client. This may consequently lead to the fact that written essentials, such as the definition of BIM visions and goals, which are commonly not directly requested by the client, are often being neglected or ignored initially. The lack of client demand is also recognized in the literature as a common reason for not using BIM in projects (Eadie, et al., 2013). Furthermore, some interviewees also stated of being in their starting phases of implementing BIM, which can also explain the current lack of BIM visions and goals. However, a lack of visions and goals may further lead to a lack of strategic intent, focus and misplacement of time and financial investments.

Organization structure

In order for the industry to benefit from reduction of errors and failure costs, contractual documentation are needed to set up adequately. However, according to the industry contractual guidelines are not always being applied due to constantly changing contracts. This phenomenon can be explained by a lack of new or amended forms of construction contracts to stimulate the implementation of BIM (Chan, 2014). However it can also be explained by uncertain clients and therefore, less mature project partners and lacking expertise of collaborating project partners

Human and culture

Education and training is usually being given only to those who specifically work with BIM and therefore general guidance within the industry is lacking. This can be explained by the fact that the costs of implementing BIM which include education and training is frequently recognized as a barrier to the implementation of BIM (Liu, et al., 2015). This also accords with earlier findings that addresses the lack of skilled personnel and education as a common barrier to the implementation of BIM. According to literature, education and training are seen as the core of BIM evolution and considered to be a solution that can accelerate the BIM learning curve. Therefore, the lack of adequately trained BIM professionals and a gap in skills will hinder the implementation of BIM (Liu, et al., 2015).

Processes and procedures

The fact that the BIM-related procedures and work instructions are limited defined or inconsistently being used can again be explained by the barrier the lack of time but, also the lack of skilled personnel and education within the industry. Furthermore, the fact that process change is being rolled out limited or insufficient within the industry, can be explained by lacking expertise and skills within the industry, but also by the cultural resistance which is frequently stated as a barrier for the implementation of BIM in the literature (Eadie, et al., 2013; Stanley & Thurnell, 2014). Introducing new processes, such as BIM, into an organisation involves the shifting of the culture of the organisation, which carries challenges with it that include the flexibility or versatility of the organisation's people and systems (Eadie, et al., 2014).

IT infrastructure

A possible explanation for advanced hardware only being available in specific work spaces can be that it is not always necessary to have these located in all company departments or areas. However, it may also be explained by high acquisition costs and therefore, the barrier hardware and software costs. This may also be the case for the acquisition of advanced BIM software. Implementing BIM necessitates organizations to purchase specific software and hardware and train their staff in the use of that software. The impact of these costs may vary according to the financial standing of the organization. According to literature, the high front-end cost of implementing BIM have also been seen to act as a significant implementation barrier (Eadie, et al., 2014). However, the limitation of being able to implement advanced BIM uses by the BIM software may also be explained by shortcomings of the software itself. Software incompatibility restricts the implementation of BIM processes and uses (Stanley & Thurnell, 2014), which is also expressed by the industry by pointing the incompatibility of Revit to directly steer the manufacturing process. However, it should also be mentioned that there is no BIM software that meets all BIM technology criteria. Over time, capabilities will need to grow to support advanced and more extensive practices and uses (Eastman, et al., 2008).

Data structure

The fact that the data management system is unstructured and not defined in work instructions can again be explained by the lack of time, but also the lack skilled personnel and therefore, the lack of training and education. This also accounts for the fact that object decomposition and libraries are not always or limited aligned with sector standards.

4.3.4 BIM future façade industry

When looking at the implementation of BIM in the future, the perspective of the façade industry goes several directions, as according to the industry organizations. Several respondents interviewed demonstrated various initiatives on how to further support the implementation of BIM within the industry, but also tackle several barriers hindering the current implementation process. Therefore, various views have been summed up and presented in this section.

Enrich IFC model

The Industry Foundation Classes (IFC) standard has been accepted increasingly over the past decade by the AEC industry as a interoperable file format. IFC files are seen the pdf files of the BIM world for exchanging data in a format compatible with most BIM software. The IFC models are semantically rich, because they do not capture the 3-dimensional geometry of objects only, but also metadata related to many other aspects of objects and the building. However, significant difficulties remain in exchanging information between Building Information Modeling (BIM) tools. The IFC exchange schema is too generic to capture the full meaning needed for direct use by different construction project stakeholders' BIM tools. It is complex and has redundancies because of the need to represent objects and relationships for a wide range of AEC sub-domains (Belsky, et al., 2015). Moreover, each project stakeholder creates the IFC in a different way and every designer gives elements different properties and may name the properties differently. This leads to the consequence that properties are not always accessible and are modified before export. Therefore, the three manufacturing organizations care to enrich or enlarge data that can be stored in the IFC model and placing metadata on the right places in the 3D model. Two manufacturing organizations explicitly mention the use of SimpleBIM to realize this.

Clash detection

In the world of BIM, clash detection a method of inspecting and identifying various interferences which can occur in the coordinating process of 3D models created in different (BIM) software's. The clash detection test detects conflicts between different elements within 3D Building Information Model prior to the start of construction activities (Raut & Valunjkar, 2017). This can be executed through several software's such as, Revit, Bentley Navigator, Solibri Model Checker and Autodesk Navisworks. According to the identified barriers per BIM use (see Appendix 6), clash detection is not done to its full extent within façade industry. Therefore, one manufacturing organization cares to implement BIM and model their objects in the near future to enable full clash detection. Furthermore, some software programs, such as Solibri, also have advanced features and offer the ability to create rules. Clash rules are some sort of formula used to select specific objects that need to be included in a clash test. One organization also cares to implement this extension in the near future to carry out advanced clash tests.

Façade Identification System (FIS)

BIM offers to the ability to structure all building information. However, according to the façade industry there is a lack of right information for the right project party at the right time. Therefore, the idea to develop a system that makes it possible to identify physical building elements throughout the lifecycle and to link the associated information with the product, the 'Facade Identification System' (FIS), is brought into life. Two manufacturing organizations care to partner this project, due to the fact that this tool will be necessary in the near future for fast and efficient building, monitoring, and maintaining of buildings and, thereby enhancing service logistics around a building. The ultimate objective is to develop a software (FIS) that:

1. enables tracing of elements can be traced both during the production process and exploitation phase;
2. stimulates the reuse of façade elements for the purpose of circular economy;
3. makes the logistical flows insightful to monitor and improve during the construction, operation and during the transformation, renovation and / or dismantling of a building;
4. measures the use of the façade element and thus, ensures a long term bond with the end user of the facade product.

The research and development activities regarding this project are planned to be finished by the end of 2018 (VMRG, 2017).

Efficient manufacturing process

Steering the manufacturing process from a BIM environment appears to be one of the most important BIM uses within the façade industry. This is also substantiated by the fact that it seen as one of drivers for implementing BIM within the organization. However, only a small group of organizations can benefit from this BIM use and steer their production process directly from a 3D BIM software. Usually, intermediate software's or intelligent links are necessary to fully steer the production process from a BIM environment, leading to a lot of rework and inefficiency. Therefore, several organizations are committed to make this process more efficient in the near future. Different views are formed to make this happen. Some organizations think that it is necessary to add certain information to the 3D model to stimulate a more efficient manufacturing process. Additionally, other organizations are of opinion that building a configuration in Revit would solve certain existing issues. Lastly, organizations also think that by linking BIM to a work preparation package, the double input may be reduced.

4.3.5   **Preliminary conclusion**

This study has identified seven main barriers hampering the implementation of BIM at the current moment within the metal façade industry. These barriers are characterized as followed:

- lack of client request,
- lack of skilled personnel and education,
- lack of time to implement BIM,
- non-complex projects,
- high software and hardware costs,
- less mature project partners,
- software shortcomings.

The lack of client request mainly occurs due to the fact that the industry is driven by market demand. In order to keep track on pace and not to get left behind with BIM developments, the industry only implements what is requested by the client. This is also substantiated by the barrier that implies the lack of time to implement specific BIM uses. This might cause the fact that BIM goals and BIM-related procedures and work instructions are lacking or limited defined. Furthermore, projects are not regarded complex enough to implement BIM and therefore, executed traditionally, since this happens to be easier and faster. The initial investments to implement BIM also seem to impede the implementation of BIM, which is substantiated by the barriers, lack of skilled personnel and education and high software and hardware costs. This also accords with earlier findings that suggests that strategical and structured BIM investments, especially related to software, stimulate the implementation of BIM. At the current moment, general BIM guidance and support is lacking within the industry and BIM software can often not execute advanced BIM uses. Moreover, not all project partners are perceived to have the same BIM competences which is expressed through limited application of contractual guidelines in practice and the lack of quality and detail of delivered models to execute certain BIM uses. Lastly, software shortcomings and incompatibility hinder the implementation of several advanced BIM uses. Thus, these barriers affect the current BIM-maturity level of the industry negatively. However, various manufacturing organizations anticipate on future needs in order to facilitate the implementation of BIM, but also tackle some of these barriers.

5. CONLUSIONS AND RECOMMENDATIONS

This chapter is meant to provide an answer for the main research question. In the conclusion the main findings of this research are presented. These findings cover each of the three research questions stated in Section 1.5. Based on these findings, the practical and academical recommendations are formulated. The practical recommendations answers the main research question by stating valuable insights on how the metal façade industry can implement BIM properly to implement BIM and increase their current BIM-maturity level. Lastly, academical recommendations are provided for further research to address the limitations of this research.

5.1   Conclusions

5.1.1   Measurement tool

This section answers the first research question *" How can the current BIM-maturity level of the façade industry be measured"*. It additionally also discusses the applicability of the tool utilized to measure the BIM-maturity level of metal façade industry.

Appropriateness of tool

According to literature reviews, existing BIM measurement tools consist of several shortcomings when needed to measure the BIM-maturity level of an organization. This study has shown that the recently developed measurement tool by Siebelink (2017) which addresses many of these shortcomings is appropriate for measuring the BIM-maturity level of organizations of the façade industry. The tool meets the demands of the VMRG in relation to this research and qualifies on various data quality dimensions such as, reliability, validity and completeness. The tool is consisting of two parts: the best practices and maturity model. The best practices enables us to consider the findings within the right context. The maturity itself includes six criteria, eighteen sub criteria and six maturity levels in order to measure the actual maturity level of the manufacturing organizations. The measurement tool also uses a principle when determining the maturity level of each sub criterion which implicates that all the elements of a certain maturity level description must be met before moving on to the subsequent level (Siebelink, et al., 2018).

Applicability of tool

Research has also shown that the BIM measurement tool is applicable for the façade industry. The tool is experienced to be quite elaborated and therefore complete, as stated by the majority of the interviewees. The respondents also stated, that the model covers all important aspects they think a BIM-maturity measurement should cover. As a researcher, the tool has been experienced to be quite detailed, yet generic enough to cover a BIM-maturity measurement of different scaled organizations belonging to different sub sectors. The best practices was experienced to be the flexible part of the tool, since adjustments in this part could easily be made to retrieve additional data. The maturity model itself was treated as the static part of the tool, also for benchmark purposes.

5.1.2 **BIM-maturity measurement**

This section provides an answer for the second research question *"What is the current BIM-maturity level of the metal façade industry"*. Furthermore, these findings are also analysed and discussed by elaborating on the remarkable measurements, BIM developments and the impact of BIM investments.

Maturity measurement

The results of the maturity measurement show that the BIM-maturity level of manufacturing organizations fluctuates between 1.6 and 4.0. These values indicate an average BIM-maturity level of 2.5 for the metal façade industry (n=13). Findings also show that organizations that participate within the BIM work group score higher than organizations that do not participate within the BIM workgroup. This is substantiated by the fact that the highest scoring organizations and thus, the supposed front runners of the industry, are those that participate within the BIM work group. Furthermore, the average maturity level of the BIM work group also appears to be higher than the average maturity level of the non-BIM work group. However, the sample size of the non-BIM work group (n=2) limits the generalizability of this finding.

Remarkable measurements

The results also show that industry organizations score remarkably high on the sub criteria management support and data exchange, as illustrated by the peaks in Figure 18. These results indicate that organizational managers are willing to support and invest in the implementation of BIM and data exchange is often facilitated through open standards (IFC) which is usually enforced in contracts. However, the drops of the figure also implicate that currently within the metal façade industry BIM vision and goals are lacking or defined to a limited extent, work instructions and procedures with regard to BIM are either lacking, limited defined or inconsistently used and the use of a document management system is either limited or not enforced in the work instructions.

BIM developments

In comparison with the sector analysis executed in 2014 and 2016 (University of Twente, 2014; Siebelink, 2017), it can be concluded that the BIM developments have grown within the manufacturing sector. Findings indicate an increase in managerial support throughout the years. Moreover, many organizations within the industry have several internal requesting actors active that try to boost the implementation of BIM. Furthermore, collaboration between project partners is becoming acknowledged within the industry. Also, higher BIM-maturity scores have been identified in comparison with two and four years ago. These developments are also substantiated by a certain increase of BIM implementation into projects in comparison with two years ago (Beers van, 2016). However, these developments are limited to comparison with a specific domain of the manufacturing sector, the metal façade industry. Therefore, the representativeness of the sample limits the generalizability of this finding.
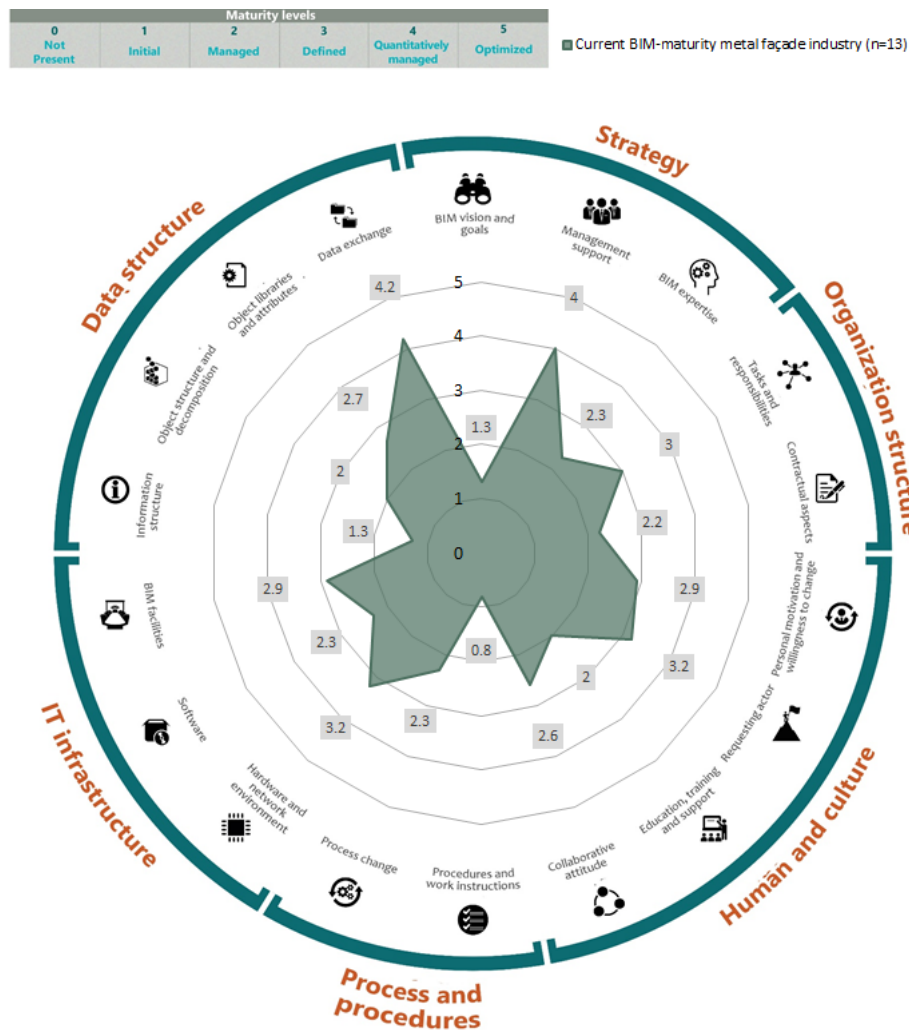
Figure 18 Current BIM-maturity view metal façade industry

Impact BIM investments

Findings also show that strategical and structured investments, especially with regard to software acquisition, usually stimulates the BIM implementation process and thus, can lead to a higher BIM-maturity level. This is also acknowledged by the façade industry by pointing out the lack of skilled personnel and education and high software costs as common barriers that hamper the BIM implementation process.

5.1.3   BIM implementation barriers and drivers

This section answers the third research question *" Which implementation problems exist when trying to implement BIM within the industry"*. Furthermore, it also elaborates on the implementation drivers and analyses and discusses how these barriers and drivers affect the current BIM-maturity and BIM implementation.

Drivers

This study has shown that the metal façade industry is mainly driven by client request or market demand to implement BIM. Additionally, industry organizations are also driven to implement BIM to take the lead within the industry by pinpointing several drivers such as, the reduction of errors

and failure costs, efficient data streams and communication, efficient manufacturing process and a better end product for the client with possibilities for maintenance.

Barriers

Apart from the drivers, this study has also identified several barriers that hamper the implementation of BIM at the current moment. The findings show that the most common barriers to implement a specific BIM use are: the lack of client request, the lack of skilled personnel and education, the lack of time to implement BIM, the fact that projects are not regarded complex enough to implement BIM, less mature project partners, high software and hardware costs and additional shortcomings of software.

Table 2 BIM implementation drivers and barriers

BIM implementation drivers	BIM implementation barriers
• Market demand • Reduction of errors and failure costs • Efficient data streams and communication • Efficient manufacturing process • Better end product and possibilities for maintenance	• Lack of client request • Lack of skilled personnel and education • Lack of time to implement BIM • Non-complex projects • Less mature project partners • High software and hardware costs • Software shortcomings

These barriers affect the current BIM-maturity level of the façade industry negatively. According to the findings, the industry is mainly driven by market demand. In order to keep track on pace and not to get left behind with BIM developments, industry organizations only implement what is requested by the client. This is also substantiated by the barrier that implies the lack of time to implement specific BIM uses. The might cause the fact that BIM goals and BIM-related procedures and work instructions are lacking or defined to a limited extent. Furthermore, projects are not regarded complex enough to implement BIM and therefore, executed traditionally, since this is perceived to be easier and faster. The initial investments needed to implement BIM also seem to impede the implementation of BIM, which is substantiated by the barriers, lack of skilled personnel and education and high software and hardware costs. This also in accordance with earlier obtained findings that suggests that strategical and structured BIM investments stimulate the implementation of BIM. Currently, general BIM guidance and support is lacking within the façade industry and BIM software can often not execute advanced BIM uses. Moreover, not all project partners are perceived to have the same BIM competences which is expressed through limited application of contractual guidelines in practice and the lack of quality and detail of delivered models to execute certain BIM uses. Lastly, software shortcomings and incompatibility hinder the implementation of several advanced BIM uses.

5.1.4   Improvement areas

The findings presented in Section 5.1.2 and 5.1.3 suggest improvement on several areas. These are the areas that regard BIM vision and goals, BIM-related procedures and work instructions and document management systems, as suggested from the remarkable drops of Figure 18. Some other areas for improvement were also recognized by the described barriers and other drops of the figure. These areas regard hardware and network environment, software and education training and support. Furthermore, some lower than the average BIM-maturity scoring sub criteria are also recognized for improvement such as, BIM expertise, contractual aspects, process change and object decomposition. The actual practical recommendations around these areas are presented in Section 5.2.

5.2   Practical recommendations and requirements

Based on the conclusions provided in Section 5.1 practical insights are provided on how the metal façade industry can facilitate the implementation of BIM to increase their current level of BIM-maturity. These recommendations are built upon the findings of this research and supported by the BIM Project Execution Planning Guide (2010).

It is of great essence for each manufacturing organization to develop a detailed execution plan for the implementation of BIM to effectively integrate BIM into their organizational or project delivery processes. This ensures that organizations are aware of the opportunities and responsibilities associated with the incorporation of BIM. Therefore, it is recommended to follow the steps mentioned below.

Define BIM vision and goals
Before the implementation itself, it is of great importance for each organization to clearly define the value of BIM within their firm. Therefore, it is essential for each organization to establish a BIM vision or mission statement to consider why BIM is important to their organization such as, competitive advantage, innovation, etc. Based on this, each organization can generate a list of BIM-related goals it wants to achieve *(strategy)*.

Align BIM uses with available resources
Followingly, at the beginning of the implementation process of a project or the organization itself, it recommended for each organization to define a list of the typical BIM uses they wish execute on project or organizational level. It is also important to consider all resources and infrastructure to perform these BIM uses. Therefore, the list created will enable each organization to align the BIM uses with available competences, the necessary information specification and type of exchange, the recommended data structure and necessary IT infrastructure *(strategy)*.

Determine required software package
As suggested by the aforementioned, organizations need to determine which software platforms and version of that software is necessary to perform the BIM uses per particular project. It is important to agree upon a software platform early in the project to prevent interoperability issues or non-executable BIM uses *(IT infrastructure)*.

Determine required hardware
It is also important for the organizations to acquire hardware that is in the highest demand and most appropriate for the majority of BIM uses they wish to execute or implement *(IT infrastructure)*.

Provide necessary training, education and support
The implementation of BIM or specific BIM uses may require new skills and competences as according to the earlier defined list. Therefore, it is necessary for each organization to outline their current capabilities against the required or desired capabilities. This will give an idea of when additional staff will need to be acquired or when staff will need to trained on new BIM technologies. General guidance across on organizational level should not be left out when considering the above *(human and culture)*.

Establish multidisciplinary work group

It is not only necessary to have education and training given on organizational level, but also to have a BIM work group or experts that represent all operational divisions and thus, the entire organization *(strategy)*. By structuring the training and education on organizational level and have experts available representing the all organizational departments, process change may be affected positively as well and therefore, rolled out throughout all organizations departments (*process and procedures)*.

Define BIM-related work instructions and procedures

It is of great essence for organizations to document and define work instructions and procedures with regard to BIM. Especially for dynamic and changing teams within organization documentation is of great importance but also a necessary base to build upon in the future *(process and procedures)*.

Utilize integrated contractual agreements

When implementing BIM on a project, ideally more integrated contracts such as design-build or Integrated Project Delivery (IPD) are preferred. These are known as are highly collaborative delivery methods that allow early involvement of contractors and thus, suppliers. These contracts facilitate information sharing based on the risk and reward structure *(organizational structure)*.

Align object decomposition with project partners and sector standards

For the purpose of collaboration and information exchange, it is also necessary to align uniformed object decompositions with project partners and sector standards. Composing objects in the same way and language is essential for integration, but also for preventing errors. This also contributes to ensuring that every project partner involved finds the right information at the right place, but is also able to deliver it in such a way. The *BIM Basis informatieleveringsspecificatie (ILS)* is a great initiative for doing this which has recently also been initiated by the BIM work group of the VMRG (*data structure*) (VMRG BIM Werkgroep, 2018).

Define and utilize a document management system

It is also recommended for each organization to consider together with the project team the communication methods, document management and transfer, etc Therefore, it is of great importance for each organization to define a document management for file make agreements on folder structure, permissions and access, folder maintenance, folder notifications file naming convention, etc. This is also necessary to facilitate smooth collaboration (*data structure*).

It should be mentioned that these recommendations are formulated to improve the current BIM-maturity level of the metal façade branch on short term (1-5 years). Furthermore, the recommendations are built on the assumption that necessary resources are available within the manufacturing organizations. Therefore, the feasibility of these implementation steps is limited to the availability of required BIM resources.
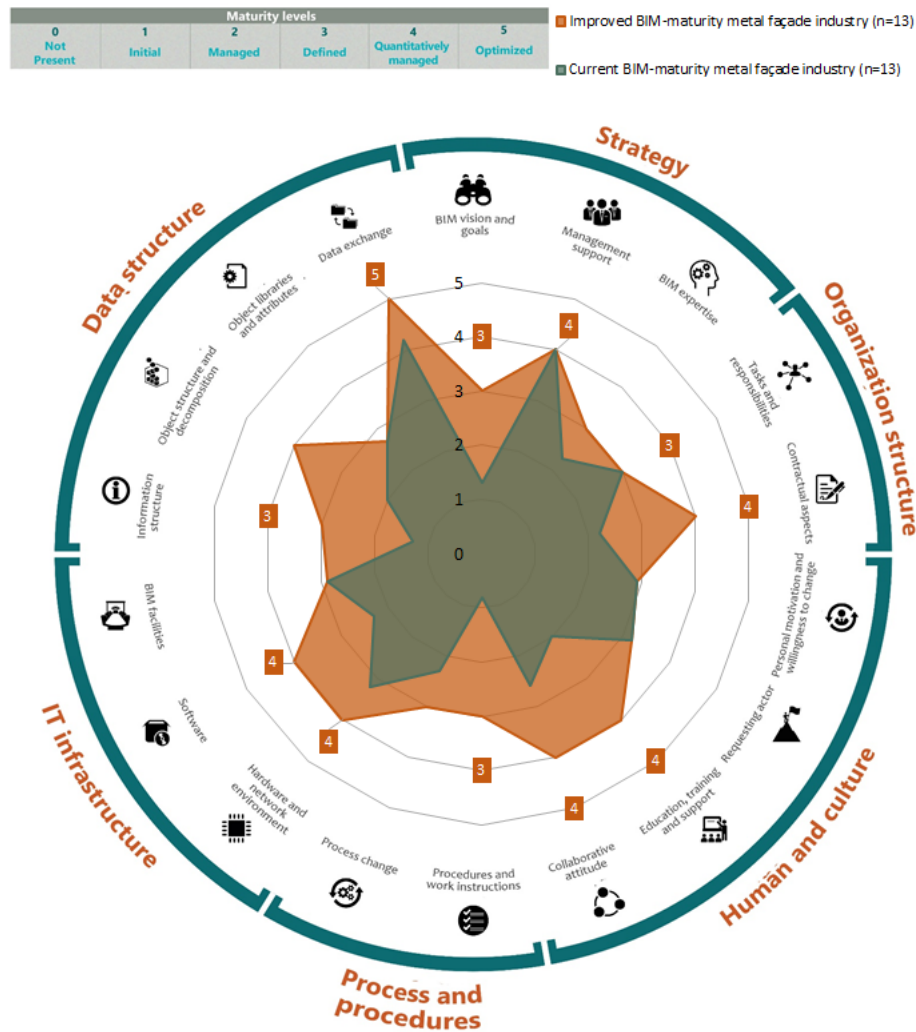
Figure 19 Indicative improved BIM-maturity view metal façade industry

The VMRG can also facilitate the implementation of BIM within the metal façade industry on longer term. It has done this initially by founding a BIM work group to establish uniformed agreements within the industry regarding the implementation of BIM. To facilitate this process further, it is recommended for the VMRG to consider why BIM is important for their organization, by defining BIM visions and goals as an association, especially while taking into consideration their BIM work group. It is also recommended to monitor these visions and goals as manufacturing organizations are evolving from the perspective of BIM and if necessary, to update as well. Furthermore, the VMRG can also facilitate the implementation of BIM within the metal façade industry, by enforcing implementation stimulating requirements in their Quality Mark for manufacturing organizations that want to differentiate their selves on the basis of BIM.

5.3   **Academical recommendations**

Further research in the metal façade industry
During this research it was experienced that not all manufacturing organizations approached, were willing to participate, especially those not belonging to the BIM work group, which may be due to protecting (proprietary) information. This is considered the limitation of this study, since it affected the total sample size (n=13) and therefore, the reliability of the findings. Notwithstanding the relatively limited sample, this study provides insights on the BIM developments of a specific domain within the manufacturing sector and therefore, valuable and practical insights on how to facilitate the implementation of BIM and thus, increase the current BIM-maturity level. With the publication of these research findings more organizations may be willing to participate in the near future. Therefore, further research in the metal façade industry is recommended in perhaps the form of a survey to reach a larger amount of organizations and therefore, broaden the research sample. The findings of further research will again be essential to benchmark earlier obtained findings.

Further research in manufacturing sector
When comparing the findings with the sector analysis (University of Twente, 2014; Siebelink, 2017) a certain increase in BIM developments is witnessed within the manufacturing sector. However this growth is solely based on the BIM-maturity measurement and therefore, BIM developments within a specific domain of the manufacturing sector, the metal façade industry. Therefore, to increase the generalizability of this finding, a more representative sample is necessary, which indicates further research within other and specific domains of the manufacturing sector. This will be necessary as well to elaborate more on the applicability of the measurement tool within the manufacturing sector of the Dutch construction industry.

Update and refine BIM measurement tool
It is also necessary to update and refine the BIM measurement tool when conducting another sector analysis. The list of BIM uses utilized for the integrated supplying and manufacturing was experienced to be incomplete and therefore required optimization. The integrated presentation of the findings which concerned the supplying and manufacturing sector also created some difficulty when wanted to benchmark with the findings of this study. It is difficult to estimate whether differentiating these sub sectors will lead to more explicit and deviating BIM-maturity patterns, since this is mainly based on the BIM developments these sub sectors experience throughout the years. However, for a better quality of comparison in the near future this might be essential as well.

BIM definition and focus
BIM has its roots in computer-aided design research from decades ago, yet it still has no single, widely-accepted definition. Due to the fragmentation within the construction industry, several definitions and characteristics are being utilized. Each sub sector within the construction industry has a different focus point when implementing BIM which is also substantiated by the reason they are driven to implement BIM. It is of great essence to define this focus point of BIM for the manufacturing sector to help manage their BIM developments and implementation process.

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APPENDICES

Appendix 1 Description maturity levels
Appendix 2 Description BIM uses
Appendix 3 Description maturity criteria
Appendix 4 Project execution within façade branch
Appendix 4 BIM investments façade branch
Appendix 5 Barriers BIM implementation process
Appendix 6 Use of Software
Appendix 7 Interview format

Appendix 1 Description maturity levels

The maturity model developed by Siebelink (2017) is consisting of six maturity levels. A generic description of these maturity levels is elaborated in the text below. These descriptions are then use as a guide to define the maturity level description of each sub criteria.

Maturity level 0 – Not present
Characteristic processes or aspects are missing in the organization and no goals formulated.

Maturity level 1 - Initial/ Ad-hoc
Internal and external BIM processes are not or to a limited extent described and are ad hoc executed. Good practices are not shared or captured in procedures and the organization is not tuned on collaboration within the supply chain. The performance of BIM-related processes and projects are unpredictable and highly dependent on the available competences of the project team.

Maturity level 2 – Managed
BIM strategies and procedures have been established for important project-related BIM processes, through which 'Good practices' can be repeated and the predictability of processes increases. The importance of collaboration within the supply chain is acknowledged by defining objectives and external basic processes, but the structure of the organization is not or insufficiently in line with this. The organisation does not change to enable a more intensive cooperation with partners. During the project BIM processes are followed, adjusted and evaluated to a limited extent.

Maturity level 3 – Defined
BIM objectives are formulated by management with strategic intent and there is a good overview of the performance and progress of BIM projects. Within this level a breakthrough in terms of cooperation in the construction chain is taking place: organizational structures and functions are (partly) focused on cooperation with chain partners, so that joint goals and activities can be established. Good BIM practices are being documented and applied across the organization. An increased unity is being developed within the organization, where confidence in BIM and the motivation for joint BIM goals are stronger than possible barriers.

Maturity level 4 - (Quantitatively managed)
BIM processes are objectively controlled, through which the performance stays within acceptable limits. Collaboration with chain partners is part of the organizational strategy. Quality programs have been drawn up that verifies the progress and outcomes of BIM processes using measurable targets. Both the culture and satisfaction of the project partners strengthen the competitive position and authority of the organization.

Maturity level 5 – Optimised
The organization operates as part of a multi-firm supply chain. This is characterized by intensive collaboration with chain partners, in which BIM processes are continuously being improved. This cooperation is guaranteed by mutual trust and (financial) dependence. Insights on the exchange of performance data makes it possible to anticipate on problems and stimulates the implementation of new BIM applications and technologies. Evaluation of processes and projects

contributes to learning about projects. The company its culture stands for openness and transparency to promote intensive BIM collaboration.

Appendix 2 Description BIM uses

Below an overview of the defined BIM uses is presented that were utilized during the BIM-maturity measurement of the façade industry. These are established through research for best practices (Beers van, 2016; Eastman, et al., 2008; Siebelink, 2017).

3D modeling (3D-ontwerpen)
BIM facilitates the development of multiple design alternatives. It furthermore enhances efficient adaption or adjustment of the design in order to meet the requirements as much as possible.

3D-detail engineering (3D-detailengineering)
Detailed engineering done by suppliers enable (main) contractors to produce complete 3D models of all components and subsystems.

Generate 2D drawings from 3D models (Genereren 2D-tekeningen o.b.v. 3D-modellen)
The design information stored in the 3D building model can be used, at any particular time, to produce 2D drawings consistent with the building model.

3D Visualization (Visualiseren van het ontwerp o.b.v. 3D-modellen)
The use of BIM facilitates the development of a spatial and insightful design that can visualized for or communicated to clients, project partners or internal members.

3D-coordination or clash detection (3D-coördinatie tussen verschillende afdelingen en disciplines interne systemen)
For this BIM application usually a conflict detection software is used to compare different building models between different departments or disciplines for coordination purposes. By doing this conflicts between systems and disciplines are identified prematurely in order to prevent construction-oriented problems. Based on the outcomes, the supplier is able to adjust the sub-design.

3D modeling amongst different disciplines (Ontwerpen met verschillende disciplines aan één bouwmodel)
BIM as a tool can be used to integrate different sub designs or aspect models into one building model. All project information (from e.g.) : manufacturers, mechanical engineers, electrical engineers, steel constructors and prefabricated producers) is accessible and managed within the building model.

Design review (Ontwerpreview & eventuele opmerkingen plaatsen)
This BIM use is meant to view the design and additionally place remarks. A building model is usually used to present the design to stakeholders to give them the opportunity to evaluate the design. This provides possible input for optimization of the design with regard to the requirements of the client and to the feasibility and execution of the design.

Data exchange between different project partners/ disciplines (Uitwisseling gegevens met andere projectpartners /-disciplines)
BIM facilitates data exchange and collaboration between different disciplines by (a) receiving data in a 3D model and (b) sharing of data from the 3D model. This enables, for example, effective clash detection between disciplines to be carried out or the steering of automated construction

within a factory to reduce construction activities on site. This application requires transparency and trust between project partners and the willingness to share information.

Extract quantities from 3D model (Genereren hoeveelheden uit het 3D-model)
During the design process, the building model can be used to extract accurate quantities. The level of detail of these quantities is highly dependent on the building model. The generated quantities can provide important information of the purchasing process or can be used as a base for the financial calculations.

Structural analysis (Constructieve analyse)
A process in which analytical modeling software utilizes the BIM design authoring model to determine the behavior of a given structural system. With the modeling minimum required standards for structural design and analysis are used for optimization. Based on this analysis further development and refinement of the structural design takes place to create effective, efficient, and constructible structural systems. The development of this information is the basis for what will be passed onto the digital fabrication and construction system design phases.

Physical building analysis (Bouwfysische analyse)
This is a process in which one or more software's are used to conduct various assessments related to for example, lighting, energy, sound, thermal and air performance for a building design by using design specifications in the building model. The goal of this BIM use is to inspect the effectiveness of the proposed design and to seek for opportunities to optimize the proposed design to reduce structure's life-cycle costs.

Phase planning/4D modeling (Koppelen 3D-model aan een planning)
The 4D model is used to make a representation of permanent and temporary facilities on the construction site, including a planning of construction activities. The construction sequence enhances a better understanding of project milestones and construction plans. Information that can be added to the building model are the use of labor, materials and associated deliveries, and placement of equipment.

Cost estimation/5D modeling (Kostenraming opstellen met het 3D-model)
If sufficient information is stored in the building model, direct quantity take-offs and cost estimates can be carried out accurately in the building model throughout the entire project lifecycle. To realize this, financial key figures are linked to the objects in the 3D model. This process allows the project team to see the cost effects of their changes, during all phases of the project, which can help reduce excessive budget overruns due to project modifications.

Purchasing management (Inkoopmanagement)
There is a link between the building model and external databases that offer the possibility to directly import products from suppliers, including geometry and product information, and also to buy these. Furthermore, it is possible to link the purchasing processes with the planning, production or execution processes in order to prevent certain problems from occurring, such as the purchase of a certain part has not been completed yet, while it has a long delivery time. This may lead to stagnation in the execution. The building model can thus visualize such bottlenecks.

Planning of production and supply (Planning van productie en leverantie)
By integrating objects from a supplier in the (4D) building model of the main contractor, the main contractor can coordinate the planning of different project partners. This provides the supplier accurate insight into the delivery sequence and installation planning of different components. This information can then be used to optimize the production process and supply chain management.

Lean engineering (Ondersteunen van leansessies met het 3D model)
More efficient working method with less waste of labor and material by making full use of the detailed information in the 3D building model. This is usually exploited by data for the planning and production supplying elements.

Steer manufacturing process (Aansturen productieproces)
Detailed information of building objects can be exported in a readable format to an automated production process with BIM. This application deprives the need for human action to program computer-based instructions for the production process.

Insights in implementation process (Inzicht in uitvoeringsprocessen)
The building model can be used to follow and coordinate various construction and implementation processes. This is essential to monitor and optimize the project planning. This application usually requires intensive involvement of the client during the planning process and realization. To make the best use of this application, the building model has to be linked to a project planning (4D model).

Object identity (Labelen en nummeren van objecten t.b.v. productie, installatie en logistiek)
Labeling and numbering is possible on three levels, to known: ID for each component, group ID for installation and a production group ID. These ID's enable the use of equivalent parts to produce or purchase. Due to consistent labeling of objects, the virtual database can be made in accordance with the as built data base.

Establish material passport (Opstellen van materiaal paspoort)
The data stored in the BIM model can subsequently be used to establish a material passport of different objects in which also important characteristics of these materials are recorded.

Quality control (Kwaliteitscontrole)
This use enables linkage between inspections, status and planning. Inspection status and documents can be linked to the building model, whereby a connection is established with the schedule. Each object can then have a field in which the status is specified. For example: "in design", "approved for construction assessment", "in progress", "inspected" etc. If these fields are associated with colors, the status can be clearly visualized, but also bottlenecks or parts that lag behind schedule can be seen (e.g. via notification). This information provides input to determine and indicate which objects are not yet completed or verified in relation to a payment term.

Sustainability assessment (Duurzaamsheidsevaluatie)
BIM can be used to evaluate a project on the basis of various sustainability criteria that may relate to materials, performance or processes. This analysis can provide information about the life span, environmental friendliness, but also the multifunctionality of the to be built object.

Compose as built file (Samenstellen as built dossier)

If all changes during the execution phase are incorporated into the building model, this building model can the serve as a basis for the as built model at the time of delivery. The 3D model can include geometric data or can be linked to object drawings, analysis, product information, supplier information, etc.

Monitor logistics through RFID tags/barcodes (Monitoren van logistiek m.b.v. RFID-tags en/of barcodes)

The building model is directly linked to a wireless technology. This application uses Radio frequency Identification for logistics and the tag ID corresponds with the object code in the building model. This gives an up-to-date view of the location and status of the components.

Locate through laser and machine guidance techniques (Plaatsbepaling d.m.v. laser- en machinebegeleidingstechnieken)

Locate objects through laser scanning to record the as built installation information and compare this with the building model.

Appendix 3 Description maturity criteria

The maturity model developed by Siebelink (2017) is consisting of 6 main criteria and 18 sub criteria. The description of each main criterion and its corresponding sub criteria is presented in the text below.

Strategy

The strategy is drawn upon the mission and goals of the organization. This strategy can be determined in line with a specific **BIM vision and associated goals**. The implementation of the strategy, however, requires **support from the management**, both verbally announced and by providing (financial) resources. Additionally, time and direction from a **BIM expert of work group** are prerequisite as well (Siebelink, 2017).

Organization structure

This criterion partly regards the formal structure of the organization, such as the division of labour and associated power. These aspects are formalized in the job descriptions, which contain **the tasks and responsibilities of the employee**. It also further regards **contractual aspects**, which are substantiated by the BIM agreements the organisation makes with project partners (Siebelink, 2017).

Human and culture

This regards a set of basic assumptions and habits that are anchored in an organization, that will be transferred to new employees as well. This determines the **personal motivation for working with BIM** and expansion of application areas. To increase the motivation it is necessary to have an BIM champion who functions as **internal requesting actor** for the application of BIM. In addition to this, the functioning of BIM is also determined by the competence to be able to work with it. The organization should therefore provide **intensive education and training** to all the people that are part of the BIM process. The integrated and multidisciplinary BIM approach, however, requires a setting and **attitude of people which is aimed at cooperation**. The culture of the organization should thus also affect the openness (to external partners) and collaborative attitude or orientation within the supply chain (Siebelink, 2017).

Process and procedures

It is important that the processes contribute to the desired functioning of BIM and vice versa. In the organizational context, the performance of BIM is dependent on the extent to which the organizational, **internal processes** for the various BIM applications are **formalized in job instructions and procedures**. BIM can also play an important role regarding the change and improvement of organizational processes. This usually regards the fact whether of whether not **process changes** are structurally being made and if they are taken along to other projects or parts of the organization (Siebelink, 2017).

IT infrastructure

The technical means within the information system primarily consists of a **(BIM) software**. Additionally, it also includes **the hardware and network environment**, which support a smooth use of the software. **BIM facilities** are also included, such as spaces where interactive coordination sessions (clash detection) with project partners can be supported with model visualizations (Siebelink, 2017).

Data (structure)

The information structure is essential to the many uses of BIM. The object-oriented approach is the core of the definition of BIM. The drafting of **an object structure and decomposition** with unique codes for all objects in the model/project, is the base for this. Depending on the applications of BIM, also various databases or object libraries can be used to ease the BIM model design processes. Specifications and characteristics of objects can be linked by means of **attributes**, possibly included in the **object libraries** or added to objects in the model otherwise. The integration with models of supply chain partners is determined by **data exchange** of object information, discipline-specific models and overarching building information models (Siebelink, 2017).

Appendix 4 Project execution within the metal façade industry

The manufacturing organizations execute different type of projects in terms of product and production scale. With the data collected during this research a classification of project execution within the metal industry is also made.
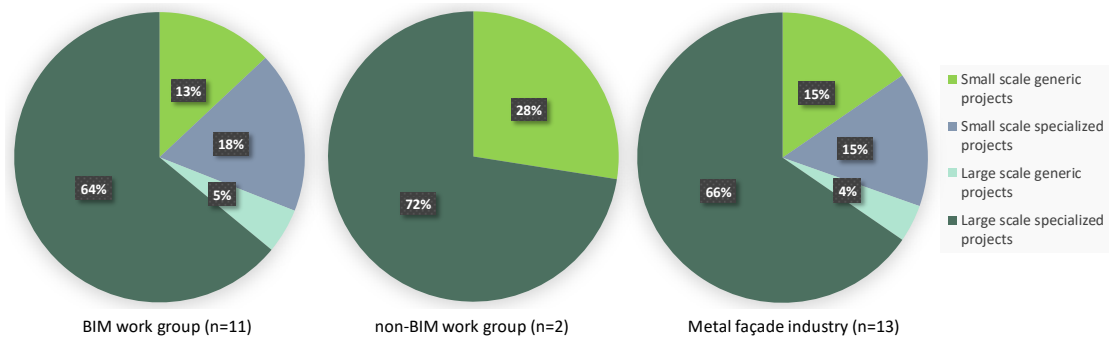
Figure 20 Classification project execution

The findings show that 64 % of projects that are being executed by industry organizations (n=13) are large scale and specialized. Furthermore, projects that include the manufacturing of small scale specialized and generic products are each executed for about 15 %. The less frequent produced products within the industry are the large scale generic products.

When considering the results within more specific boundaries, it appears that majority of projects executed by the organizations of the BIM and non-BIM workgroup are also based on the manufacturing of specialized projects on a large scale. However, when looking at the BIM work group (n=11) a small shift and thus, increase towards small scale specialized projects is witnessed. This shift is witnessed towards the opposite direction and thus, towards the small scale generic projects when looking at the non-BIM work group (n=2). Moreover, according to the results, the organizations that do not belong to the BIM workgroup do not execute small scale specialized and large scale generic projects, or perhaps to a limited extent.

The BIM work group appears to be a proper reflection of the metal façade industry when considering the project execution pattern as according to Figure 20. The fact that the organizations of the non-BIM work group present a project execution pattern that deviates from the industry sample (n=13) can be due to a coincidence of interviewing two organizations with the same deviating pattern. Due to the limited sample size of this group it is difficult to generalize on their project execution pattern.

Appendix 5 BIM investments metal façade industry

The manufacturing organizations show different expense patterns with regard to BIM. Below, the patterns applicable for the research sample representing the metal façade industry (n=13) are summarized.

Education and training
According to the findings, 4 organizations spend less than 500€ on BIM training and education per fulltime-equivalent per year. Furthermore, 6 organizations spend between the 500 and 2500€ for the same per year. Lastly, 3 organizations spend above 2500€ of which 1 spends above 5000€ on BIM training and education per fulltime-equivalent per year.
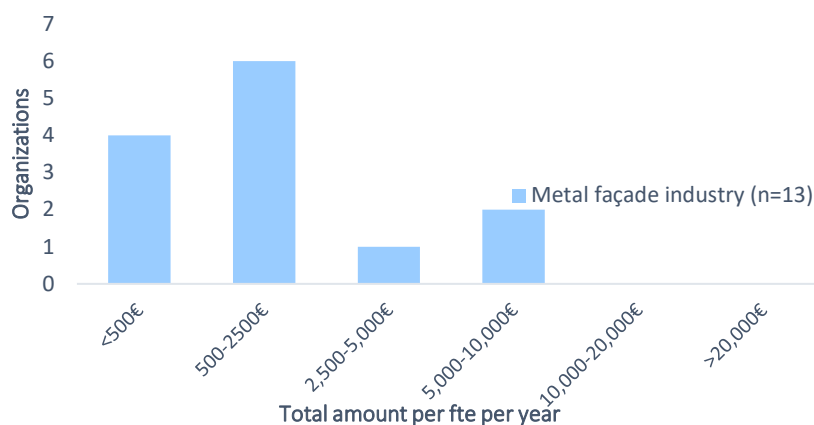
Figure 21 Expenditures on BIM training and education

Software
According to the findings, the majority of the metal façade industry invests less than 20.000 € on the acquisition of BIM software per year. More specifically, 8 organizations invest less than 20.000 € on the acquisition of BIM software per year of which 4 organizations invest less than 10.000 €. A smaller proportion of the industry and thus, 3 organizations invest between 20.000-40.000 € per year to acquire BIM licenses.
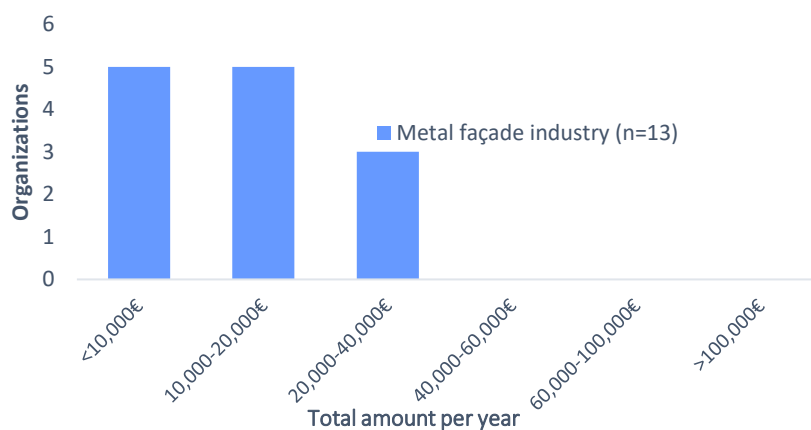
Figure 22 Expenditures on software

Appendix 6 Barriers BIM implementation process

The table below presents a summary of the identified barriers per BIM use. This is derived from the statements of the respondent during the interview trajectory and thus, applicable for the consulted research sample of the metal façade industry (n=13).

Table3 Identified BIM implementation barriers

3D Modeling	3D-detailengineering	Generate 2D drawings from 3D models
Lack of skilled personnel 2D modeling is easier and faster Not requested by the client	Lack of skilled personnel Not requested by the client Large files with a high level of detail cannot sufficiently be detailed due to shortcomings of particular BIM software's Not required for simple and non-complex projects	Not requested by the client Lack of skilled personnel Not required for simple and non-complex projects Lack of a sufficient software program
3D Visualization	**3D-coordination or clash detection**	**3D modeling amongst different disciplines**
Not always necessary Time-consuming	Not all project partners model in 3D Not requested by the client Client (contractor) does not facilitate a platform for this	Not requested and facilitated by the client Model server is expensive Not always efficient due to the fact that changes executed by other partners (e.g. architects) lead to major changes in own model when modeling on a relative high level of detail Costs of software/hardware do not weigh up against the benefits
Design review	**Data exchange between different project partners/ disciplines**	**Extract quantities from 3D model**
Not requested by client Software cannot generate bcf files	Not requested by client Not all project partners model in 3D Not all suppliers all capable of extracting the (correct) information from the 3D model Gap between manufacturer and contractor serves as barrier	Not all project partners model in 3D Insufficient level of detail Highly dependent on purchase management Is usually executed again in non-BIM environment
Structural analysis	**Physical building analysis**	**Phase planning/4D modeling**
Lack of skilled personnel and education Not requested by client Other simplistic methods available Dependent on the complexity of the project Complex and time-consuming Cannot be executed by the BIM software Externally outsourced Costs of software/hardware do not weigh up against the benefits	Lack of skilled personnel and education Not requested by client Other simplistic methods available Cannot be executed by the BIM software Externally outsourced Dependent on supplier Costs of software/hardware do not weigh up against the benefits	Not requested by client Time-consuming No available software for execution or shortcomings of software
Cost estimation/5D modeling	**Purchasing management**	**Planning of production and supply**
Lack of skilled personnel and education Not requested by client Calculation is not that advanced yet The quality and level of detail of the delivered 3D models are not sufficient enough	Insufficient level of detail Materials are ordered in advanced to compensate long delivery schedules Not all suppliers all capable of extracting the (correct) information from the 3D model Not all projects are executed in 3D	Not requested by client Time-consuming No direct link with BIM software No added value for the company Software shortcomings Requires a large amount of data

Table 3 Identified BIM implementation barriers

Cost estimation/5D modeling	Purchasing management	Planning of production and supply
	Level of detail is too high making it less efficient to work with a 3D BIM software	Level of detail is too high making it less efficient to work with a 3D BIM software
Lean engineering	**Steer manufacturing process**	**Insights in implementation process**
Time-consuming Not requested by client No direct (intelligent) link with BIM software Software shortcomings	Lack of skilled personnel and education Software shortcomings Lack of BIM software that supports both modeling in a 3D environment and steering of production process	Not requested by client Lack of skilled personnel and education Cannot be done with the BIM software No added value for the organization Done in an non-BIM environment
Object identity	**Establish material passport**	**Quality control**
Time-consuming Done in an non-BIM environment	Not requested by client Time-consuming Done in an non-BIM environment	Time-consuming Done in an non-BIM environment A small proportion of the quality control can be in a 3D environment Lack of skilled personnel and education
Sustainability assessment	**Compose as built file**	**Monitor logistics through RFID tags/barcodes**
Time-consuming No added value for the organization Not requested by client Software shortcomings Done in a non-BIM environment Lack of skilled personnel and education	Not requested by client Lot of ambiguity of what is meant with as-built file Does not exist in reality	Not requested by client Lack of skilled personnel and tools Time-consuming No added value for the organization
Locate through laser and machine guidance techniques		
Time-consuming Not requested by client Lack of skilled personnel and tools Not necessary for small, non-complex projects		

Appendix 7 Use of Software

The table below presents a summary of utilized software per BIM use. This is derived from the statements of the respondents during the interview trajectory and thus, applicable for the consulted research sample of the metal façade industry (n=13).

Table 4 Software utilization

3D Modeling	3D-detailengineering	Generate 2D drawings from 3D models
Revit HiCAD Solidworks Inventor Bocad	Revit HiCAD Solidworks Inventor Bocad	Revit HiCAD Solidworks Inventor Bocad AutoCAD
3D Visualization	**3D-coordination or clash detection**	**3D modeling amongst different disciplines**
Revit HiCAD Solidworks Visualize Inventor Bocad	Revit Inventor Bocad Navisworks Solibri/ Solibri Viewer/ Solibri Model Checker Simple BIM Tekla BIM Site BIM 360 Glue	Revit (in combination with A360) HiCAD Inventor Bocad
Design review	**Data exchange between different project partners/ disciplines**	**Extract quantities from 3D model**
Solibri BIM Collab Gmail Navisworks BIM 360 Glue Inventor Tekla BIM Site	Docstream HiCAD Simple BIM Solibri Viewer Tekla BIM Site Revit Chaapo Bricys BIM 360 Team Bocad Inventor Trimble	HiCAD Solidworks Revit Orgadata Inventor Bocad
Structural analysis	**Physical building analysis**	**Phase planning/4D modeling**
Solidworks LogiKal	Revit LogiKal	x
Cost estimation/5D modeling	**Purchasing management**	**Planning of production and supply**
Solibri/ Solibri Viewer	Isah LogiKal Revit (in combination with ERP) Inventor Bocad ShuCal	Revit Orgadata ShuCal
Lean engineering	**Steer manufacturing process**	**Insights in implementation process**
Solibri BIM 360 Glue Inventor	HiCAD WICAM Lantek CAM ShuCo Revit (in combination with AutoCAD, Unilink and LogiKal)	Revit

Table 4 Software utilization

Lean engineering	Steer manufacturing process	Insights in implementation process
	Inventor Bocad	
Object identity	**Establish material passport**	**Quality control**
HiCAD Solidworks Revit Inventor Bocad Orgadata	x	Shop Floor LogiKal Orgadata
Sustainability assessment	**Compose as built file**	**Monitor logistics through RFID tags/barcodes**
x	Revit HiCAD Bocad	x
Locate through laser and machine guidance techniques		
Revit Inventor		

Appendix 8 Interview format

BIM maturity analyse in de gevel industrie

Algemene gegevens

Datum interview: ………………………………………………

Interviewer(s):   Raysha Ramautarsing……………………………………………………………………………………

Duur interview: ………………………………………………

Naam organisatie: ……………………………………………………………………………………

Geïnterviewde(n):   ………

Functie(s):   ………

Interviewvragen deel 1: open vragen en best practices
Algemeen

1. Wat is de totale FTE (fulltime-equivalent) werkzaam binnen uw organisatie?

☐ < 5 FTE   ☐ 5-20 FTE   ☐ 21-50 FTE   ☐ 51- 200 FTE   ☐ 201-500 FTE   ☐ > 500 FTE

....

(NB: Bij deze vraag wordt verondersteld dat 1 FTE voor 40 werkuren per week staat)

2. Kunt u zich als organisatie classificeren op basis van de type projecten die u uitvoert?

....
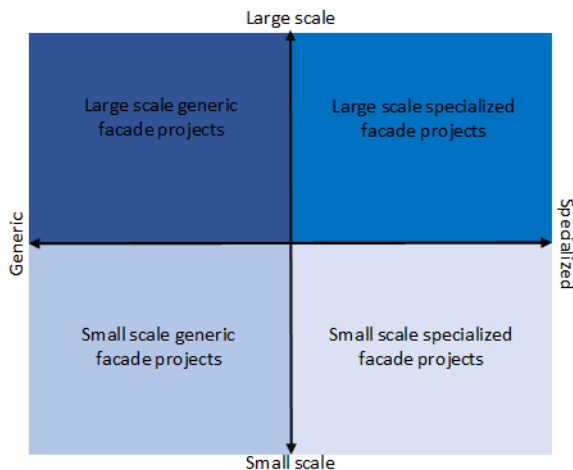
3. Welke rol speelt BIM binnen uw organisatie? (controle: komt dit later ook terug in het subcriterium BIM visie en doelstellingen)

....

4. Hoe kijkt u aan tegen de ontwikkeling van BIM binnen de gevelindustrie?

………

5. Hoe positioneert u uw eigen organisatie hierbinnen (als koploper)?

………

Best practices

1. <u>Verstrek het formulier voor de betreffende deelsector uit bijlage A aan de respondent, zodat hiermee de vragen 2 t/m 5 kunnen worden ingevuld.</u>
    Kunt u op het formulier aankruisen welke BIM toepassingen door uw organisatie worden benut en welke BIM softwares hiervoor worden geraadpleegd? Deze toepassingen zijn ingedeeld in een categorie met algemene toepassingen en een categorie met specifieke toepassingen voor uw deelsector. (Alleen nog de eerste kolom invullen)

	Volgorde van imple-mentatie	**Toepassingen gevelbouwers**	Geraad-pleegde BIM softwares	Toegepast in % van totale aant. projecten	Barrières voor implementatie
☐		3D-ontwerpen			
☐		3D-detailengineering			
☐		Genereren 2D-tekeningen o.b.v. 3D-modellen			
☐		Visualiseren van het ontwerp o.b.v. 3D-modellen			
☐		3D-coördinatie tussen verschillende afdelingen en disciplines (clash detectie / raakvlakmanagement)			
☐		Ontwerpen met verschillende disciplines aan één bouwmodel (via gezamenlijke server)			
☐		Ontwerpreview & eventuele opmerkingen plaatsen			
☐		Uitwisseling gegevens met andere projectpartners /-disciplines			
☐		Genereren hoeveelheden uit het 3D-model			
☐		Constructieve analyse			

☐		Bouwfysische analyse			
☐		Koppelen 3D-model aan een planning (4D-model, bouwfasenplanning)			
☐		Kostenraming opstellen met het 3D-model (5D-model)			
☐		Inkoopmanagement			
☐		Planning van productie en leverantie (4D-model)			
☐		Ondersteunen van leansessies met het 3D model			
☐		Aansturen productieproces (Computer Aided Manufacturing, CAM)			
☐		Inzicht in uitvoeringsprocessen			
☐		Labelen en nummeren van objecten t.b.v. productie, installatie en logistiek			
☐		Opstellen van materiaal paspoort			
☐		Kwaliteitscontrole			
☐		Duurzaamsheidsevaluatie			
☐		Samenstellen as built dossier			
☐		Monitoren van logistiek m.b.v. RFID-tags en/of barcodes (koppeling bouwmodel met draadloze technologie)			
☐		Plaatsbepaling d.m.v. laser- en machinebegeleidingstechnieken (koppeling 3D model met draadloze technologie)			

2. Zijn er BIM toepassingen binnen uw organisatie die niet in deze lijst voorkomen? Wilt u deze op het formulier noteren?

………

3. Hoe was de volgorde van implementatie van BIM toepassingen binnen uw organisatie? Kunt u een volgorde aangeven in de aangevinkte lijst met toepassingsgebieden (evt. aangevuld met ontbrekende toepassingen uit vraag b)?

………

4. Welk percentage van de projecten wordt uitgevoerd met BIM? Kunt u dit ook bij benadering aangeven per aangekruiste toepassing? (Voorbeeld: 3D-ontwerpen wordt in 30% van de projecten toegepast, het genereren van hoeveelheden uit het 3D-model wordt in ongeveer 10% van de projecten gedaan)

☐ 0%   ☐ 1-20%   ☐ 21-40%   ☐ 41-60%   ☐ 61-80%   ☐ 81-100%

NB: Aan de hand van deze vraag kan worden vastgesteld of BIM meer projectgewijs of organisatiebreed wordt geïmplementeerd.

……

5. Zijn er BIM toepassingen die u overweegt te gaan gebruiken, maar dit momenteel niet doet? Kunt u in de lijst met toepassingen aangeven welke barrières de implementatie of verdere ontwikkeling van bepaalde toepassingen belemmeren? <u>Gebruik hiervoor het overzicht met mogelijke barrières uit bijlage B.</u>

……

6. Bij welke stappen in het implementatieproces heeft uw organisatie lastige barrières overwonnen? Welke barrières? Hoe is hierbij een doorbraak gekomen?

……

7. Is uw organisatie momenteel bezig of heeft het plannen om nieuwe toepassingen te implementeren? Welke? Met welke reden?

……

8. Kunt u verder een aantal redenen (drijfveren) aangeven die voor uw organisatie van belang zijn (geweest) om BIM toe te passen / om te investeren in de implementatie van BIM?

……

9. Wat is het jaarlijkse gemiddeld totaal dat u investeert in BIM d.m.v. :

   a. Training en educatie per FTE

   ☐ < €500/jr   ☐ €500-2.500/jr   ☐ €2.501-5.000/jr   ☐ €5.001-10.000/jr   ☐ €10.001-20.000/jr   ☐ > €20.000jr

   ………

   b. Software

   ☐ < €10.000/jr   ☐ €10.001-20.000/jr   ☐ €20.001-40.000/jr   ☐ €40.001-60.000/jr   ☐ €60.001-100.000/jr   ☐ > €100.000/jr

   ………

10. Op welke termijn denkt uw organisatie deze investering terug te verdienen?

    ☐ < 1jaar   ☐ 1-3 jaar   ☐ 4-6 jaar   ☐ 7-8 jaar   ☐ 9-10 jaar   ☐ > 10jaar

    ………

11. Wat is voor uw organisatie de belangrijkste BIM toepassing?

    ………

Interviewvragen deel 2: beoordeling criteria uit het BIM maturity model
BIM visie en doelstellingen
De strategie op organisatieniveau kan worden geconcretiseerd voor BIM door hierin een BIM visie en bijbehorende doelstellingen op te nemen.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen BIM visie of doelstellingen geformuleerd	Basisvisie is gedefinieerd	BIM doelstellingen op hoofdlijnen vastgesteld	BIM visie past binnen de bredere organisatorische missie en strategie. Er is met ketenpartners overeenstemming over de BIM visie	BIM doelstellingen zijn SMART opgesteld	BIM visie en doelstellingen worden regelmatig beoordeeld en zo nodig bijgesteld.	

1. Is er een bepaalde BIM visie geformuleerd? Is deze vertaald naar een BIM doelstelling?

……

2. Past de ontwikkeling van BIM binnen het bredere strategische beleid van de organisatie (vormt dit een drijfveer)? Is deze visie afgestemd met andere partijen in de (deel)sector?

……

3. Hoe concreet zijn doelstellingen voor ontwikkeling en implementatie van BIM geformuleerd?

……

4. Zijn de BIM doelstellingen specifiek en meetbaar? Is er een termijn opgenomen in de doelstellingen, waarbinnen deze gerealiseerd moeten worden? Hoe realistisch is dat?

……

5. Hoe hebben nieuwe BIM ontwikkelingen of technologieën invloed op de visie en doelstellingen?

……

Managementondersteuning

De mate waarin het management ondersteuning biedt aan de BIM implementatie (operationalisering van de BIM visie en doelstellingen).

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen ondersteuning van het management	Beperkte, ongestructureerde ondersteuning (bijv. onderzoeken haalbaarheid BIM). Middelen worden ad hoc beschikbaar gesteld.	Voldoende ondersteuning voor implementatie BIM, maar met beperkte middelen	Volledige ondersteuning voor implementatie BIM met passende middelen	Er worden voldoende middelen ter beschikking gesteld om BIM verder te ontwikkelen en nieuwe toepassingen te implementeren	Volledige ondersteuning voor continue inspanningen om BIM verder te ontwikkelen. Deze ondersteuning is ook voor de toekomst gewaarborgd.	

1. Is er ondersteuning voor BIM vanuit het management? Uit welke aspecten bestaat deze ondersteuning: financieel, uitdragen belang van BIM, etc.?

………

2. Worden er voldoende middelen ter beschikking gesteld om BIM toe te passen (zijn de investeringen in de BIM implementatie afhankelijk van projectbudgetten of zijn er aanvullende middelen vanuit 'centrale potjes')?

………

3. Zijn deze middelen ook toereikend om BIM verder te ontwikkelen en nieuwe toepassingen te implementeren?

………

4. Hoe is de ondersteuning voor de toekomst gewaarborgd? (Is er een meerjarig programma opgesteld waarin de ondersteuning is gedefinieerd?)

………

BIM expert / werkgroep / afdeling
Mede <u>afhankelijk van de organisatiegrootte</u> **kan een BIM expert en/of BIM werkgroep/afdeling zijn aangesteld. De BIM experts hebben een adviserende en ondersteunende rol binnen het implementatieproces.**

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen BIM expert, werkgroep of afdeling	BIM expert met weinig tijd voor BIM initiatieven / Een aantal BIM geïnteresseerden komen samen (op onregelmatige basis) om BIM implementatie te bespreken	BIM expert met voldoende tijd voor BIM ondersteuning en initiatieven / Werkgroep waarin niet alle bedrijfsonderdelen zijn opgenomen.	BIM expert werkt nauw samen met alle onderdelen uit de organisatie. Multidisciplinaire werkgroep met vertegenwoordiging uit alle operationele divisies	BIM expert maakt onderdeel uit van het (hoger) management. / Alle niveaus van de organisatie zijn vertegenwoordigd in een BIM groep, incl. hoger management	BIM gerelateerde besluitvorming van de expert/groep wordt meegenomen in de strategische planning van de organisatie om te kunnen bijsturen o.b.v. ervaringen en ontwikkelingen	

1. Is er binnen de organisatie een BIM expert, een BIM werkgroep of afdeling aangesteld om de implementatie en toepassing van BIM centraal aan te sturen?

……

2. Is er voldoende tijd en prioriteit voor de BIM expert/groep om zich voor BIM in te zetten?

……

3. Worden alle operationele divisies vertegenwoordigd door de BIM werkgroep?

……

4. Uit welk onderdeel/ welke onderdelen en lagen van de organisatie is deze persoon / zijn deze personen afkomstig? Maken zij deel uit van het hoger management?

……

5. Hebben besluiten of initiatieven van de BIM expert/groep invloed op het strategische beleid van de organisatie? (Of is het slechts een uitvoerend orgaan?)

……

Taken en verantwoordelijkheden

De mate waarin de taken en verantwoordelijkheden m.b.t. BIM processen zijn geformaliseerd en de wijze waarop deze worden ingevuld.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen taken en verantwoordelijkh eden gedocumenteerd	BIM taken en verantwoordelijkh eden zijn slecht of in beperkte mate vastgesteld.	Basistaken m.b.t. BIM proces vastgesteld, maar zijn beperkt geïntegreerd in de verantwoordelijkh eden en taakomschrijvinge n van de reguliere functies.	Verantwoordelijkh eid voor BIM processen ligt bij de projectteams / operationele units. De BIM activiteiten zijn geïntegreerd in taak- of rolomschrijvingen	Structuur, functies en bijbehorende taken en verantwoordelijkh eden zijn zodanig gewijzigd dat de BIM processen optimaal worden ondersteund, zowel gericht op interne als externe toepassingen.	Taken en verantwoordelijkh eden worden regelmatig beoordeeld, zodat ze goed afgestemd blijven op de veranderende BIM omgeving	

1. Zijn de taken en verantwoordelijkheden tav het BIM gebruik gedocumenteerd in functieomschrijvingen of rolbeschrijvingen? In welke mate zijn deze geformuleerd? Wordt dit op projectbasis vastgesteld of is dit uniform over de projecten heen?

………

2. Is het werken met BIM geïntegreerd in de taken van de reguliere functies (werkvoorbereider, ontwerper etc.) of zijn er specialisten nodig om bijv. software te bedienen?

………

3. Ondersteunen de taken het BIM gebruik? Wordt er in de taken en verantwoordelijkheden een onderscheid gemaakt tussen verschillende BIM toepassingen?

………

4. Wat is de invloed van een veranderende BIM omgeving op de definities van taken en verantwoordelijkheden? Worden deze taken regelmatig beoordeeld zodat ze afgestemd blijven op verandering?

………

Contractuele aspecten
De mate waarin er ten aanzien van BIM harde afspraken worden gemaakt met andere partijen.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
BIM wordt niet meegenomen binnen contracten, protocollen of anderszins geformaliseerde afspraken.	Projectmatig dan wel afhankelijk van projectteams wordt BIM (deels) meegenomen in contracten of protocollen. Hiervoor is binnen de organisatie echter geen standaard of richtlijn aanwezig.	Vanuit de organisatie zijn er duidelijke richtlijnen opgesteld voor de verankering van BIM binnen contracten of protocollen, maar deze worden in de praktijk nog onvoldoende gehanteerd.	De samenwerking middels BIM is expliciet vastgelegd binnen de contracten of protocollen met andere partijen. De organisatie is in staat om bij deze formalisatie het voortouw te nemen /proactief te handelen.	BIM-gerelateerde afspraken zijn specifiek en meetbaar vastgelegd in contracten of protocollen: dit levert duidelijkheid over welke informatie wanneer en hoe moet worden aangeleverd.	Veranderend BIMgebruik, Nieuwe inzichten t.a.v. BIM en Mogelijke wijzigingen in juridische voorwaarden worden nauwgezet gemonitord, zodat de contracten of protocollen hiermee in overeenstemming gehouden kunnen worden.	

1. Wordt BIM meegenomen binnen de contracten, protocollen of geformaliseerde afspraken? Zijn er binnen de organisatie richtlijnen voor de wijze waarop BIM binnen de contracten wordt meegenomen? Zijn deze standaarden of richtlijnen project afhankelijk?

………

2. Worden deze standaarden en richtlijnen voldoende gehanteerd in de praktijk?

………

3. Zijn de BIM gerelateerde afspraken specifiek en meetbaar? Is het duidelijk wanneer en hoe welke informatie aangeleverd moet worden?

………

4. Worden de BIM gerelateerde afspraken continu gemonitord zodat de contracten en protocollen hiermee in overeenstemming gehouden kunnen worden?

……

Persoonlijke motivatie & bereidheid te veranderen

Persoonlijke drijfveren om BIM implementatie te accepteren en te ondersteunen. De organisatie moet hierbij bereid zijn een 'verandertraject' te ondergaan dat betrekking heeft op de gehele manier van werken. De heersende organisatiecultuur heeft grote invloed op de mate en snelheid waarmee veranderingen worden doorgevoerd.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Organisatie-cultuur werkt demotiverend voor implementatie van BIM	Organisatie-cultuur ondersteunt de transitie naar BIM niet, persoonlijke drijfveren bepalen op projectbasis of BIM kan worden toegepast.	De persoonlijke motivatie voor BIM wordt nog onvoldoende ondersteund door de cultuur, ondanks de inspanningen vanuit de top van de organisatie om dit te veranderen	De motivatie voor gezamenlijke BIM doelen zorgt steeds meer voor een eenheid binnen de organisatie t.a.v. BIM en een grotere bereidheid om de manier van werken te veranderen	Cultuur in de organisatie stimuleert BIM processen en werkwijzen, waardoor het mogelijk is om traditionele functies en processen aan te passen in het belang van BIM (samenwerking)	Door de sterke motivatie voor het gebruik van BIM en de bereidheid zich voortdurend aan te passen aan de BIM ontwikkelingen, kan de organisatie snel reageren op een veranderende omgeving.	

1. BIM wijkt in vele opzichten af van traditionele werkwijzen. Je zou het daarom kunnen zien als een verandertraject. Vormt de organisatie cultuur een barriere voor de implementatie van BIM? Is de transitie merendeels afhankelijk van de individuele drijfveren of die binnen een projectteam?

....

2. Wordt er vanuit de top van het management ingespannen de traditionele werkwijze te doen veranderen?

....

3. Verschilt deze motivatie t.a.v. de specifieke BIM toepassingen?

....

4. Indien BIM op projectbasis wordt ingevoerd en uitgebouwd, hoe worden dan de noodzakelijke veranderingen op organisatieniveau doorgevoerd?

………

Vragende actor (intern)

Een vragende actor fungeert als aanjager voor het BIM implementatieproces. Deze zogenaamde BIM champion stuurt en stimuleert andere mensen in de organisatie t.a.v. BIM.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen vragende actor (BIM champion)	BIM champion geïdentificeerd, maar beperkte tijd toegewezen aan BIM initiatief	BIM champion met (net) voldoende toegewezen tijd	Meerder vragende actoren binnen de organisatie (vanuit verschillende lagen/divisies)	Er is een BIM champion binnen de directie/leiding-gevenden van de organisatie. Deze staat in nauw contact met de operationeel verantwoordelijken	BIM champion binnen de directie werkt nauw samen met BIM champions vanuit andere organisaties of instanties	

1. Zijn er binnen de organisatie één of meerdere personen die fungeren als aanjager voor de implementatie en het gebruik van BIM?

……

2. Hebben deze aanjagers voldoende tijd om deze rol optimaal te vervullen?

……

3. Vanuit welke laag/lagen van de organisatie is/zijn deze aanjager(s) actief? Is er ook een champion binnen de directie aanwezig die nauw in contact staat met de operationeel verantwoordelijken?

……

4. Werken de aanjagers van het BIM implementatieproces samen met partners, andere organisaties of instanties om BIM ontwikkeling verder te stimuleren?

……

Educatie, training en ondersteuning

Dit bepaalt de bekwaamheid van mensen om met BIM software en conform BIM procedures te kunnen werken. Onder educatie, training en ondersteuning vallen zowel de algemene voorlichting als de gerichte instructies en begeleiding m.b.t. de uitvoering van BIM taken.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen educatie of specifieke training voor BIM processen	Educatie en training ongestructureerd, slechts wanneer individuen hierop aandringen	Educatie en training voor mensen die met BIM te maken hebben. Zij hebben de beschikking over bedieningsvoorschriften met instructies omtrent het werken met BIM software.	Algemene voorlichting over BIM wordt organisatiebreed gegeven. Uitgebreide educatie en trainingssessies voor mensen die met BIM werken	Educatie- en trainingspro-gramma voor de organisatie is afgestemd op de persoonlijke behoefte met een belangrijke plaats voor begeleiding en ondersteuning in de praktijk: 'training on the job'.	Educatie en training wordt continu verbeterd o.b.v. de lessen die geleerd worden binnen de organisatie (good/bad practices)	

1. Wordt er binnen de organisatie educatie of training gegeven m.b.t. BIM software / BIM toepassingen? Hoe gestructureerd vinden deze plaats?

………

2. Wat is hiervan de inhoud (algemene voorlichting en/of specifieke training en begeleiding)? Ook ervaringen en praktijksituaties (leren van good/bad practices)?

………

3. Wat is de doelgroep van deze educatie en training / wie komen ervoor in aanmerking? (organisatiebreed)

………

4. Zijn er bedieningsvoorschriften opgesteld die de gebruiker instrueert over het werken met BIM software? Verschilt dit per toepassingsgebied?

………

5. Zijn er IT medewerkers/professionals die persoonlijke begeleiding en technische ondersteuning kunnen bieden bij het BIM gebruik?

....

6. Worden educatie en training continu gemonitoord o.b.v. good/best practices?

....

Samenwerkingsgerichtheid

De mate waarin de houding en instelling van mensen is gericht op samenwerking. Dit wordt onder meer bepaald door aspecten binnen de bedrijfscultuur, zoals openheid en transparantie t.o.v. partners. Externe motivatie door bijv. contractuele verplichtingen kan ook een belangrijke rol spelen.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Organisatie is sterk intern georiënteerd. BIM processen zijn slechts intern	Samenwerking tussen ketenpartners is ad hoc en meer reactief dan proactief	Belang van samenwerking wordt onderkend. De samenwerking via BIM wordt meegenomen in de contractbesprekingen.	Gezamenlijke activiteiten met ketenpartners om structuren, taken en processen af te stemmen	Externe samenwerking is onderdeel van de organisatiestrategie. Onderling vertrouwen tussen ketenpartners bevordert samenwerking	Intensieve samenwerking met ketenpartners, waarbij processen continu worden verbeterd. Vertrouwen en besef van onderlinge afhankelijkheid liggen hieraan ten grondslag.	

1. In welke mate is de organisatie voor BIM gebruik afhankelijk van samenwerking met ketenpartners? Beïnvloedt dit de focus van de organisatie? Komt dit ook terug in de visie/strategie?

....

2. Word samenwerking middels BIM meegenomen in contract besprekingen?

....

3. Zijn er gezamenlijke activiteiten met ketenpartners om BIM toepassingen, taken en processen uit te breiden en/of te verbeteren?

....

4. Vormt externe samenwerking onderdeel van de organisatie strategie?

....

5. Indien er intensief wordt samengewerkt: waarop is deze samenwerking gebaseerd? Is dit ook contractueel verankerd?

....

Procedures en werkinstructies (organisatorische en projectmatige processen)

De mate waarin organisatorische en projectmatige processen zijn gedefinieerd, bijv. in procedures en werkinstructies. Dit bepaalt de consistentie en de prestatie van de processen.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen BIM procedures/ werkinstructies gedocumenteerd	BIM processen zijn beperkt gedefinieerd. Indien aanwezig worden de instructies niet consistent gebruikt, waardoor processen onvoorspelbaar zijn en afhangen van persoonlijke competenties	Instructies/ procedures zijn vastgesteld voor belangrijke BIM processen, wat ten goede komt aan de voorspelbaarheid en herhaalbaarheid van processen.	Voor de belangrijkste BIM toepassingen zijn gedetailleerde werkinstructies opgesteld. Hierin zijn good practices verwerkt en is steeds meer aandacht voor externe processen.	Gedetailleerde procesdocumentatie met het oog op het waarborgen van kwaliteit. Door de gedetailleerde procedures zijn geavanceerde BIM toepassingen mogelijk. Prestaties blijven binnen acceptabele grenzen en de voorspelbaarheid van processen is groot	De gedetailleerde procesdocumentatie wordt regelmatig onderhouden en geüpdatet o.b.v. grondige evaluaties. Hierdoor kan optimaal worden geleerd over projecten heen.	

1. In welke mate zijn er gedetailleerde procedures of werkinstructies opgesteld waarin de processen t.a.v. BIM staan beschreven? Worden deze instructies consistent gebruikt? Hangt dit af van persoonlijke competentie?

....

2. Zijn deze procedures of instructies aanwezig voor alle belangrijke BIM toepassingen of processen? Hoe gedetailleerd zijn deze en wordt aandacht besteed aan externe procsessen?

....

3. Hoe wordt gewaarborgd dat deze procedures door iedereen consistent worden gevolgd? Zijn er bijv. kwaliteitsdoelen opgesteld om de prestaties te meten?

....

4. Wat is de invloed van opgedane ervaringen en resultaten op de werkinstructies (zijn het meer statische of dynamische documenten)?

……..

Procesverandering
De mate waarin BIM een aanjagende rol kan vervullen voor verandering en verbetering van organisatorische processen

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
BIM wordt beschouwd als hulpmiddel voor (bepaalde) werkzaamheden, maar leidt niet tot fundamentele procesverbetering.	BIM vormt in beperkte mate een drijfveer voor verandering en verbetering van processen. Dit is in hoge mate afhankelijk van de competenties en drijfveren van specifieke personen/teams.	BIM vormt een drijfveer voor het verbeteren van processen, maar traditionele structuren en gewoonten vertragen deze transitie vooralsnog. Aanpassingen op projecten worden beperkt uitgerold naar andere delen van de organisatie.	BIM wordt beschouwd als effectieve aanjager van procesverbetering. Veranderingen worden goed gedeeld met andere afdelingen/teams en hebben een positieve invloed op zowel interne als externe processen.	De BIM-gedreven verandering en verbetering van processen draagt er toe bij dat het monitoren en bijsturen van processen wordt bevorderd.	BIM draagt er toe bij dat processen voortdurend kunnen worden geoptimaliseerd, mede via intensieve samenwerking met andere partijen en disciplines.	

1. Wordt BIM meer beschouwd als hulpmiddel bij bestaande processen of leidt BIM tot fundamentele procesverandering en –verbetering? Hoe afhankelijk is dit van de competenties en drijfveren van specifieke personen en teams?

………

2. In welke mate wordt procesverandering en specifieke aanpassigen uitgerold naar andere delen van de organisatie ? Word deze transitie enigzins vertraagd door traditionale structuren en gewoonten?

………

3. Dragen de BIM-gedreven veranderingen bij tot het bevorderd monitoren van processen?

………

4. Draagt BIM er toe bij dat processen voortdurend geoptimaliseerd kunnen worden (door eventueel intensieve samenwerking met ketenpartners?

………

Hardware en netwerkomgeving

De fysieke elementen en systemen die benodigd zijn om de BIM software te kunnen opslaan en te kunnen gebruiken. De netwerkomgeving maakt het mogelijk om een bouwmodel en hieraan gekoppelde data intern en extern uit te wisselen. Indien er real time netwerkoplossingen worden toegepast, kan er tevens gelijktijdig aan een BIM worden gewerkt.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen hardware die in staat is om de BIM software te laten draaien	Hardware is gedeeltelijk in staat om basis BIM software te laten draaien. De netwerkomgeving is slechts geschikt voor intern dataverkeer / benodigde netwerkstructuur is niet aanwezig bij partners.	Mensen die met BIM werken, beschikken over hardware die in staat is om basis BIM software te laten draaien. De netwerkomgeving faciliteert de uitwisseling van (deel)modellen.	Geavanceerde hardware-systemen zijn gedeeltelijk aanwezig binnen de organisatie. De toewijzing van deze systemen is afhankelijk van de behoefte en BIM toepassing	Alle hardware is in staat om geavanceerde BIM software te laten draaien. De netwerkomgeving ondersteunt het gelijktijdig werken aan een bouwmodel door meerdere partijen	Er is een programma opgesteld om de BIM hardware-systemen up-to-date te houden	

1. Zijn de fysieke systemen - de hardware - in de organisatie in staat om BIM software te laten functioneren (en alle gewenste BIM toepassingen te ondersteunen)?

……

2. Wordt ook de geavanceerde BIM software ondersteund? Op alle werkplekken in de organisatie of slechts in specifieke ruimtes?

……

3. In welke mate ondersteunt de netwerkomgeving de samenwerking van verschillende partijen in een BIM? Worden er deelmodellen via het netwerk uitgewisseld of wordt er ook gelijktijdig aan het bouwmodel gewerkt met meerdere partijen binnen een netwerkomgeving?

……

4. Hoe worden de hardware en netwerksystemen onderhouden en doorontwikkeld om nieuwe BIM toepassingen mogelijk te maken?

……

Software

Besturings- en toepassingsprogramma's waarmee BIM toepassingen worden gefaciliteerd.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen BIM software	Er is software aanwezig waarmee BIM data kan worden ingezien.	Er zijn basis BIM software-systemen	Geavanceerde BIM toepassingen worden ondersteund door het softwarepakket	Uitwisseling van gegevens wordt probleemloos gefaciliteerd door de software	Er is een programma opgesteld om de BIM software-systemen up-to-date te houden	

1. Zijn er BIM softwarepakketten aangeschaft om de diverse BIM processen uit te voeren? Zijn deze specifiek voor een bepaald toepassingsgebied? Voor wie is de software beschikbaar?

………

2. Is de software in staat om (onderdelen van) een BIM uit te wisselen met externe partijen?

………

3. Kent de software nog beperkingen waardoor niet alle gewenste BIM toepassingen kunnen worden benut?

………

4. Hoe wordt gewaarborgd dat de software ook nieuwe BIM toepassingen kan faciliteren?

………

BIM faciliteiten
Fysieke voorzieningen en functionele ruimten die worden gebruikt om BIM processen binnen de organisatie te bevorderen.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen BIM werkplek of ruimte aanwezig	Eén of enkele werkplekken aanwezig die geschikt zijn om BIM data te bekijken	Er is een ruimte of werkplek aanwezig met een scherm die groot genoeg is om met meerdere personen samen te werken	Er is een ruimte / er zijn ruimtes beschikbaar voor samenwerken en vergaderen met de mogelijkheid om via een groot scherm, bijv. een smartboard, te communiceren	Onder de normale werkplekken zijn meerdere werkplekken ingericht t.b.v. BIM samenwerking	Er is een beleid opgesteld om de (veranderende) behoeften van BIM ruimtes te managen en hierop aanpassingen te doen.	

1. Zijn er specifieke werkplekken of ruimtes ingericht om BIM processen te ondersteunen, bijv. voor visualiseren van een 3D bouwmodel of gezamenlijk reviewen van een ontwerp?

……

2. Hoe geadvanceerd zijn deze ruimtes ingericht? Kunnen de ruimtes grootschalige vergaderingen faciliteren?

……

3. Zijn er nog aanpassingen gedaan aan 'normale werkplekken' om de samenwerking middels BIM beter te kunnen ondersteunen?

……

4. Zijn er aanvullende behoeften wat betreft de BIM faciliteiten bij een verdere ontwikkeling van BIM in de organisatie? Wordt deze eventuele behoefte omgezet in beleid voor aanvullende voorzieningen?

……

Informatieopbouw
Gebruik van een documentmanagementsysteem (bijv. Sharepoint) om projectgegevens gestructureerd op te slaan en toegankelijk te maken.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen systeem voor opslag en management van data	Gebruik van het documentmanagementsysteem is ongestructureerd en afhankelijk van behoefte en competentie binnen het projectteam	Gebruik van het documentmanagementsysteem is voorgeschreven in procedures. Het systeem is niet gekoppeld aan het bouwmodel.	Voor de belangrijke BIM toepassingen is het documentmanagementsysteem gekoppeld aan het Bouw Informatie Model	Het documentmanagementsysteem is volledig gekoppeld aan het Bouw Informatie Model. Ook gegevens van ketenpartners zijn in het systeem geïntegreerd	Alle projectgebonden gegevens worden vanuit een organisatie-overkoepelend systeem beheerd. Een datamanager is verantwoordelijk voor het continu waarborgen van de consistentie en kwaliteit van de gegevens.	

1. Wordt er een documentmanagementsysteem gebruikt (zoals Sharepoint)? Wordt dit systeem gebruikt voor alle BIM toepassingen / bij alle projecten?

……

2. Is gebruik van het documentmanagementsysteem opgenomen in werkprocedures en/of taakomschrijvingen?

……

3. Is dit systeem gekoppeld voor alle toepassingen aan het BIM platform?

……

4. Is het documentmanagementsysteem voor intern gebruik of fungeert het binnen een project als 'overkoepelend' systeem, waarin alle partijen hun informatie kunnen opslaan?

……

Objectenstructuur / objectdecompositie

Een methodiek voor naamgeving en codering van objecten (bijv. een System Breakdown Structure). Er ontstaat een structuur van coderingen die worden toegekend aan een fysiek of functioneel element op verschillende detailniveaus van een bouwwerk.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen vaste methodiek voor naamgeving en codering van objecten	Objectdecompositie wordt op projectbasis vastgesteld, maar is niet uniform binnen de gehele organisatie	Uniforme objectdecompositie (coderingsmethodiek) vastgesteld voor de gehele organisatie, maar dit wordt niet gedeeld met projectpartners	Organisatorische objectdecompositie wordt afgestemd en gedeeld met andere partijen en/of standaarden in de sector	Organisatorische objectdecompositie wordt consistent geüpdatet o.b.v. richtlijnen binnen de sector. Duidelijke afspraken met ketenpartners over te hanteren objectenstructuur.	De organisatie is actief betrokken bij inspanningen in de sector om de objectdecompositie te standaardiseren en te verbeteren.	

1. Wordt er gebruik gemaakt van een systematische objectdecompositie, zoals een System Breakdown Structure (in het kader van de Systems Engineering werkwijze), de Stabu of de RGD BIM norm (Rijksgebouwendienst)?

....

2. Wordt deze decompositie per project opgesteld of wordt er gebruik gemaakt van een uniforme decompositie met gestandaardiseerde objectcoderingen?

....

3. Vindt er samenwerking plaats om de decompositie af te stemmen met externe partners? Worden duidelijke afspraken gemaakt over het consistent updaten van de objectendecompositie ?

....

4. Is uw organisatie betrokken bij verdere standaardisatie van objectstructuren in de sector?

....

Objectbibliotheken en -attributen

Het is mogelijk gebruik te maken van gestandaardiseerde objecten vanuit een objectenbibliotheek. De objectattributen vormen een toevoeging van niet grafische informatie aan objecten in het bouwmodel, waarmee onder meer kenmerken en eigenschappen van een object worden gedefinieerd.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Er wordt geen gebruik gemaakt van een objectenbibliotheek. Er wordt geen (niet grafische) informatie toegevoegd aan de objecten	Binnen de organisatie worden verschillende, onderling niet afgestemde objectenbibliotheken gehanteerd. Toevoeging van objectattributen is ad hoc.	Uniforme objecten-bibliotheek vastgesteld voor de hele organisatie. Niet geometrische basisgegevens worden gekoppeld.	Objecten uit de objectbibliotheek en niet geometrische informatie worden in lijn gebracht met sectorstandaarden	Standaard objecten en objectinformatie kunnen worden opgehaald uit beschikbare bibliotheken via open standaarden	De organisatie houdt zich voortdurend op de hoogte van ontwikkelingen met betrekking tot standaardisatie van de object-bibliotheken en attributen en past zich hierop aan.	

1. Wordt er bij de opbouw van Bouw Informatie Modellen gebruik gemaakt van een objectenbibliotheek?

....

2. Heeft de organisatie een generieke objectenbibliotheek opgebouwd of wordt voor ieder project een specifieke bieb gemaakt?

....

3. Worden er objecten uit de objectbibliotheek uitgewisseld met projectpartners (via open standaarden)? Worden de objecten uit de objectenbibliotheek in lijn gebracht met sectorstandaarden?

....

4. Zijn in de objectenbibliotheek standaard sets van eigenschappen gekoppeld aan de objecttypen? Welke (niet geometrische) informatie wordt apart nog toegevoegd aan de objecten in het bouwmodel (eigenschappen materialen, eisen, etc.)?

....

5. Hoe gaat uw organisatie om met ontwikkelingen in de sector om de objectenbibliotheken te uniformeren?

……

Data-uitwisseling
De uitwisseling van data, het delen en verder werken op basis van gegevens (bouwmodellen) van ketenpartners. Dit maakt het mogelijk om data van diverse ketenpartners te integreren in één BIM.

Maturity levels voor subcriterium

0 Niet aanwezig	1 Initieel	2 Gemanaged	3 Gedefinieerd	4 Kwantitatief gemanaged	5 Optimaliserend	Score
Geen uitwisseling van data	Uitwisseling van data via het bouwmodel is beperkt en ad hoc. Uitwisseling van gegevens is hierdoor onvoorspelbaar en doelen worden vaak niet gehaald.	Uitwisseling van data is voornamelijk gericht op intern (her)gebruik. Externe uitwisseling van data wordt bemoeilijkt door het ontbreken van onderlinge afspraken en datastandaarden	Data-uitwisseling tussen ketenpartners is goed gedefinieerd (in contracten). Er wordt verder gewerkt o.b.v. (delen van) het bouwmodel van partners.	Uitwisseling van bouwmodellen vindt plaats via open standaarden (bijv. IFC). Dit bevordert het delen en verder werken met informatie van meerdere ketenpartners. Transparantie en openheid van organisaties nemen toe.	Uitwisseling van data om BIM processen continu te verbeteren. Uitwisseling van prestatiegegevens om problemen te identificeren en nieuwe BIM toepassingen/technologieën te implementeren	

1. Een onderdeel van samenwerking is de uitwisseling van gegevens via/vanuit het bouwmodel. In welke mate wordt informatie wordt er via het Bouw Informatie Model uitgewisseld? Is dit voor intern gebruik of wordt informatie gedeeld met ketenpartners?

....

2. Wordt er een BIM verstrekt aan een partner die hiermee verder werkt of wordt er zelf verder gewerkt op basis van bouwmodellen van een partner?

....

3. Waardoor wordt uw organisatie gedreven om data uit te wisselen met partners? Is dit opgelegd in een contract of is de organisatie zelf sterk afhankelijk van externe gegevens ?

....

4. Wordt hierbij gebruik gemaakt van open standaarden (IFC) of zijn jullie afhankelijk van vooraf gemaakte afspraken over het te hanteren bestandsformaat?

……

5. Worden er ook prestatiegegevens uitgewisseld om BIM processen gezamenlijk te verbeteren?

……

Afsluiting

Laatste vraag: Zijn er volgens u nog belangrijke BIM aspecten die niet aan de orde zijn gekomen?

………

………

Heeft u verder nog opmerkingen?

………

………

Hartelijk dank voor uw tijd en informatie!

Bijlagen

Bijlage A – Barrières bij implementatie van BIM

Bijlage A - Barrières voor implementatie van BIM

A. ☐ Opdoen van voldoende kennis en ervaring is een langdurige en stapsgewijze ontwikkeling

B. ☐ Niet alle ketenpartners kunnen mee in de BIM werkwijze, waardoor extra inspanningen zijn vereist om gehele project met BIM uit te voeren

C. ☐ Contractuele barrières: met name m.b.t. de uitwisseling van informatie, de verdeling van verantwoordelijkheden en risico's én de verdeling van beloningen.

D. ☐ Markt is nog onvoldoende klaar voor BIM, waardoor concurrentie wordt ondermijnd

E. ☐ Hardware systemen zijn niet geschikt voor (verdere) implementatie van BIM

F. ☐ Tekortkomingen van softwaresystemen beperken de uitbreiding van BIM toepassingen

G. ☐ Toegankelijkheid van de data voor de verschillende projectpartners kan niet goed worden geregeld

H. ☐ Standaarden voor de uitwisseling van data ontbreken of zijn niet goed gedefinieerd

I. ☐ Interoperabiliteit wordt als problematisch ervaren tijdens het ontwerpen en produceren.

J. ☐ Inspanningen om een integraal 3D-model te ontwikkelen en te beheren zijn te groot

K. ☐ Kosten van nieuwe software/hardware wegen niet op tegen de baten

L. ☐ (her)Opleiding van personeel: organiseren en bekostigen van educatie en training

M. ☐ Onvoldoende motivatie/steun binnen de organisatie om de transitie te maken naar de 'BIM werkwijze'

N. ☐ Ontwikkeling van nieuwe procedures en werkprocessen is ingewikkeld en tijdrovend

O. ☐ Voor verdere implementatie van BIM dient samenstelling van het werknemersbestand gewijzigd te worden (de gevraagde competenties sluiten niet meer aan)

P. ☐ Onvoldoende ondersteuning vanuit het management of een gebrek aan een voortrekker die het implementatieproces van BIM aanwakkert

Q. ☐ Er is onvoldoende detailniveau in de bouwmodellen om optimaal gebruik te kunnen maken van BIM (bijv. voor detailengineering / ontwerp installatieonderdelen of genereren van hoeveelheden)

R. ☐ Gegevens uit het bouwmodel zijn niet geschikt voor koppeling aan externe systemen, bijv. B&O-systemen of geautomatiseerde productie

S. ☐ BIM sluit niet aan op de bekende werkmethodieken die gericht zijn op het maken van 2D tekenwerk en het aansturen van productie

T. ☐ Beperkte ontwerp vrijheid en oplossingsruimte aangeboden door de architect

U. ☐ Het gebruiken van BIM wordt niet opgeëist door de opdrachtgever

V. ☐ Het gebruik van BIM is niet relevant of winstgevend voor het type of schaal van het project

W. ☐ Het is onduidelijk wie de uiteindelijke eigenaar wordt van het BIM model

X. ☐ Minimale vertrouwen tussen ketenpartners verhindert de implementatie van BIM

Y. ☐ Er is onvoldoende kennis over de mogelijkheden in een BIM omgeving om intern bedrijfsprocessen hierop af te stemmen en te verbeteren

Z. ☐ Er is geen software die zowel werken in een BIM-omgeving alsmede productieaansturing ondersteunt

AA. ☐ Anders, nl. ………