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Collaborating with BIM

A QUALITATIVE RESEARCH ON THE BIM PRACTICES AT DE RUWBOUW GROEP

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Merima Bašić

DE RUWBOUW GROEP
UNIVERSITY OF TWENTE

DE RUWBOUW GROEP

UNIVERSITY OF TWENTE.

Bachelor of Science Civil Engineering thesis report at the University of Twente

M. (Merima) Bašić

Supervisor University of Twente:

F. (Farid) Vahdatikhaki

Supervisor De RuwBouw Groep:

A. (Albert) Gils

Veenoord, June 2017

PREFACE

This research has been performed as a graduation assignment in the final stage of the Bachelor of Science Civil Engineering at The University of Twente. In order to do so, I performed an internship at De RuwBouw Groep in Veenoord from April 2017 until June 2017.

The goal of this research was to help De RuwBouw Groep with the impediments they face concerning information exchange and communication in Building Information Modelling (BIM) projects.

I would like to thank every person who has helped me with this report. From the University of Twente this is my supervisor Farid Vahdatikhaki. I would like to thank you for the extensive feedback and the quick answers despite being abroad.

Moreover, I would like to thank De RuwBouw Groep for giving me the chance to do my graduation assignment here and providing everything I needed to do so. Especially I would like to thank my supervisor, Albert Gils for arranging the interviews on such short notice and giving me feedback and support during my internship. Furthermore, my gratitude goes out to all the people, internal as well as external, who took the time to give answers to my questions during the interviews.

Finally, I want to express my gratitude towards my family, especially my parents and my sister, and my friends for their support during the entire process. Especially, I would like to thank my friend and peer review partner Pamela Daccache for extensively reviewing my report and providing me with feedback during all the stages of my research.

I hope you enjoy reading this report!

Merima Bašić

Veenoord, June 2017

SUMMARY

Introduction: The client of this research is DRBG. This is a construction company that constructs prefab floors and walls. DRBG has big projects and deals with a big part of the lifecycle of their products. For this reason they have implemented BIM into their projects. They work based on Open BIM principles and conform the basis ILS. BIM stands for Building Information Modelling and is a process of collaboration and information exchange.

Theoretical framework: The first aim of the literature review was to investigate what the scope of BIM was and to form a personal opinion about this. During this report, BIM will be seen as a dynamic process that needs input from all the involved stakeholders in order to fulfil its full benefit. The focus will be on BIM as means of sharing the data during the entire lifecycle process and on reaching further than just a 3D model. The applications of BIM range from improved visualisation to enabling more accurate calculations. The benefits and difficulties from the research are divided into three categories: organisational, technical and human.

Research design: The objectives of this research were to: investigate the sources and root causes of male-practices in BIM implementation, to investigate what the current BIM implementation practices at DRBG are, when the difficulties occur and what kind of difficulties occur and to identify the areas of improvement in the BIM implementation process and suggest the improvements that could be made. To meet these objectives, a literature study was performed, along with internal and external interviews and finally an analysis of the results.

The current BIM process at DRBG: The most important difference between a BIM project and a standard project was the decline of failure costs. This is caused by the improved visualisation and the improved impact analysis. Moreover, there has been a shift in the information exchange, moving it to the early stages of a project. Another shift has taken place in the workload, also moving it to the beginning phase. Found impediments can be categorised into five themes: inadequate information exchange, poor understanding of BIM by partners, protocol issues, unclarity about the new division of roles and finally hard- and software issues.

Assessment of the results: The recommendations that were given for the found impediments include an early determination whether a project is BIM and which LOD variant will be followed. Moreover, a restructuring of the website could help improve information exchange. In order to solve the impediment that arises due to poor BIM understanding, it is important that DRBG shares their DRBG expertise with their partners. When it comes to the issues with the BIM protocol, the creation of standard teams could help, as well as scaling the customers to their BIM expertise and making it more appealing to them to follow the protocol and deliver a good model. Furthermore, the goal and usefulness of the training should be communicated more clearly, the Solibri checks should be monitored and analysed and internal surveys should be held to boost the innovation. The recommendations that had the least cost and most benefit are the creation of standard teams and the restructuring of the internal trainings.

TABLE OF CONTENT

LIST OF ABBREVIATIONS

Below is a list of abbreviations that have been used throughout this report. The abbreviations are listed in alphabetical order.

AEC	Architecture, Engineering and Construction
BCF	BIM Collaboration Format
BIM	Building Information Modelling
DRBG	De RuwBouw Groep
IFC	Industry Foundation Classes
ILS	Informatieleveringsspecificatie (Information delivery specifications)
LOD	Level of Detail

1. INTRODUCTION

1.1 WORK PROCESSES AT DRBG

The client of this project is the company De RuwBouw Groep. From now on the abbreviation DRBG will be used instead of the full name. This is a company that is part of the bigger CRH, which originates in Ireland. CRH has multiple locations across the world, including several companies in The Netherlands. DRBG is one of the structural departments of CRH and deals mainly with the construction of prefab walls and floors. The projects of DRBG include a big part of the lifecycle process of a product, from the design to the sale and realisation of the products. This means that there are many internal and external stakeholders involved in each of the projects. An overview of the functions at DRBG can be found in Attachment B – Overview functions.

Because this company is so big and works with this many external parties, it has to maintain certain policies when it comes to exchanging information. This includes making sure all information is available at all times for the concerned parties and that the information is uniform. Moreover, it is important to store information in such a way that it is readable even if the used software is not installed on the computer to avoid buying expensive licenses. Because of the complexity of their projects as described above, DRBG has decided to introduce BIM into their projects. More precisely, DRBG works according to the Open BIM principle, meaning that they collaborate with others using the file format IFC.

BIM stands for Building Information Modelling and consists of collaboration frameworks and technologies in order to integrate process- and object-oriented information during the entire life cycle of a building in a multi-dimensional model (Sebastian & van Berlo, 2010). Although the graphical 3D-model is the most well-known function of BIM, there are also many other ways to represent information. This differs from various documents concerning specifications or planning to additional 2D-drawings. Thus, BIM does not only support geometric information, but also non-geometric features of the objects (such as, weight, capacity and price) by the means of a central model. In fact, BIM supports all activities concerning the decision-making process during the lifecycle of a structure. To ensure the quality of the models, DRBG has taken up basis ILS as a standard for their models. Basis ILS are agreements about the specifications of a model and can be found in Attachment C – Basis ILS. Moreover, DRBG has decided to work based on LEAN principles. The goal of this principle is to decrease waste and rework.

When beginning a collaboration, a client has three processes to choose from, these are 2D, LOD 300 and LOD 350. LOD stands for Level of Detail and is used to assess the level of information that is available about the design in the model. Because 2D is not BIM, that process will not be taken into account in this research. The LOD 300 and LOD 350 processes can be found in Attachment D – LOD Processes.

The workflow of a project can be found in Attachment E – Workflow. Here the process starts at the LOD 200 and this level where a conceptual design is ready. At this level BIM is important for the orientation and thus determining whether a design is feasible either financially or structurally. The structural part of DRBG is not yet present at this level of the project and DRBG only takes on an advising role at this point. The LOD 300 is the level where the permits are

requested and the technical design for the sale is finished and fixed. At this level BIM is used to explore all the options the buyer has, for example the placement of windows or the addition of extra rooms and to enable visualisation. In the transition between the LOD 300 and the LOD 350 the design is made usable for the contractors. The application of BIM is to enable the demarcation and scope division and to specify the project into the client's assumptions. The LOD 350 is the level where the design is applicable for engineering and this is the clash moment for the models where any mistakes or misinterpretations can be detected. During this phase, DRBG fulfils the modelling and engineering role. In the transition between the LOD 350 and the LOD 400 the design is prepared for the production. BIM then contains the production and work drawings. Finally, the LOD 400 means that the design is suitable for production. For DRBG this means that they are again responsible for the modelling and engineering. In the transition between the LOD 400 and the LOD 500 the design is realised. In this phase, BIM contains the building information. The role that DRBG takes on is to produce the final product. The LOD 500 phase means that the product is completed.

1.2 BOOKMARK

In the below table (Table 1) the bookmark of this report is presented. The bookmark is structured according to the method of Kemper and Keizer (2006). In this method, three main phases are distinguished: the orientation phase, the research phase and the solution phase (Kempen & Keizer, 2006).

Orientation phase	Research phase	Solution phase
1. Introduction	2. Theoretical framework	6. Main conclusions, limitations and recommendations
3. Research design	4. The current BIM process at DRBG	
	5. Assessment of the results	

Table 1: Bookmark

2. THEORETICAL FRAMEWORK

The goal of the literature review is to capture the state of the art in the BIM implementation strategies and review the pertinent use cases and subsequent lesson learnt. Additionally, the literature will be analysed to determine the benefits, challenges, opportunities and threats of various BIM implementation strategies. This would help better map the current situation of DRBG and propose strategies to improve their BIM implementation practices.

2.1 THE SCOPE OF BIM

The scope and the expectation of BIM vary across disciplines and within each discipline, depending on the viewpoint of the beholder (Gu & London, 2010). However, all the literature agrees on one aspect, which is that the viewpoint and scope of the BIM user is highly important in the BIM implementation process, making it important for companies to communicate their viewpoint and scope to their employees (Azhar, 2011) and (Grilo & Jardim-Goncalves, 2010). Because the development of the BIM 3D model is a progressive elaboration, researchers argue it is necessary to see BIM as a dynamic process instead of simply a model. Only if this is the case, the full benefits of BIM implementation can be achieved. They elaborate on the dynamic process, stating that if BIM is truly a dynamic process, the 3D BIM is built up by multiple different members of a project team and thus it can assist all the parts of the model (Grilo & Jardim-Goncalves, 2010). According to Azhar (2011), BIM means more than just 3D intelligent models, since it requires changes in the workflow and in the project delivery process as well. This is further corroborated by the study of Babič et al. (2010), where it is found that BIM is much more than just a way to store data for the building model. They state that BIM should contain information that is needed in the particular phases of the building life cycle (Babič, Podbreznik, & Rebolj, 2010). The research of Bryde et al. (2013) agrees with this and sees BIM as the most common denomination for the new way of approaching the design, construction and maintenance of buildings. For this reason, it is argued that BIM can also be seen as the reason for a large paradigm shift in the construction industry in the last decade (Bryde, Broquetas, & Volm, 2013). Azhar (2011) mentions the paradigm shift as well and adds to that by contending that within this new paradigm, the integration of the roles of all project stakeholders is required.

Sebastian and van Berlo (2010) agree with the previously discussed researches as well, stating that BIM consists of collaboration frameworks and technologies in order to integrate process- and object-oriented information during the entire life cycle of a building in a multi-dimensional model. Moreover, it enables centralized and efficiently coordinated information exchange between all project participants.

However, Shen, et al. (2012) do not fully agree with the previously discussed scopes, defining BIM as a ‘’modelling technology and associated set of processes to produce, communicate and analyse building models”. They do agree however, that the biggest difference of the BIM tools as opposed to the existing ones, is that the focus of the BIM tools lies within the data instead of the drawings or 3D images (Shen, Shen, & Sun, 2012). More specifically, they argue that the BIM tools provide the information of what can be supported rather than what is contained.

During this report, BIM will be seen as a dynamic process that needs input from all the involved stakeholders in order to fulfil its full benefit. The focus will be on BIM as means of sharing the data during the entire lifecycle process and on reaching further than just a 3D model.

2.2 BIM IMPLEMENTATION

As there are many varying scopes of BIM, there are a many different applications. Azhar (2011) states that BIM can be used for the visualization, fabrication of shop drawings, review of codes, estimation of costs, construction sequencing, detection of conflicts/interference/collisions, forensic analysis and finally facilities management. Grilo and Jardim-Goncalves (2010) agree with this and add that BIM is also applicable to help visualize and develop potential solutions to the conflicts that appear during the coordination process. However, they state that currently the most popular application of BIM is in the complex project where BIM can help develop collaboration techniques (Grilo & Jardim-Goncalves, 2010).

Coates et al. (2010) elaborate on the BIM application by stating that BIM is implemented in the right way if the implementation is accurate, meaning that it is clear and non-falsifiable and that it can be assessed as accurate and repeatable. Moreover, they agree with the scope of Sebastian and van Berlo (2010) and state that it should be applicable and usable by all stakeholders across the life-cycle of the project. Attainability and cumulativeness are also important features concerning the benchmarks. Furthermore, the right implementation of BIM is consistent, meaning if different people use it, the results will stay the same. However, at the same time it should be flexible, allowing different organizations or markets to perform the assessment. Moreover, the process should be informative and neutral, allowing non-prejudiced guidance. Finally, the BIM process should be specific, providing well-defined metrics and purposes that are industry-specific. Coates et al. (2010) agree with the research of Bryde et al. (2013) as well and believe BIM is mostly a foundational tool for implementing an efficient process.

Bryde, et al. (2013) elaborate further on the right BIM implementation and distinguish seven pillars in the BIM implementation strategy: elimination of waste, increase of feedback, the delay of decisions to achieve consensus, fast delivery, build-in integrity, the empowerment of the team and the ability to see the whole (Bryde, Broquetas, & Volm, 2013).

According to Gu and London (2010) the right implementation should go along with changes in the four key domains: work processes, resourcing, scope/project initiation and tool mapping. These processes are interrelated and influenced by the phase in the project life cycle because BIM is related to the project requirements, the stakeholder needs and the capabilities of the collaborator (Gu & London, 2010).

Apart from the industrialization of construction, integration and interoperability are very important topics in the construction industry when talking about progress (Babič, Podbreznik, & Rebolj, 2010). The definition of interoperability can be understood as: “the ability of two or more systems or components to exchange information and to use the information that has been exchanged” (Grilo & Jardim-Goncalves, 2010). The benefit of interoperability is that it eliminates the costly process in which every application has to be integrated with other applications. The lack of interoperability in software and knowledge exchange is one of the major difficulties in the construction industry (Grilo & Jardim-Goncalves, 2010). This can be caused by the perspective of the sector on interoperability. Interoperability is seen as only useful for data aspects of

information systems and it should be extended to a more technical approach. If successful interoperability is to be achieved, it is important that the technological issues of the connected systems as well as the connection between the business processes are considered (Grilo & Jardim-Goncalves, 2010). However, for this to happen, interoperability needs to be redefined to: ''A field of activity with the aim to improve the manner in which enterprises, by means of Information and Communications Technologies (ICT), interoperate with other enterprises, organizations, or with other business units of the same enterprise, in order to conduct their business'' (Grilo & Jardim-Goncalves, 2010).

2.3 BENEFITS OF BIM

Interactions make up a big part of the early stages of the design process and in this process, users play a big role (Shen, Shen, & Sun, 2012). However, there seems to be difficulties in the communication process between the designer and the users, causing dissatisfaction with the final design. Many of these difficulties appear because users are unable to envision a design from a paper. This is where the use of BIM is necessary to increase the understanding of users. Thus, according to Shen et al. (2012), one of the benefits of BIM is that it supports the communication process by allowing all participants in the design process to become equally involved. Moreover, Grilo and Jardim-Goncalves (2010) add to this by stating that the interaction between the individual members of a project group is not the only advantage of BIM, it also helps to raise their collective understanding about the project requirements and constraints.

From the research of Bryde et al. (2013), the largest positive benefit of BIM seemed to be the reduction or control of cost. This is then followed by the reduction or control of time, the improvement of communication and coordination, the increase or control of quality, the reduction of negative risk and the clarification of the scope. The reduction or control of cost is due to the integrated 5D model, where BIM immediately updates the schedule and the budget if there is any design change and makes it possible to anticipate on aspects that may cause delay. Moreover, BIM enables collaboration and trust, causing the improvements in communication and coordination. Because all changes can be viewed immediately by all concerned parties, there is no reason for miscommunication (Bryde, Broquetas, & Volm, 2013). Sebastian and van Berlo (2010) agree with this and see the benefits of BIM as bringing more effectiveness, higher efficiency, reduced time and errors and improved quality.

The research of Azhar (2011) elaborates on this and perceives the accurate geometrical representation of the parts of a building in an integrated data environment as the biggest benefit of BIM. Other benefits also agree with the previously discussed papers and include a faster and more effective process because the sharing of information is easier. Moreover, the design is better because BIM enables a more rigorous analysis of building proposals. On top of that, the whole life cycle costs and environmental data are better controlled and the quality of the production is higher. Finally, BIM provides a better customer service because proposals are better understood.

Babič et al. (2010) argue that all the benefits arise from the fact that the construction process becomes more transparent because the model becomes the common denominator. This helps contribute to a better understanding of the project boundaries and leads to a better understanding of the financial consequences of the decisions that are made. Moreover,

transparency makes it easier and more accurate to plan on the short term and this leads to a shorter construction process and less delays.

The benefits of BIM and interoperability are within the fields of communication, coordination, cooperation and collaboration (Grilo & Jardim-Goncalves, 2010). Communication is the main purpose of interoperability, or more specific, to exchange information. BIM enables designers to more easily and accurately communicate their ideas to the other project team members. Moreover, it facilitates the research of alternative solutions by modelling the ''what if'' scenarios. The goal with the coordination is to align the activities that have a mutual benefit, while gaps and overlaps are avoided and thus more efficient results are achieved. With cooperation, it is desired to obtain mutual benefits through the sharing or partitioning the work. BIM makes it possible to visualise the constructability and the constructions sequences. Finally, collaboration makes it possible to achieve results which individual participants would not be able to achieve alone. However, the majority of the projects which are denoted as BIM, are basic 3D models. They may have coordination and cooperation, but they are not truly collaborative and thus not all the benefits of BIM are used. The most advantage is gained in early collaboration.

2.4 DIFFICULTIES WITH BIM

However, there are negative impacts of BIM that can be distinguished as opposed to the benefits. Despite of this, Bryde et al. (2013) argue that there are fewer negative impacts than there are benefits and they elaborate on this by stating that most of these negative impacts are not specifically about BIM, but have to do with soft- or hardware issues. These challenges could be taken up by better training of the employees involved about the use of this hard- and software. Moreover, extra costs have been made in the form of rework, training and computer upgrades. However, these costs can be reduced by implementing BIM immediately from the beginning of a project. Most of these costs are also one-time expenses, for example the purchase of licenses or hardware. Unfortunately, not all challenges are as easy to overcome, the most difficult ones are the ones related to people. BIM depends on the willingness of people to share the information of their company and not restricting its flow in order to protect ownership and intellectual property rights. Thus, people remain the biggest uncertainty in the BIM implementation (Bryde, Broquetas, & Volm, 2013). Coates et al. (2010) agree that the biggest uncertainty lies within the users and think a good implementation of BIM could be in danger due to misinterpretation of design, lack of communication and interoperability between stakeholders and no control or sharing of documentation (Coates, et al., 2010).

The research of Sebastian and van Berlo (2010) adds to the difficulties by pointing to the issue of mismatches between expected BIM deliverables and BIM requirements, which is caused by different scopes people have of BIM. This can result in the increasing of risks, costs and inefficient implementation while also limiting the potential of the BIM use (Sebastian & van Berlo, 2010). Thus, again highlighting the importance of the scope people have of BIM. It is important to make clear to all the involved parties why BIM is implemented and what is to be expected of it. Gu and London (2010) elaborate on the importance of the scope and argue that the difficulties that appear during the use of BIM can be due to the lack of awareness and training. Moreover, the Architecture, Engineering and Construction industry's fragmented nature and reluctance to change its existing practices can be a cause of these difficulties. Furthermore another barrier is the lack of clarity in the AEC industry when it comes to roles, responsibilities

and the distribution of benefits. Working according to BIM principles needs a change in the distribution of the roles and responsibilities during a project because some roles may disappear, while other new roles will emerge to support the BIM project. Furthermore, from this study it is found that the collaboration still primarily consists of 2D drawings being exchanged instead of a full information model. More difficulties they found, had to do with security. These issues are namely the data security of model servers and include Intellectual Property (IP) concerns and the protection of copyrights. Because these are legal issues, they can be taken up by greater awareness and legal measures. The research of Azhar (2011) distinguishes legal and technical risks as well. A legal risk is the need to protect data through, for example, copyright laws. This prohibits the concept of an open BIM and a free flow of information. However, according to Azhar (2010) this risk cannot be solved easily and every situation where this occurs requires an unique solution. However, collaborative and integrated project delivery contracts can help prevent such risks. Concerning the technical aspect, one of the greatest risks is the elimination of an important check and balance mechanism which is present in the current paradigm.

Shen, et al. (2012) focus on the risks of the BIM tools and state that one risk of BIM tools is that they focus on increasing the designer's efficiency rather than improving the user's performance during the design process. It has to be emphasized more how important the communication between designer and user is to enable an efficient design process.

Moreover, a problem arises within the combined use of different BIM applications. The current main exchange format for BIM, i.e., IFC, cannot store and carry all relevant data that is needed for the multi-featured construction processes. Moreover, IFC does not offer the possibility to structure all the data in a single super schema (Redmond, Hore, Alshawi, & West, 2012). Furthermore, the traditional way of sharing data in a BIM context is to export a file from an application and then importing that file in another application. This causes the creation of multiple copies of data. However, the purpose of BIM is not solely to automate paper-based processes, but to synchronise information across applications in order to speed up workflows and to support decisions. The exchange of that can be classified in three formats: direct links, proprietary file exchange and public product data model exchange (Redmond, Hore, Alshawi, & West, 2012). Direct links extract data from one application and then write this data using another receiving application. A proprietary exchange format mainly has to do with geometry. Finally, public product data model exchange formats are open and publicly managed schema and language (Redmond, Hore, Alshawi, & West, 2012).

3. RESEARCH DESIGN

3.1 RESEARCH MOTIVATION AND AIM

The projects of DRBG depict the major part of the lifecycle process of a building, from the design to the sale and realisation of the properties. This means that there are many internal and external stakeholders involved in each of the projects. This makes the projects often highly complex due to the involvement of a great number of stakeholders. However, communication comes with great difficulties when there are numerous different parties involved (Bryde, Broquetas, & Volm, 2013). When working with people, there is always a factor of responsibility involved, whereas it is uncertain if everyone takes their responsibility (Bryde, Broquetas, & Volm, 2013). This can be the case when agreements are made which are not communicated to all the parties involved or when something that is said gets misunderstood or misinterpreted.

BIM was meant to make the communication easier, however, despite the implementation of BIM, not every need is met. DRBG still experiences difficulties with the communication and in particular with information exchange. Because the information exchange is not yet optimal, it does not eliminate waste or rework and thus prohibits DRBG to fully work according to LEAN principles. The main difficulties appear in the transitions from the LOD 300 to the LOD 350 and from the LOD 350 to the LOD 400, thus the phases where the model contains the information that is interesting for most parties, e.g. the client, the partners and DRBG itself.

Another problem occurs because the knowledge exchange is still not moved to the early phases of a project and many additional data is being added in the end phases, causing frustrations and miscommunications. This means that the modelling process is still not as efficient as it should be and this causes an increase in time spent on a project and a raise in the failure costs.

Thus, the problems that DRBG is experiencing mostly have to do with communication and information exchange, both internally and externally during the different stages of a project.

In view of the problems stated above this research pursues the following objectives:

- Investigate the sources and root causes of male-practices in BIM implementation.
- Investigate what the current BIM implementation practices at DRBG are, when the difficulties occur and what kind of difficulties occur.
- Identify the areas of improvement in the BIM implementation process and suggest the improvements that could be made.

3.2 RESEARCH QUESTIONS

MAIN QUESTION

How can the BIM practices improve at DRBG to ensure efficiency and avoid redundancies in the BIM process?

RESEARCH QUESTION 1

What statues does the literature provide concerning BIM and what are the difficulties that are dealt with?

- How is BIM perceived by companies?
- What is the reason BIM is being implemented by companies?
- What are the benefits of BIM?
- What impediments are faced in BIM implementation?

RESEARCH QUESTION 2

What is the current BIM process at DRBG?

- What are the scope and goal of BIM according to DRBG?
- What is the difference between a standard project and a BIM project?
- What are the current impediments in the BIM practices at DRBG as experienced by the employees?
- Who are the users of BIM at DRBG and have they had any training before they started using BIM?

RESEARCH QUESTION 3

How can the difficulties that occur with information exchange concerning BIM be assessed to lead the BIM implementation in the right direction?

- What are the specific impediments that DRBG is dealing with?
- What can be changed to solve the problem?
- How does these changes fit into the policy of DRBG?

3.3 RESEARCH STRATEGY

The research techniques that will be implemented are different for each of the research questions, concerning the nature of each question.

Research question 1 is a literature question, thus the research that will be needed to answer this question is limited to literature research. To do so, scientific articles are researched and the relevant data from those articles is noted and connections are made between the articles. These data and connections are then taken into account for the remaining research questions. At the end, the findings from the literature are compared with the findings from the interviews to be able to make the recommendations.

Furthermore, research question 2 is an analytical one, the goal is to investigate the current situation. To do so first a number of observations are made. Both in real life and from the literature of previous projects. Based on the observations, an interview is put together for the employees of DRBG, the format can be found in Attachment F – Interview DRBG. Moreover, an interview is performed among partners of DRBG to get a view of the entire process, this format can be found in Attachment G – Interview partners. The goal is to interview people from all the

phases of a project at DRBG and to get a view that is as specific as possible. This is why a number of seven employees have been interviewed, their functions include one drafter (or modeler), one coordinator for advice and calculation, two heads of the department, one standardisation engineer and two project coordinators. Furthermore, six people from four external companies are interviewed and their functions include three BIM managers, two modelers and a project manager.

In order to answer question 3 a procedure is followed, where first a hypothesis is stated, then it is analysed, and finally it is verified and validated. Because of the limited time span, the validation of the proposed policies is carried out by taking experts' opinions into account.

The data that is needed to answer the research questions can be found in documents of DRBG and scientific literature concerning information exchange, BIM and interoperability. These are the data that are already available, are of a scientific quality and have to be analysed to filter the relevant data for this research. Furthermore, the data that need to be gathered, come from observations and interviews. These data could be of less quality and need to be handled with a critical approach. Among the people who are interviewed, there are two types of experts: epistemic experts, whose expertise is a function of what they know, and performative experts, whose expertise is a function of what they do (Redmond, et al., 2012). An epistemic expertise can provide justifications for a range of propositions in a domain and a performative expertise can perform a skill in accordance to the rules and virtues of a practice (Redmond, et al., 2012).

Because the research will focus on the human implementation rather than the technical design of BIM, models are of less relevance to this research.

4. THE CURRENT BIM PROCESS AT DRBG

In this chapter the current situation at DRBG concerning BIM collaboration will be researched. First the scope and goal of BIM according to DRBG will be looked into. Then, the difference between standard projects and BIM projects at DRBG will be discussed. Moreover, the current impediments will be listed and finally the users and the training they received will be researched. The data that is gathered here, is received from the interviews. The goal of the performed interviews was to get a better and more clear insight in the current BIM practices at DRBG as well as their partners. The questions that were asked can be found in Attachments F and G. The answers that were given are generalized and not assessed individually for each respondent.

4.1 THE SCOPE AND GOAL OF BIM ACCORDING TO DRBG

The BIM vision of DRBG is (Gils, 2017):

''BIM at DRBG stands for an object oriented working method, which serves as a means to improve the exchange of building information intern as well as extern. DRBG believes in the BIM working methods as an important instrument to optimise the quality, the lead time and the total costs during the entire lifecycle. The 3D-model has a supporting role in this process. DBRG works following the Open BIM principle.''

By implementing BIM DRBG wants to accomplish the following goals (Gils, 2017):

- Improve the relations with the customers through better communication.
- Enable working with different kinds of software and still be able to view everything that has been made through the use of Open BIM (e.g. DRBG works with the 3D-modelling software Tekla, while many of their clients work with Revit).
- Reducing rework, which can be accomplished by engineering and producing based on the complete and right information (e.g. a lot of time is lost by re-drawing entire drawings because there is one comment). This is working based on LEAN principles.
- Stimulate the exchange of knowledge at the beginning of a project, to support the modelling process (e.g. the reinforcement specification drawings are made available only a week before the project due date).
- Reduce the project completion time.
- Enable quality control for incoming and outgoing information using the correct software (e.g. Solibri Model Checker).
- Utilize the full potential of prefab.

4.2 THE DIFFERENCE BETWEEN STANDARD PROJECTS AND BIM PROJECTS

When asked about the differences between standard projects and BIM projects, respondents noted that many benefits were still not noticeable because of the limited time since BIM projects have been undertaken by the company. However, numerous differences could be listed that were evident right away. Both respondents from DRBG and from the external parties stated that a BIM project brought benefits to their work in some way and a BIM project is usually perceived as more preferable than a standard project. A standard project is, in this situation, defined as a

project that does not consist of BIM collaboration and is either 2D or 3D. The most important differences are summarized below.

One of the most important differences, and also one of the benefits from Chapter 2, include the decline of failure costs as a result of the virtual representation of the building. Because of the improved visualisation, clashes and mistakes are discovered more easily and failures can be detected earlier on in the process. On top off that, the impact analysis of decisions becomes easier and more clear resulting in even lower failure costs. However, most of the decisions have to be taken earlier on in the process, due to the shift in information exchange as opposed to standard projects. Because most of the information exchange needs to take place at the beginning of a BIM project, most decisions have to be made at that point as well.

Moreover, the users at DRBG have stated that the work process becomes more clear when a project includes BIM collaboration. This is namely because version control becomes easier when working with a model as opposed to 2D drawings. Furthermore, the current work process can be optimized even more by analysing mistakes and recalling the process with help of the model, whereas a work process including 2D drawings could not be optimized anymore.

However, users have also stated that the workload has not so much disappeared, but it has shifted from the drafters to the planners. Planners have to put more time into the project to lead it in the right direction.

External parties also state that they noticed a decline in failure costs. Moreover, meetings are more efficient because the model can serve as a communication tool to discuss decisions and their impact, while also making the process more insightful. Due to the increased insightfulness of the process, the faith in the partners increases and collaboration is stimulated. External parties mentioned cases where the collaboration started even before there was an official job and while there were no agreements on the budget.

4.3 CURRENT IMPEDIMENTS

One of the most important cases to look into were the impediments the users of BIM experience. Most impediments were faced by both DRBG and external parties and were also present in the literature. Below, the answers are summarized into categories and the impediments they face include:

- Inadequate information exchange
- Poor understanding of the BIM process by partners
- Issues with the BIM protocol
- The new roles BIM creates
- Hard- and software issues

INADEQUATE INFORMATION EXCHANGE

For the enabling of BIM collaboration, the information exchange has to be shifted towards the earlier stages of a project (Babič, Podbreznik, & Rebolj, 2010). One of the dangers of this, is that changes cannot take place anymore in later stages and thus if something is not sold, it cannot be altered to try to sell it again. This is something contractors find hard to accept according to the

respondents. Changes require rework which again needs time and expenses and this is far from the ideal situation.

Moreover, respondents stated that a project is classified too late as a BIM project. In order to lead the collaboration in the right direction, the project has to be classified as a BIM project before it is communicated towards the partners. Furthermore, the classification about which LOD variant the project belongs to is also not determined and communicated on time. If this is determined on time, the communication to the partners would become easier, as it would follow from the LOD process which information is needed at which stage of the project.

Furthermore, external parties have suggested that it is not always clear to them what is expected at which point in time. They do want to deliver a good model, however they do not know exactly when a model is right or which information is needed. Some respondents have trouble with finding certain information on the site of DRBG as well. It is communicated that something can be found on the site, however it is not always clear just how much information there is and what is relevant for them.

POOR UNDERSTANDING OF THE BIM PROCESS

According to the majority of the respondents, BIM has become an all-purpose-word, which is just tossed over the fence in order to let the other party figure it out. From the literature, it can also be concluded that the scope and the application of BIM vary and are unclear to most of its users (Gu & London, 2010). This causes many companies to state that they can take part in the BIM collaboration, while they are unable to do so, according to the respondents. The companies that do so, are mostly the smaller ones which are just starting with 3D drawing and BIM collaboration and because of that, there are great differences in the quality of models which are received. When an inadequate model is received, the contractor is often not capable or willing to alter it to the basis ILS agreements, again causing loss of time and extra expenses for DRBG.

However, not everyone at DRBG is on the same level of BIM understanding as well. Many of the drafters do not know how to collaborate using BIM, as they have not received any briefing or training on the BIM collaboration process. Some of the respondents have suggested training for the drafters in order to enlarge their BIM knowledge.

Moreover, respondents have suggested that they do not know who checks the in- and outgoing models with Solibri. Drafters would like to check their own models, because they are the ones who know best what they have done. However, for this to happen they would need training in the Solibri software.

PROTOCOL

As most companies, DRBG has a collaboration protocol including contractual requirements and demands for the BIM models, the property and use of the models, BIM-processes and responsibilities (Gils, 2017). However, most contractors and subcontractors also have their own collaboration protocol and every company wants their protocol to be followed by others. This causes frustration and does not improve the collaboration. Moreover, the protocols are often big

documents with up to thirty pages and people are not willing to read all of it in order to eventually combine the protocols of all the involved parties.

Being in the role of the sub-contractor, in most of the projects, DRBG has to follow the protocol of the contractor, as all the other sub-contractors do. Because the protocol also includes model specifications which are essential for the directions of the machines, not following their own protocol forces DRBG to redesign models and do rework just to make it suitable for their use. This means that extra time and expenses are involved in the project.

Furthermore, cases were reported where respondents could not find the protocol or other documents on the website. The names of the documents presented on the website were unclear and respondents got lost in the information excess presented on the website.

DIVISION OF ROLES

BIM collaboration causes some changes in the distribution of work and the roles different functions play in a project (Gu & London, 2010). New functions arise, while others are no longer necessary. Respondents have stated that the function of a drafter is disappearing, or more accurately, being replaced by the function of a modeler. Moreover, the interviews from the external parties have made it clear that contractors want a shift to take place in the current hierarchy, where not all the communication happens through the contractor, but the sub-contractors communicate among themselves. This is in order to speed up the process and minimalize the misunderstandings.

However, not all role divisions are as clear. Within DRBG it is unclear to the respondents who does the check of the model in the beginning. Because of this, it is also difficult to assess the quality of the model.

Moreover, in the current situation there is not enough personnel to do a check when the model is finished and has to be sent back to the contractor. Drafters often know their model is lacking something, however they are not capable of checking it themselves because they have not received training to do so.

HARD- AND SOFTWARE ISSUES

External respondents have stated that the IFC files can contain errors that were not present in the model itself. That is why it is preferred by them that the IFC file is accompanied by a Revit model and possibly 2D drawings. However, this again causes the defragmentation of information and can cause people to work in different versions of the model. Because of this, it is not the policy of DRBG (Gils, 2017) and does not improve the BIM collaboration (Redmond, Hore, Alshawi, & West, 2012).

4.4 USERS AND TRAINING

As there are many different applications for BIM (§ 2.2), there are also many different functions at DRBG that use BIM in their work. The users of BIM vary from drafters (or modelers), coordinators of advice and calculation, heads of departments, standardisation engineers, project coordinators, BIM managers to project managers.

Within DRBG itself, users have stated that they did not receive any specific training about the BIM collaboration, while they suggested that the collaboration is the major goal of BIM according to DRBG. The knowledge they now possess about BIM collaboration is gained through experience and trial and error. Some have, however, had training for 3D modelling and model checking (e.g. Tekla/Revit and Solibri trainings).

From the interviewed contractors, two have responded that their companies had an initial BIM collaboration training for all the employees. They have stated that this was beneficial for their BIM knowledge and the collaboration with other parties.

5. ASSESSMENT OF THE RESULTS

In this chapter the impediments that were noted in §4.3 will first be compared to the external interviews and then to the literature. Based on this comparison, improvements will be searched in the external interviews as well as the literature. For every impediment there will be recommendations given. Furthermore, an cost-benefit analysis will be performed to get an image of the cost it takes to implement each recommendation in relation to the benefit that recommendation has. Finally, the improvements and their results will be discussed.

5.1 THE IMPEDIMENTS

In the table below (Table 2) an overview can be found of the difficulties that are experienced by DRBG and their partners. Moreover, it is highlighted whether an impediment is present in the literature (§2.4).

Impediment	Experienced by DRBG?	Experienced by partners?	Present in the literature?
Inadequate information exchange	X	X	X
Poor understanding of BIM	X	X	X
Protocol issues	X	X	
The new distribution of roles	X		X
Hard- and software issues		X	X
Restriction of information flow because of privacy issues		X	X

Table 2: Comparison of the impediments

5.2 IMPROVEMENTS

From the results of the literature review (Chapter 2) and the interviews (Chapter 4) there are improvements suggested that could address the difficulties that are listed above (Table 2). Below is an overview of the improvements that can be made per impediment.

INADEQUATE INFORMATION EXCHANGE

For the enabling of BIM collaboration, the information exchange has to be shifted towards the beginning stages of a project (Babič, Podbreznik, & Rebolj, 2010). For the AEC industry, this was rather difficult to accept and even more difficult to implement. Often there are changes made to a design if something is not sold on time in order to still sell it. However, changes made in later stages require rework and rework again requires more time and expenses.

One of the reasons this happens is that a project is classified too late as a BIM project. Whereas from the literature it becomes clear that that a project should be classified as a BIM project as soon as possible in order to have the full benefit of BIM collaboration (Bryde, Broquetas, & Volm, 2013). Moreover, it is not clear to which LOD variant the project belongs. Because of this, it is not always clear to the parties involved what is expected of them. The communication would become easier if beforehand everything was made clear and from the LOD chart it would follow what is expected at which point in time.

Furthermore, the documents that can be found on the site are unclearly structured and given names that are not logical. Because of this, customers often mistake documents or do not even know certain documents can be downloaded. The result of this is then that the partners do not know what is expected of them and struggle to deliver a model that is to the standards of DRBG.

Thus, the recommendations that are proposed to improve the information exchange are:

- Determine beforehand whether or not a project will be executed following the BIM collaboration. If this is determined at the first contact with customers, the planning can be made according to this.
- Determine beforehand to which LOD variant (e.g. 2D, LOD 300 or LOD 350) a project belongs. This has to be determined at the first contact as well and then the steps which have to be taken follow logically from the LOD classification.
- Structure the documents on the website in order to give customers more insight into the available information. This includes moving relevant documents such as the collaboration protocol, the information about the LOD variants and the information about ILS and BCF to the subchapter 'BIM' instead of 'Downloads' to group all the documents needed for a BIM project in one chapter. Moreover, the names of the documents should be given more logically, including renaming the summary of the protocol to match the content.

POOR UNDERSTANDING OF BIM

Because the scope and the application of BIM vary and are unclear to most of its users, BIM has become an all-purpose-word (Gu & London, 2010). When discussing the BIM process, the word 'BIM' is just tossed over to the other party to let them figure it out. Due to this unclearness many companies think they can take place in the BIM collaboration while they are not able to do so. When an inadequate model is received, the contractor is often not capable or willing to alter it to the basis ILS agreements, again causing loss of time and extra expenses for DRBG. However, many of the parties that deliver poor models, do so not out of unwillingness but out of incapability. Many of the smaller contractors do not have the expertise that DRBG has and struggle to deliver a model that is up to standard.

Thus the recommendations that are proposed to improve the BIM understanding are:

- Provide more information to the contractors who have a poor understanding of BIM. These contractors understand the importance of BIM and want to use it themselves, however they need support in doing so. Thus, DRBG could share their expertise and put more effort into the set-up of one project in order to 'teach' these parties about BIM collaboration. If the process is made clear once or even twice, the collaboration should improve.

PROTOCOL ISSUES

The protocol of DRBG includes contractual requirements and demands for the BIM models, the property and use of the models, BIM-processes and responsibilities (Gils, 2017). However DRBG is not the only company with a collaboration protocol and every party wants their protocol to be followed. Because the DRBG protocol includes specifications necessary for the directions of the machines as well, it causes rework for DRBG if the protocol is not followed. This then means that extra time and expenses are involved in the project.

Moreover, if the protocol is however precisely followed (e.g. the model is LOD 350 following the basis ILS and can directly be used by DRBG), there is no gain for the customer. On the other hand, if the model is not up to level, the customer does not experience any inconvenience.

Thus, in order to improve the difficulties concerning the different protocols, the following recommendations are made:

- Create standard teams. When people work in the same group in every project, every party gets familiar with the different protocols of the other parties. Moreover, mistakes that are made once, can immediately be evaluated and prevented for next projects.
- Scale the different customers according to their BIM expertise and this way determine which DRBG employees should be part of which team. Some people are better in dealing with parties that have less expertise and transferring their own expertise.
- Make it more appealing to customers to follow the protocol. If a party can deliver a model on the LOD 350, then this should be rewarded with a form of discount on the price. On the other hand, if a company delivers only 2D drawings, this should be punished with a higher price because of the extra work that has to be put in to design a model. Finally, a model on the LOD 300 should be neutral because it does not require any extra work, however it is not desirable either.

THE NEW DISTRIBUTION OF ROLES

BIM collaboration causes some changes in the distribution of work and the roles different functions play in a project (Gu & London, 2010). The workload shifts and some functions are replaced altogether. This causes unclarity about the responsibilities each functions has. The greatest difficulty has to do with the checking of models with Solibri, either at the entrance or when the model has to be sent back to the customer. Although drafters often know their model is not up to standard, they do not have the expertise to check this. This causes frustration and unnecessary rework later on. However, the people also have to realise it is beneficial for them to do this check and that it is not just something the management wants them to do on top off all the work they already have to do. It is important that the drafters realise that when communicating with customers who blame them for a failure they can back up their work with the model check and refer to this to make clear to the customer where the failure comes from (and that it might not even be a mistake that is made by the drafter).

Moreover, in order to facilitate their employees as much as possible, one contractor regularly holds a survey about the difficulties employees encounter. They also have room to suggest

improvements and suggest subjects they would like to know more about, such as innovations or changes.

Thus, the collaboration would benefit from these recommendations:

- Provide the employees with the expertise they need through internal trainings (there is enough knowledge within DRBG to facilitate this). The main focus of these trainings is to make clear to the employees that using Solibri will not cause extra work for them, it will rather lighten their work load and solve their frustrations. Moreover, the trainings should be specific and relatable for the drawers and not go in depth about subjects that are relevant for other professions.
- When the checks are being executed, it should be monitored who does them and what the results are. The monitoring firstly serves to see whether someone has checked their model and secondly to analyse whether there is a clash that happens more often than others. If this is the case, the reason for this should be found accompanied with a possible solution.
- Regularly do an internal survey to check what the employees think and if they require training about a certain subject. Moreover, this could be a good way to innovate and bring in new knowledge. If the employees suggest a subject that is not familiar to DRBG, this could be looked into and it could turn out to be something that is of use for DRBG.

HARD- AND SOFTWARE ISSUES

A possible solution for the shortcomings of IFC, is ''cloud'' computing (Redmond, Hore, Alshawi, & West, 2012). Cloud computing both contains the applications being delivered as a service through the internet and the hard- and software systems in the data-centre that provide the services (Redmond, Hore, Alshawi, & West, 2012). However, a drawback of this solution is the issue of privacy. Companies do not want to share everything with everyone, but want to control the information that is shared.

5.3 COST-BENEFIT ANALYSIS

In §5.2 several recommendations were mentioned for the improvement of the BIM collaboration at DRBG. However, some recommendations take up more effort to implement than others and some will have more impact than others. Because of that, an cost-benefit diagram is presented to provide an overview of the recommendations and their ranking. The ideal situation is that a recommendation has a great impact, while taking low effort. These can be found in the top left corner and are ranked '++'. First the scores are explained per recommendation and below the diagram can be found (Table 3). This analysis is carried out by presenting the recommendations to experts and ranking the recommendations according to their opinions and preferences.

Determine BIM project: This recommendation scores high on the impact because it makes the process a lot easier for all the involved parties if it is determined whether a project is a BIM project at the begin stages. Then the necessary steps can be taken as soon as possible and this prevents frustration and diffusion later on. Moreover, it scores a medium on effort, because it is not only up to DRBG, but other parties are involved with this decision. This decision can be held back by the other parties and can cause DRBG to have to put in extra effort to persuade them.
Determine LOD variant: Similar to the determination whether a project is BIM or not, the

determination of the LOD variant scores high on impact. From the LOD variant it becomes clear what the planning of the project will be and which information is needed in which stage. However, it scores medium on effort as well, because it is dependent on other parties too.

Structure website: The structuring of the website scores medium on the impact, because it is not immediately related to projects. However, on the long term customers will have less trouble with meeting agreements because they can easier access the relevant information and will more likely do so. It scores low on effort because there are no other parties involved and it is a matter of changing document names and places.

Help-out customers with BIM: Helping out other parties with the BIM collaboration will have a high impact because the collaboration will improve directly. The customers who cannot deliver a model that is up to standard will learn to do so if they are guided more in the process and on the long term they can fully collaborate in BIM projects. However, it scores high on effort too because in the beginning there is a need of money and time to implement this. DRBG has to provide their own employees in order to help these parties.

Scale customers: When the customers are scaled to their expertise, the teams can be divided more easily, it is a supporting recommendation and scores therefore medium on impact. It scores low on effort because it is a matter of structuring by someone who knows the customers and their expertise. Moreover, there has already been made a beginning with this scaling.

Create standard teams: This recommendation scores high on impact because it will help solve the issues with protocols almost completely. If the protocols can be combined to work for both DRBG and their partners on the long term, the amount of rework that has to be done on models will decrease collaboration will benefit from it. Moreover, it scores low on effort because there are no other parties involved and it is a process that has already been started up by DRBG. Now it is only a matter of continuing forming the teams by someone who knows the employees and their capabilities and then dividing the teams among the already scaled customers.

Make it appealing to follow protocol: The impact of this recommendation will be high because there will be more customers who will follow the protocol as they will see the benefits of it for themselves. As a result of that, the amount of rework will decrease. However, it does score medium on effort because it is again dependent on external parties and their willingness to accept the new prices.

Internal trainings: This recommendation scores a high on impact as well because DRBG will have more knowledge and a better insight in their own processes and limitations. Because of this knowledge and insight the collaboration will be easier. It scores low on effort because there are no other parties involved and the budget and time is available for trainings. Moreover, the expertise is already present within DRBG, it only has to be shared.

Monitor checks: The monitoring of model checks will cause more checks to be executed and it provides a base to get more insight into the clashes that appear. The analysis can be used to prevent certain clashes in the future. Because it is a supporting tool, it scores medium on impact. Furthermore, monitor checks score low on effort because it only requires software and expertise which is already present in DRBG.

Hold surveys: Holding internal surveys among the employees can give a better insight into the difficulties they encounter and can help find new innovations. It does not directly help in the BIM process however and that is why it scores medium on impact. However, it does not require much effort to implement and can fairly easily be executed and therefore scores a low on effort.

Benefit ↓ / Cost →	Low	Medium	High
High	**++** *Create standard teams *Internal trainings	**+** *Determine BIM project *Determine LOD variant *Make it appealing to follow protocol	**0** *Help-out customers with BIM
Medium	**+** *Structure website *Scale customers *Monitor checks *Hold surveys	**0**	**-**
Low	**0**	**-**	**- -**

Table 3: Cost-Benefit analysis

5.4 DISCUSSION

From Table 2, it becomes clear that the difficulties DRBG is experiencing are not unique and are all either present in the literature or experienced by the partners or both.

The issues that have to do with the protocol are not explicitly mentioned in the literature, however these issues can be scaled to inadequate information exchange and poor understanding of the BIM collaboration.

When it comes to the restriction of information flow in order to protect privacy, DRBG does not have problems with this. This is because DRBG works with the concept of Open BIM and does their best to facilitate this in searching for partners who believe the same. Some of their partners however, do not work according to Open BIM principles and this requires unique collaboration agreements.

Although DRBG experiences some hard- and software issues, they do not have difficulties with IFC as external respondents have reported. Because of the privacy issues that go along with cloud computing, this solution is not preferred by DRBG. Thus, they have adopted the Open BIM principle in order to solve these problems.

From Table 3, it becomes clear that the most preferred recommendations are the creation of standard teams and the internal trainings. These recommendations fit well into the policy of DRBG according to the experts and can be implemented rather quickly, because DRBG is already in the process of implementing them. The recommendation that will cost DRBG the most, is helping-out the customers who lack BIM expertise.

6. MAIN CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

In this chapter the main conclusions are drawn based on previously discussed findings and results. Finally the limitations of the research will be listed.

6.1 CONCLUSIONS

Based on the objectives, a set of research questions has been formulated. Below these research questions have been answered.

WHAT STATUE DOES THE LITERATURE PROVIDE CONCERNING BIM AND WHAT ARE THE DIFFICULTIES THAT ARE DEALT WITH?

To answer the question what statue the literature provides concerning BIM application and what the difficulties and benefits are that are dealt with, the question is divided into sub questions.

The first sub question concerns the scope and from the literature it becomes once again clear how important the scope is. Most of the researches lie an emphasis on BIM as a dynamic process and not a way of sharing information and data. Moreover, most of the researchers agree that the benefits of BIM stretch out across the entire lifecycle of a project and do not stop when the building is completed.

With the numerous different scopes, there have to be numerous different applications as well. The applications range from improved visualisation to enabling more accurate calculations. However, all the applications need changes in the work process of the company in order to use its full benefit. This is something that is made very difficult by the AEC industry's fragmented nature and thus results in many companies struggling to make these changes.

The third sub question concerns the benefits and throughout the literature there are many answers that can be given here. The benefits can be divided into organisational, technical and human benefits. Organisational benefits have to do with the improved effectiveness, thus reducing time and errors while improving the quality. The technical benefits arise within the improvement of the model itself, allowing for better visualisation, enabling the calculations to take place earlier in the process and being able to see the impact of decisions before the building is actually constructed. The human aspect of the benefits includes better communication, better understanding and more trust between the different parties because of the transparency of the model.

However, there are also difficulties that can be distinguished. Again, the difficulties can be divided into three categories, organisational, technical and human. The organisational difficulties include the question of privacy and the willingness of a company to cooperate, an aspect that many companies even outside the AEC industry are experiencing difficulties with. The literature does not provide an ideal answer for these impediments, other than to make it an important factor in each project and to make clear agreements on the matter. Technical difficulties are rather easy to overcome and appear when a company is not capable of meeting the hard- and software adjustments that go along with BIM. This has namely to do with financial drawbacks and can be solved when the full benefit of BIM is overseen as opposed to the one-time expenses that are required for the hard- and software. Finally, the human factor will remain an uncertain one and possibly the largest impediment to overcome. Because, for BIM to work correctly,

humans have to do so. Whether this last aspect is the case depends among other things on the policy a company has and the training of the employees.

WHAT IS THE CURRENT BIM PROCESS AT DRBG?

To be able to answer the question what the current BIM process is at DRBG, the question is divided into sub questions.

The first sub questions concerns the scope and goal of BIM according to DRBG. For DRBG the BIM working method is an important instrument to optimise quality, lead time and expenses of their projects. DRBG works according to Open BIM principles.

To answer the second sub question, what the difference is between a standard project and a BIM project, the answers of the respondents have been analysed. The results of these interviews did generally not differ much from one another. Most of the respondents agreed on the differences between a standard project and a BIM project. These differences include a decline in failure costs, an improvement in visibility and a shift in the time period in which the information exchange takes place. However, one respondent from an external interview made a comment which none of the DRBG employees came up with, namely that the process becomes more clear to all the users when a project is BIM as opposed to a standard project. Moreover, one respondent within DRBG noted that the workload has not disappeared, however it shifted to the early stages of a project.

Concerning the second sub questions, about the impediments that users face, these include information that is received too late, collaboration that is held back by parties who have poor understanding of the BIM process, issues concerning different protocols, the new roles that emerged in the BIM process and hard- and software issues. These issues were for the most part also present in the literature and are not odd in comparison to the difficulties most companies experience in the AEC industry.

The fourth sub question concerns the users and training they received concerning BIM. The users of BIM include drafters (or modelers), coordinators of advice and calculation, heads of departments, standardisation engineers, project coordinators, BIM managers to project managers. Within DRBG, there was no specific training about the BIM collaboration. External respondents have had a collaboration training and state that it was useful for them.

HOW TO LEAD THE BIM APPLICATION IN THE RIGHT DIRECTION?

In order to answer the question what can be done to lead the BIM application in the right direction, the question is divided into three sub questions.

The first sub question concerns the specific problem DRBG encounters, these problems include inadequate information exchange, poor BIM understanding, issues with the protocol and issues about the new distribution of roles.

The second sub question deals with the improvements that can be made, which are strict agreements or sharing the expertise. Moreover, the situation would benefit from the forming of standard teams and making it more beneficial to follow the collaboration protocol of DRBG.

Furthermore, the website could use more structure and the employees will benefit from trainings and surveys.

The third sub question concerns the policy of DRBG. Most of the proposed solutions do fit in the policy of DRBG according to the experts and some of the solution were already planned to execute.

6.2 LIMITATIONS

Because of the limited timespan, it will not be possible to fully validate the proposed policies and solutions. However, the opinion and feedback of experts is taken into account when proposing the recommendations, to enable validation of the results.

Furthermore, the focus of this project was not to find new implementations for BIM within DRBG, rather on improving the existing implementations. Because of this, only the employees who are currently working with BIM are taken into account. Moreover, DRBG is only present from the LOD 300 to the LOD 500, thus only these levels and their corresponding BIM applications will be analysed during the research.

Finally, because of the limited timespan, the performed interviews were limited to only four external interviews. Because of this, not all the projects of DRBG are taken into account within this research. However, the aim was to interview external parties which differ as much as possible from one another.

6.3 RECOMMENDATIONS

For further research the results of the given recommendations could be analysed and used to further improve the recommendations.

Moreover, other projects of DRBG could be taken into account, including the 2D projects. this is in order to find new implementations for BIM and to broaden the use of BIM in the projects of DRBG.

Furthermore, to assess more impediments, interviews could be held with more partners. For this research the interviews were limited to just four external interviews, however in the ideal situation all the customers should be interviewed.

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ATTACHMENTS

ATTACHMENT A – TABLE OF TABLES AND TABLE OF FIGURES

TABLE OF TABLES

TABLE OF FIGURES

ATTACHMENT B – OVERVIEW FUNCTIONS

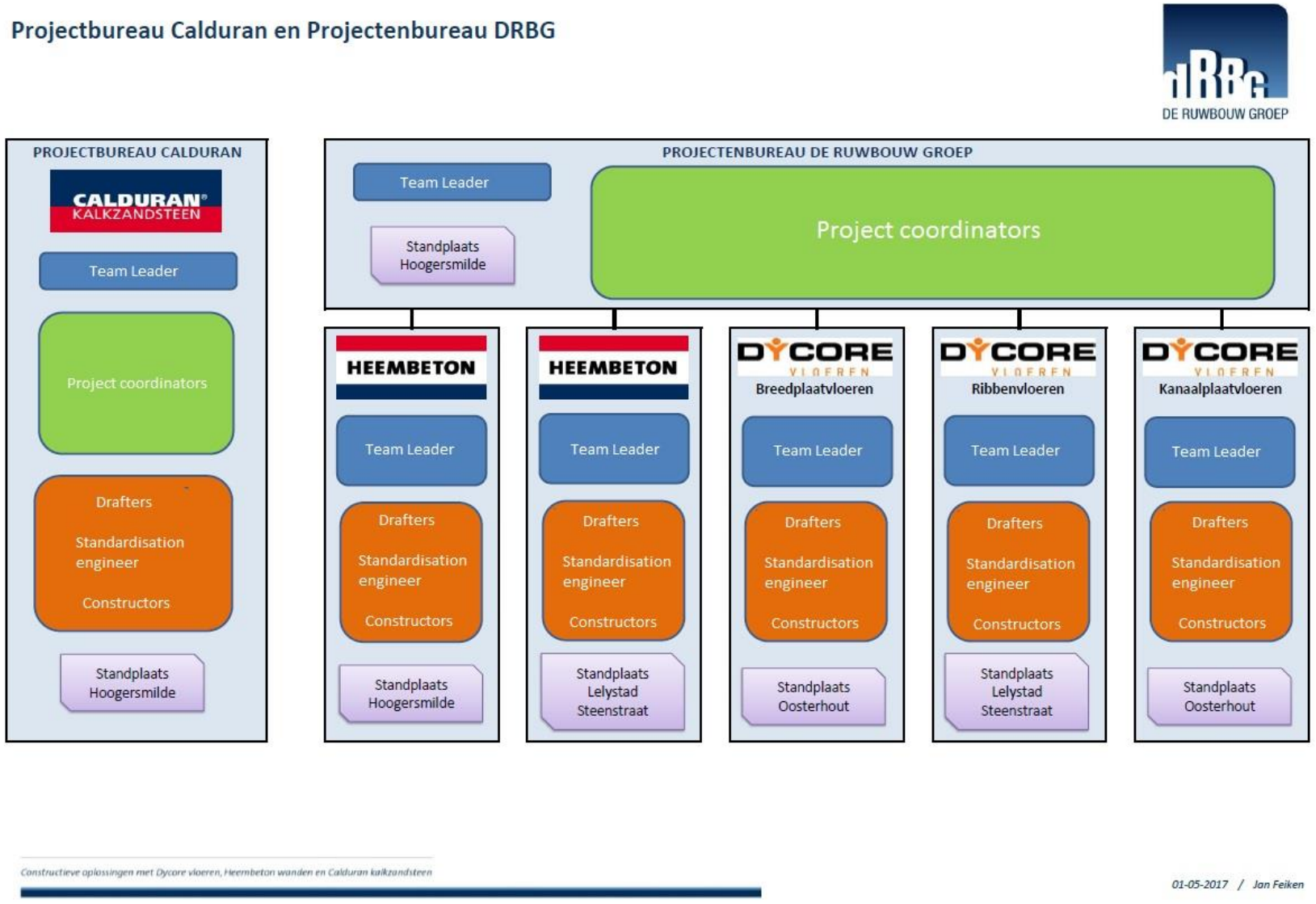
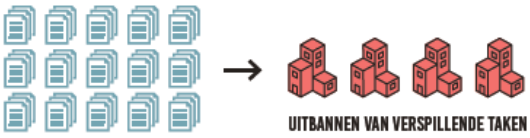


Figure 1: Overview functions

BIM BASIS INFORMATIELEVERINGSSPECIFICATIE

1. WAAROM GAAN WE INFORMATIE EENDUIDIG UITWISSELEN?

Om informatie efficiënter en effectiever te borgen en hergebruiken.



2. HOE GAAN WE INFORMATIE EENDUIDIG UITWISSELEN?

Op basis van kennis en ervaringen uit de praktijk is naar voren gekomen dat er een grote gemeenschappelijke deler is.
Er wordt niets nieuws ontwikkeld, maar er wordt gebruik gemaakt van bestaande structuren, gebaseerd op openBIM IFC.

3. WELKE STRUCTUUR GAAN WE HANTEREN?

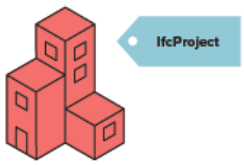
Onderstaande afspraken dragen eraan bij dat iedere betrokken partij altijd de juiste informatie op de juiste plek kan vinden en zelf kan aanleveren.

Checklist basis informatieleveringsspecificatie

3.1 BESTANDSNAAM

- ✔ Zorg altijd voor een uniforme en consistente benaming van (aspect) modellen binnen het project.

voorbeeld:
<Bouwwerk>_<Discipline>_<Onderdeel>



3.2 LOKALE POSITIE EN ORIËNTATIE - NULPUNT

- ✔ De lokale positie van het bouwwerk is onderling gecoördineerd en ligt vlak bij het nulpunt.

tip: maak gebruik van een fysiek 0-punt object, gepositioneerd op 0.0.0., en exporteer deze mee naar IFC.

3.3 BOUWLAAGINDELING EN -NAAMGEVING

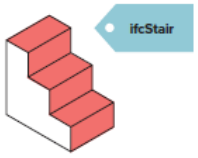
- ✔ Alleen bouwlagen benoemen als IfcBuildingStorey-Name.
- ✔ Alle objecten toekennen aan de juiste bouwlaag.
- ✔ Zorg er binnen een project voor dat alle partijen exact dezelfde consistente naamgeving aanhouden, numeriek te sorteren met een tekstuele omschrijving.

voorbeeld 1: 00 begane grond
voorbeeld 2: 01 eerste verdieping

3.4 CORRECT GEBRUIK VAN ENTITEITEN

- ✔ Gebruik het meest geëigende type BIM-entiteit, zowel in de bronapplicatie als de IFC-entiteit.

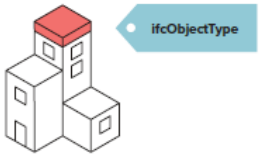
voorbeeld: vloer = IfcSlab, wand = IfcWall, balk = IfcBeam, kolom = IfcColumn, trap = IfcStair, deur = IfcDoor etc.



3.5 STRUCTUUR EN NAAMGEVING

- ✔ Objecten consistent structureren en aanduiden.
- ✔ In basis altijd TYPE (ifcType, ifcObjectType of ifcObjectTypeOverride) van elementen correct invullen.
- ✔ Waar van toepassing ook Name (ifcName of NameOverride) correct invullen.

voorbeeld: dakisolatie, type: glaswol



3.6 INFORMATIEINDELING CLASSIFICATIE NL-SFB

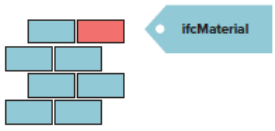
- ✔ Voorzie objecten in basis van een viercijferige NL-SfB variant-elementencode.

voorbeeld: 22.11

3.7 OBJECTEN VOORZIEN VAN CORRECT MATERIAAL

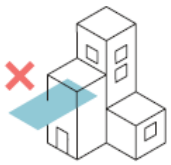
- ✔ Voorzie objecten van een materiaalbeschrijving (ifcMaterial).

voorbeeld: kalkzandsteen



3.8 DOUBLOURES EN DOORSNIJDINGEN

- ✔ In basis zijn doorsnijdingen en doublures in een aspectmodel niet toegestaan. Controleer hierop.



DEZELFDE TAAL LEREN SPREKEN, DOEN WE SAMEN

Bedenk bij het benoemen van objecten of de naam voldoet aan de volgende criteria. Controleer hier op, weet welke informatie je overdraagt.

- ✔ Betekenisvol
- ✔ Begrijpelijk
- ✔ Logisch
- ✔ Inzichtelijk
- ✔ Consistent
- ✔ Herkenbaar

4. HOE BORGEN WE ANDERE/TOEKOMSTIGE OBJECTINFORMATIE?

ObjectInformatie wordt geborgd in de juiste property's en propertysets zoals die in IFC zijn gedefinieerd.

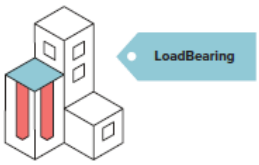
voorbeeld: bij balken maken de eigenschappen FireRating, LoadBearing en IsExternal onderdeel uit van de Pset_BeamCommon.

ifc Property Sets

- Pset##Common; LoadBearing
- Pset##Common; IsExternal
- Pset##Common; FireRating
- ....

4.1 DRAGEND / NIET DRAGEND - LOADBEARING

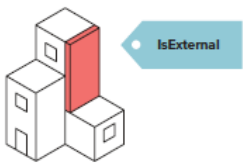
- ✔ Voorzie objecten, wanneer van toepassing, van de eigenschap LoadBearing [True/False].



4.2 IN / UITWENDIG - IS EXTERNAL

- ✔ Voorzie objecten, wanneer van toepassing, van de eigenschap IsExternal [True/False]

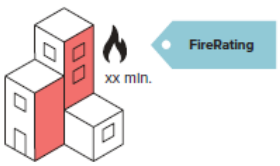
tip: zowel binnenblad als buitenblad van de gevel behoren tot IsExternalTrue.



4.3 BRANDWERENDHEID - FIRERATING

- ✔ Voorzie objecten, wanneer van toepassing, van de eigenschap FireRating.

voorbeeld: Vul hier de wbdbo waarde in minuten in bijvoorbeeld: 30, 60, 90 minuten.



4.4 PROJECTSPECIFIEK

- ✔ Bepaal projectspecifiek welke IFC properties je gebruikt.

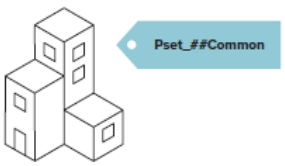


Figure 2: Basis ILS

ATTACHMENT D – LOD PROCESSES

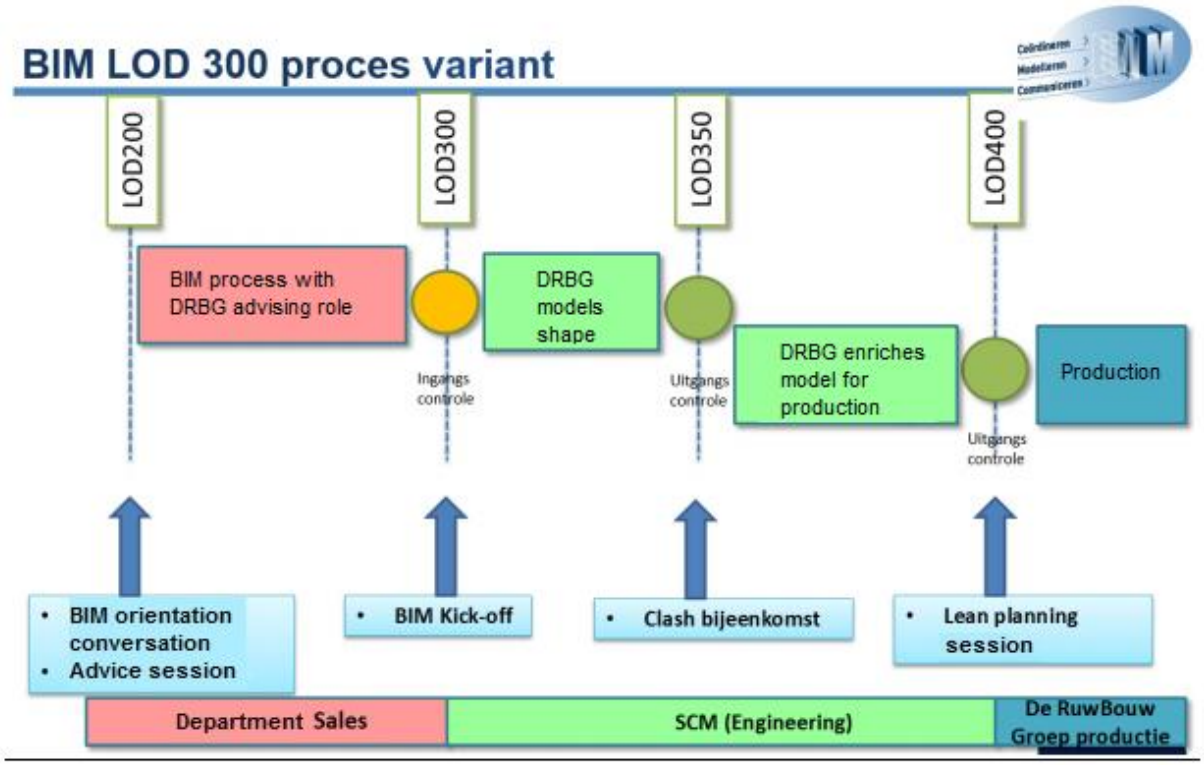


Figure 3: BIM LOD 300

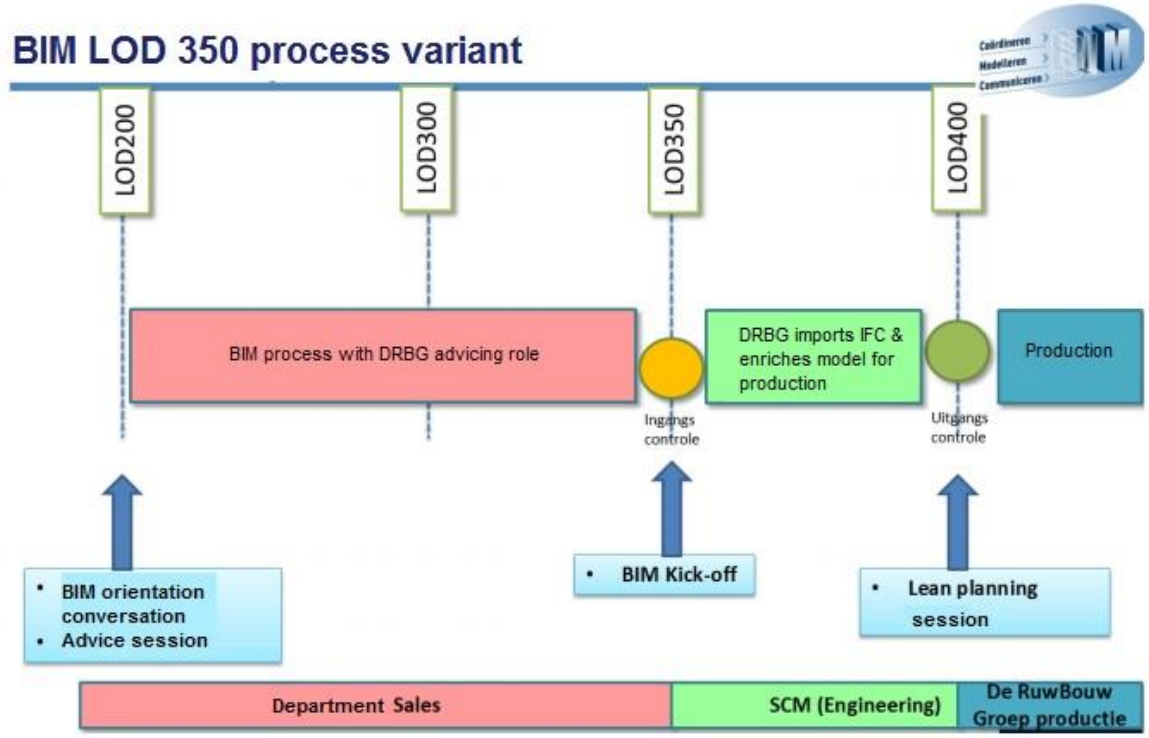


Figure 4: BIM LOD 350

ATTACHMENT E – WORKFLOW

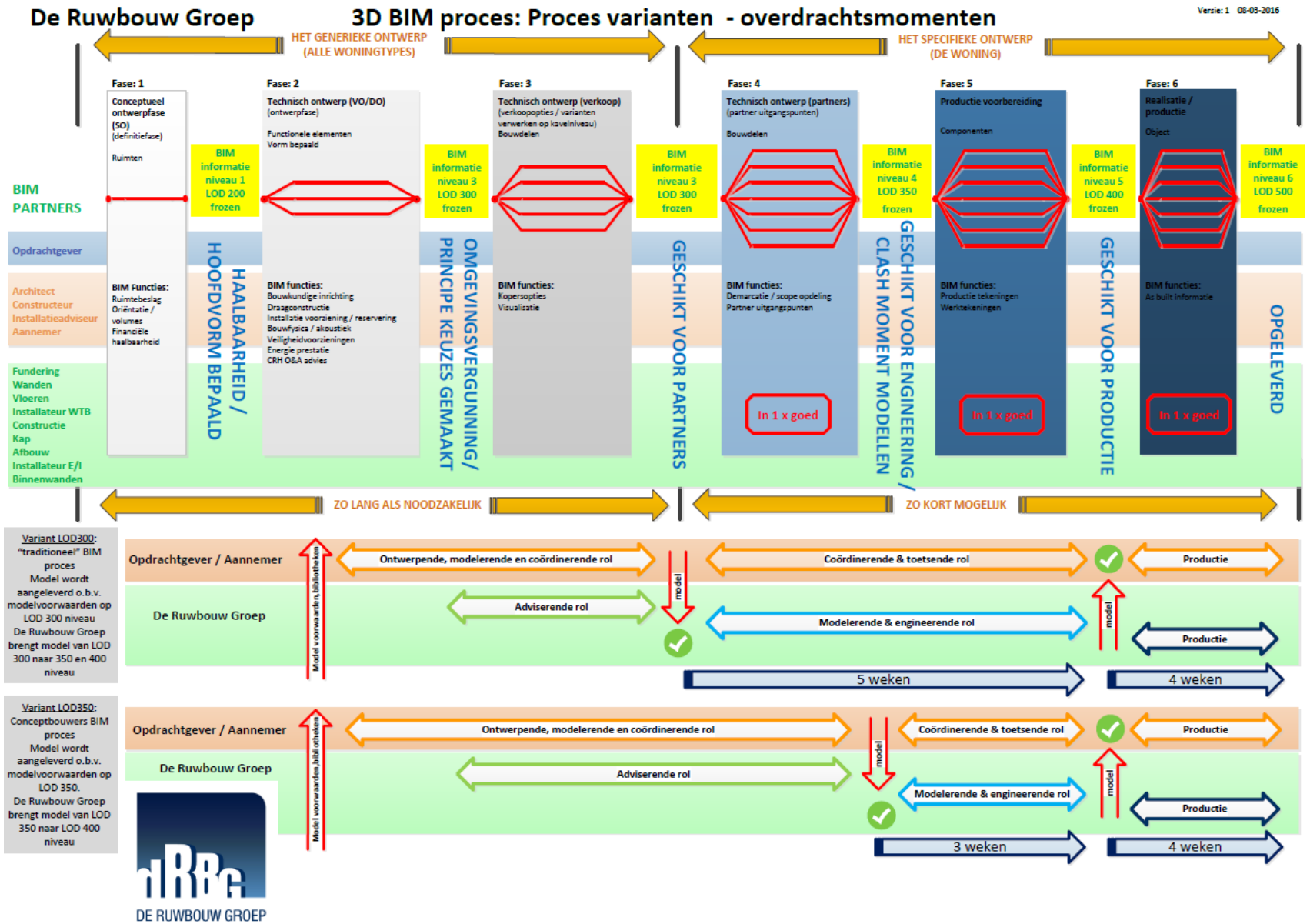


Figure 5: Workflow

ATTACHMENT F – INTERVIEW DRBG

Organisation

1. What is your current function at DRBG?
2. How and to which extent do your activities relate to BIM?
3. Some organisational aspects have to be altered in order to work BIM (e.g. functions disappearing or the creation of new functions). What have you noticed about this in your current function?

Process

4. What are the differences between the standard project and a BIM project? What are the changes in the process and the method in a BIM project as opposed to a standard project?
    a. Has the BIM collaboration had a positive effect on the information exchange and the communication?
    b. Which aspects of the standard method disappear in BIM projects and would you like to bring back?
    c. What is the ideal situation according to you? What would you like to see happen?
5. Do you ever experience difficulties in your activities that have to do with BIM or are even caused by BIM?
    a. In which situation do these difficulties occur?
    b. What are the causes of these difficulties according to you?
    c. And what are the effects of these difficulties?
    d. Do the difficulties appear within DRBG or with outside parties?
    e. According to you, what would have to change to solve these difficulties?
6. BIM requires some adjustments to hard- and software. Do you ever experience difficulties with this (e.g. not enough licences)?
7. DRBG has a BIM protocol, how does this protocol relate to your daily activities?
    a. Are there aspects of the protocol that do not function well according to you?
        i. If yes, how can this be solved?
    b. Are the people with whom you work, both within DRBG as outside parties, thoroughly informed about this protocol?
        i. If no, what can be changed to achieve this?

Education

8. Did you receive any education concerning BIM before you started working BIM?
    a. If yes, what kind of education?
    b. If yes, was this education sufficient for your current activities?
        i. If no, do you have any suggestions for improvement?
        ii. If yes, what were the strong points of the course?
    c. If no, how did you acquire your current knowledge concerning BIM?
    d. Do you think there would be improvement in the BIM collaboration if people were educated better concerning BIM?

ATTACHMENT G – INTERVIEW PARTNERS

Organisation

1. What is your current function?
2. How and to which extent do your activities relate to BIM?
3. What are the scope and the goal of BIM within your organisation?

Process

4. What are the benefits of BIM collaboration according to you?
    a. Do you have past experiences with other partners that could be beneficial to DRBG?
    b. What are the aspects of your collaboration with DRBG that could be beneficial to other partners?
5. What are the differences between the standard project and a BIM project? What are the changes in the process and the method in a BIM project as opposed to a standard project?
    a. Has the BIM collaboration had a positive effect on the information exchange and the communication?
    b. What is the ideal situation according to you? What would you like to see happen?
6. To which extent are you familiar with the collaboration protocol of DRBG?
    a. Do you use it in your projects with DRBG?
    b. Do you prefer a LOD 300 or a LOD 350 process? Why?
    c. How do you handle communication through Solibri and BCF?

Improvements

7. How do you deal with partners who cannot or will not work fully BIM?
8. How do you deal with information exchange that happens too late in the process?
9. Do you ever experience difficulties in your activities that have to do with BIM or are even caused by BIM?
    a. In which situation do these difficulties occur?
    b. What are the causes of these difficulties according to you?
    c. And what are the effects of these difficulties?
    d. According to you, what would have to change to solve these difficulties?

Education

10. Did you recieve any education concerning BIM before you started working BIM?
    a. If yes, what kind of education?
    b. If yes, was this education sufficient for your current activities?
    c. If no, how did you acquire your current knowledge concerning BIM?
    d. Do you think there would be improvement in the BIM collaboration if people were educated better concerning BIM?

Finally

11. Do you have any points for improvement in your collaboration with DRBG?