Reaching the promised land of BIM

An explorative study on Dutch Building projects

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Preface

Presented here is the result of my graduation project. Herewith I complete my master Construction Management and Engineering at Delft University of Technology. Over the past six months I dived into the subject of the transition between the project and operation phase in Dutch building projects with Building Information Modeling. I look back on an intensive but fun period in which I had the possibility to speak with many to different people, with different functions from different companies.

I feel privileged with the opportunity to have graduated at Brink Groep in Rotterdam. The people welcomed me with open arms and gave me a look inside the company with passionate and motivated people. The sincere interest that was shown and the time the people made for me when I needed a different perspective on my thesis gave me extra support during my graduation process.

Above all, without the support of my graduation committee this research would not have been possible. I would like to thank Alexander Koutamanis, my first supervisor, for all the helpful sessions in which I received feedback, advice and support. I also want to thank my second super visor Haiko van der Voort for his inspiring view on my report and Hans de Bruijn for his insights in creating added value with my research. A special thanks go to Toine Bullens and Maarten Zwemmer with whom I regularly sat around the table. The sessions have supported me enormously. Thanks to them I look back on a great graduation period at Brink Groep.

I am really grateful for my family and friends who supported me in the last couple of months and gave me distraction when needed. Thank you! Lastly, I want to thank Barend for your loving support and help at all times.

Lauren Veerhuis
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MANAGEMENT SUMMARY

Reaching the promised land of BIM

Introduction

The building industry can be characterized by fragmentation between organizations and processes (Becerik-Gerber & Rice, 2010). The increasing number of both professions and organisations involved in the building industry leads to fragmentation of tasks (Nawi, Nasrun, Baluch, & Bahaudin, 2014). This fragmentation is also apparent in the transition between the project and operation phase in building processes. In many cases the building project is seen as the total of activities that is necessary for the completion of the building itself. As a result, the project is finished as soon as the building is ready for its use (Buijs, de Jong, Leenders, van Riesen, & Warmels, 2003).

The transition between the project and operation phase is a quality-oriented process, which aims to verify if the performance of the facilities, systems and components complies with the specified objectives and criteria. A proper transition ensures that the new building is at optimal productivity at the beginning of the operation phase. In addition, it increases the probability that equipment maintains its level of performance during the entire lifetime.

Despite the importance of the transition between the project and operation phase, both literature and practice show that the in building projects the transition is not proceeding properly. Unstructured and incomplete two-dimensional documents that are handed over are inefficient and ineffective for use during the operation and maintenance of the building (Wu & Issa, 2012). It therefore causes friction between the stakeholders in the two phases and causes a labour-intensive transition towards the operational phase. In addition, a poor transition between the project and operation phase causes difficulties for correct verification of the performance of the facilities, systems and components, which ultimately results in otherwise avoidable financial expenses and delays.

Now that Building Information Modeling (BIM) is changing the way of working during the entire building life cycle, the inefficiencies related to the poor transition between the project and operation phase can potentially be solved. BIM is a life cycle method that extends beyond the design and construction phase. It facilitates seamless exchange of information throughout the different stages of the building life cycle, which supports the transition between the project and operation phase. In practice, however, there is, despite the use of BIM, still no seamless exchange of information in the transition between the project and operation phase. While BIM is praised for its added value throughout the entire life cycle of a building, its potential is not realised in practice.

Currently, there is a lack of knowledge about why the fragmentation still occurs and how BIM can offer support in improving the transition between the project and operation phase. Therefore, this research aims is to understand the reason why the transition of information between the project and operation phase of a building project is not proceeding properly while using BIM. The following research question is used for this research:

How can Building Information Modeling offer support in improving the transition between the project and operation phase in Dutch building projects?

In order to answer this main research question, the following sub-questions are defined and answered:

1. How are current Dutch Building projects organized and what is the possible Role of BIM in this context?
2. What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?
3. How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?

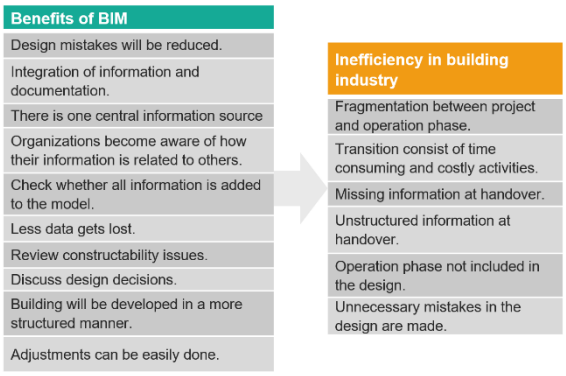
Research approach

The research can be characterized by a constructivist approach. This approach is known for learning and understanding the world around us through questioning and interpretation. The approach is also known as an approach for qualitative research. As this research focuses on understanding the issues involved with the implementation of BIM, it can be characterized as qualitative research (Creswell & Creswell, 2009).

To answer the main research question, a research framework is set up. The research is divided into four parts: The literature review, the case studies, lessons learned and the synthesis.

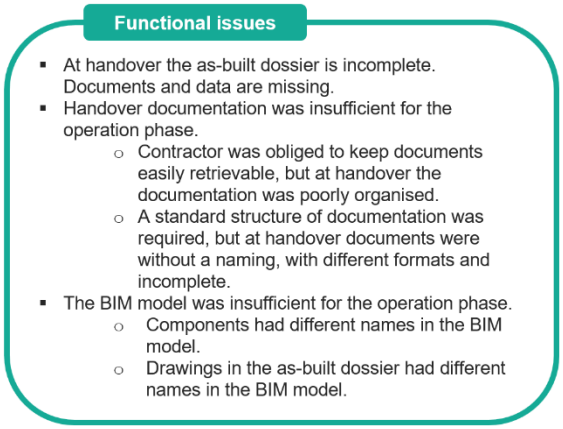
Results

By analysing the literature study (phase I), several inefficiencies in the building industry, which negatively influence the transition between the project and operation phase are identified. The literature study has shown that in theory BIM offers added value for a variety of different inefficiencies in the building industry. This also applies to the transition between the project and operation phase. In the following figure, an overview is given of the identified added values of BIM which will theoretically offer a solution for the identified inefficiencies in the building industry.

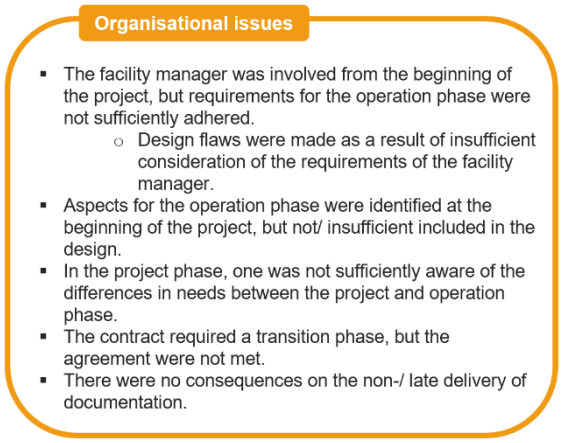


In addition, the literature shows that working with BIM requires both the implementation of a new technique and the improvement of collaboration between stakeholders. This latter relates to the fact that when one works with BIM it is expected to involve stakeholders early in the process. In addition, BIM requires the implementation of new roles and responsibilities and stakeholders are required to be transparent in sharing their information.

The results of the case studies (phase II) show that despite the use of BIM, a number of issues still affect the transition between the project and operation phase. The issues that arise can be divided into two main categories: Functional issues and Organisational issues. The functional issues involve issues relating to the functional outcome of BIM. These are the issues that are linked to the BIM model at handover.



The organisational issues concern the issues relating to the process and the people as well as their behaviour with regard to BIM.



From the cross case analysis and the generative session (phase III), several lessons learned have emerged. The lessons learned can be seen as points of attention which are important when one at the beginning of the project decides to work with BIM in the operation phase. The points of attention can be divided into two categories. There are points of attention of the general use with BIM in de building industry and points of attention that specifically affect the transition between the project and operation phase. The points of attention are as follows:

When one wants to work with BIM…

… agreements must be made about the structure of information in both the BIM and the separate as-built file.

… good communication and clear agreements about the level of detail of information that is linked to the objects in the BIM model are recommended.

… one should create policies on how to manage the information, keep it up-to date and about how to keep the information complete during the project.

… it is important to keep track changes and correct information in both the as-built dossier and the BIM model from the beginning of the project.

When one wants to work with BIM in the operation phase, ….

… one should involve the facility manager early in the project and include the necessary requirements for the operation phase into account in the design.

… it is important that one is aware of the differences in needs between the project and operation phase.

… it is recommended that the organisation of the transition phase is made compulsory in the contract.

… it is advised to define at the beginning of the project what the BIM model must comply with before it can be used in the operation phase.

Conclusion

Based on the findings of this research, several conclusions can be drawn (phase IV).

When the issues that emerge from the case studies are analysed, a number of conclusions can be drawn. First, a major contradiction in the implementation of BIM became apparent. On the one hand, BIM ensures improved collaboration. It creates the possibility to work together more easily via an integrated platform. On the other hand, working with BIM asks for improved collaboration between the stakeholders. This while the improvement of collaboration is in itself seen as a challenge within the construction industry.

Second, two types of issues with the implementation of BIM were identified. A number of these issues can be seen as structural, while others can be considered ‘teething problems’. The implementation of BIM as a new technique poses challenges. These are challenges that invariably come into play when implementing a new technique and are therefore are seen as teething problems. However, the case studies also reveal structural problems in the building industry. These issues are identified as problems in the building industry with and without BIM. However, the use of BIM puts the inefficiencies of the building industry under a magnifying glass. For example, the lack of involvement of the facility manager at an early stage of the project. This is seen as an issue in the building industry, that is not mitigated with the use of

BIM. In addition, the lack of transparency between stakeholders causes problems with and without the use of BIM.

One can conclude from this analysis that only working with BIM will not provide the solution for the issues that relate to the transition between the project and operation phase. BIM is a tool that can provide support but it is not a stand-alone solution for the structural problems in the building industry. As a result, before the full benefits of using BIM can be examined, the structural problems of the building industry need to be solved. The analysis of this research also shows that the structural problems are all related to the management of information processes during the building life cycle. It thus seems, that before one can examine how BIM can offer support to the transition between the project and operation phase, the information management processes for which BIM is a supportive tool, must be redesigned.

Recommendations

From the analysis of the points of attention, four categories are identified. These categories are all related to the organisation of the information management processes in 'the beginning' of the project. The categories are about how the information management process is organised and not directly about how it should be executed during the building project. The categories are: Determining the information needs; the role of stakeholders with regard to the information; the quality of the information and; Determining the process in which the BIM model is generated

For each category the following recommendations focus on what is required when organising the information management process for that specific category.

Determining the information needs

- Ensure that one is aware of the differences in needs between the project and operation phase.
- Make sure agreements are made on the level of detail of the BIM model in the BIM protocol.

The role of stakeholders with regard to the information

- Be aware that the facility manager is included in the organisation structure.
- Ensure that in the contract decisions are made on how documents will be shared between stakeholders
- Be aware that all stakeholders are aware of the documentation structure

The quality of information

- Ensure that a documentation structure for the BIM model is defined in the BIM protocol.
- Include the organisation of the transition between the project and operation phase in the contract.
- Decide in advance how often and when it will be checked if the information is up-to-date, complete and whether the agreed structure is consistently used.
- Check from the beginning whether the BIM model is as-built on a random basis

Determining the process in which the BIM model will be generated

- Create a strategy on how it will be assured that the data in the BIM model and the as-built dossier remains up-to-date.
- Before the handover, ensure that it is examined whether the BIM model fully complies with the BIM protocol.
- Ensure all modifications in the operation phase will be included in the BIM model.

MANAGEMENT SAMENVATTING

Naar het beloofde land van BIM

Introductie

De bouwsector wordt gekenmerkt door fragmentatie tussen zowel organisaties als processen (Becerik-Gerber & Rice, 2010). Het toenemend aantal functies en organisaties in de bouwsector leidt tot fragmentatie van de taken (Nawi et al., 2014). Deze fragmentatie is ook zichtbaar in de overgang tussen de project- en beheerfase. In veel gevallen wordt het bouwproject gezien als het totaal aan activiteiten dat nodig is voor de oplevering van het gebouw zelf. Hierdoor is het project afgerond zodra het gebouw klaar is voor gebruik en valt de organisatie van de overdracht naar de beheerfase buiten het belang van het project (Buijs, de Jong, Leenders, van Riesen, & Warmels, 2003.

De overgang tussen de project- en beheerfase is een kwaliteitsgericht proces, dat als doel heeft te verifiëren of de prestaties van voorzieningen, systemen en componenten voldoen aan de gestelde doelstellingen en criteria. Een goede transitie zorgt ervoor dat het nieuwe gebouw aan het begin van de beheerfase optimaal productief is. Bovendien verhoogt het de kans dat apparatuur haar prestatieniveau gedurende de gehele levensduur behoudt.

Ondanks het belang van een goede overgang tussen de project- en operatie fase blijkt uit de literatuur en de praktijk dat de overgang bij bouwprojecten vaak niet goed verloopt. Ongestructureerde en onvolledige tweedimensionale documenten worden overgedragen aan de beheerder. Deze documenten zijn inefficiënt en ineffectief voor het gebruik tijdens de management en onderhoud van het gebouw in de beheerfase (Wu & Issa, 2012). Hierdoor ontstaat er wrijving tussen de stakeholders in de twee fasen en wordt de overgang naar de beheerfase arbeidsintensief. Daarnaast leidt de slecht overgang tussen de project- en beheerfase tot problemen bij het correct verifiëren van de prestaties van de voorzieningen, systemen en componenten. Dit leidt uiteindelijk tot vermijdbare financiële kosten en vertragingen.

Nu Building Information Modeling (BIM) de manier van werken gedurende de gehele levenscyclus van een gebouw verandert, kunnen de inefficiënties met betrekking tot de slechte overgang tussen de project- en beheerfase potentieel worden opgelost. BIM is een levenscyclusmethode die verder reikt dan de ontwerp- en uitvoeringsfase. Het zorgt een ononderbroken uitwisseling van informatie in de verschillende stadia van de levenscyclus van het gebouw mogelijk. Dit ondersteunt de overgang tussen de project- en beheerfase.

Echter, in de praktijk is er, ondanks het gebruik van BIM, nog steeds geen ononderbroken uitwisseling van informatie tussen de project- en beheerfase. Hoewel BIM wordt geprezen om zijn toegevoegde waarde gedurende de gehele levenscyclus van een gebouw, wordt het potentieel ervan in de praktijk niet gerealiseerd.

Tot op heden is er een gebrek aan kennis over waarom de fragmentatie in het bouwproces nog steeds voorkomt en hoe BIM ondersteuning kan bieden bij het verbeteren van de overgang tussen de project- en beheerfase. Het doel van dit onderzoek is dan ook te begrijpen waarom de overgang van informatie tussen de project- en beheerfase van een bouwproject niet goed verloopt ondanks het gebruik van BIM. Voor dit onderzoek wordt de volgende onderzoeksvraag beantwoord:

Hoe kan Building Information Modeling ondersteuning bieden bij het verbeteren van de overgang tussen de project- en beheerfase in Nederlandse bouwprojecten?

Om deze onderzoeksvraag te kunnen beantwoorden, zijn de volgende deelvragen gedefinieerd en beantwoord:

1. Hoe zijn huidige Nederlandse bouwprojecten georganiseerd en wat is de mogelijke rol van BIM in deze context?
2. Welke problemen en onderliggende oorzaken bestaan er binnen de aspecten die van invloed zijn op de overgang tussen de project- en beheerfase in Nederlandse bouwprojecten met BIM?
3. Hoe kan BIM ondersteuning bieden bij het voorkomen van de problemen en onderliggende oorzaken in de overgang tussen de project- en beheerfase in Nederlandse bouwprojecten?

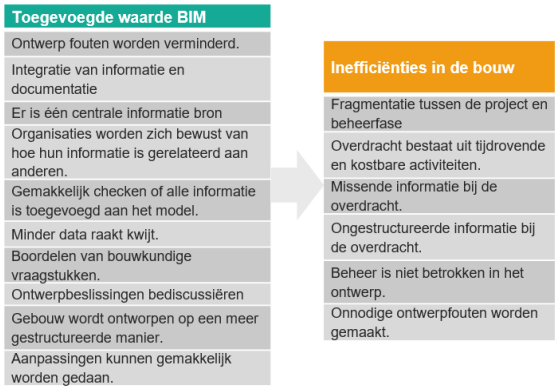
Onderzoeksaanpak

Het onderzoek wordt gekenmerkt door een constructivistische benadering. Deze aanpak staat bekend om het leren begrijpen van de wereld om ons heen door middel van bevraging en interpretatie. De benadering staat dan ook bekend als een aanpak voor kwalitatief onderzoek. Aangezien dit onderzoek zich richt op het begrijpen van de problematiek rond de implementatie van BIM, kan het worden gekarakteriseerd als een kwalitatief onderzoek (Creswell & Creswell, 2009).

Om de onderzoeksvraag te kunnen beantwoorden is er een onderzoeksopzet gecreëerd. Het onderzoek is onderverdeeld in vier fasen: De literatuurstudie, de case studies, de opgedane kennis en de synthese.

Resultaten

Op basis van de literatuurstudie (fase I), zijn er verschillende inefficiënties in de bouwsector geïdentificeerd die de overgang tussen de project- en beheerfase negatief beïnvloeden. Uit de literatuurstudie is gebleken dat BIM in theorie toegevoegde waarde levert voor de verschillende inefficiënties in de bouwsector. Dit geldt ook voor de inefficiënties met betrekking tot de overgang tussen de project- en beheerfase. In de volgende figuur is een overzicht gepresenteerd van de geïdentificeerde toegevoegde waarden van BIM die theoretisch een oplossing bieden voor de geïdentificeerde inefficiënties in de bouw.



Daarnaast blijkt uit de literatuur dat het werken met BIM zowel de implementatie van een nieuwe techniek als de verbetering van de samenwerking tussen stakeholders vereist. Dit laatste heeft te maken meet het feit dat wanneer men met BIM werkt, er wordt verwacht dat stakeholders in een vroeg stadium van het project worden betrokken. Daarnaast vereist BIM de implementatie van nieuwe rollen en verantwoordelijkheden en zijn stakeholders verplicht om transparant te zijn in het delen van informatie.

Uit de resultaten van de case studies (fase II), blijkt dat ondanks het gebruik van BIM een aantal inefficiënties nog steeds van invloed zijn op de overgang tussen de project- en beheerfase. De problemen die zich voordien, kunnen worden onderverdeel in twee categorieën: functionele issues en organisatorische issues.

De functionele issues hebben betrekking op de functionele uitkomst van het bouwproces met BIM. Dit zijn de issues die samenhangen met de oplevering van het BIM-model.

Functionele problemen

- Bij oplevering is het as-built dossier onvolledig. Documenten en gegevens ontbreken.
- De overdrachtsdocumentatie was onvoldoende voor de beheerfase.
  - Aannemer was verplicht dat documentatie gemakkelijk terug te vinden was, maar bij de oplevering was documentatie slecht georganiseerd.
  - Standaard structuur was vereis, maar bij oplevering bleek naamgeving en documentatie onvolledig en ongestructureerd.
- Het BIM-model was onvoldoende voor de beheerfase
  - Componenten in BIM-model hadden verschillende namen
  - Tekeningen hadden in het BIM-model andere namen dan in het as-built dossier.

De organisatorische issues hebben betrekking op de issues die betrekking hebben op het proces, de mensen en hun gedrag ten aanzien van BIM.

Organisatorische problemen

- De facility manager was vanaf het begin betrokken, maar de eisen voor de beheerfase werden onvoldoende nageleefd.
  - Ontwerpfouten werden gemaakt als gevolg van onvoldoende aandacht voor de beheerfase.
- Aan het begin van het project zijn aspecten voor het beheer geïdentificeerd, maar niet/te weinig opgenomen in het ontwerp.
- In de projectfase was men zich onvoldoende bewust van de verschillen in behoeften tussen de project en beheerfase.
- Het contract vereiste een overgangsfase, maar de overeenkomst werd niet nagekomen.
- Er waren geen gevolgen voor het niet of te laat aanleveren van documentatie.

Uit de cross case analyse en de generatieve sessie (fase III) zijn verschillende lessen getrokken. De opgedane kennis kan worden geformuleerd als aandachtspunten die van belang zijn wanneer met aan het begin van het project besluit om met BIM te werken in de beheer fase. De aandachtspunten zijn onder te verdelen in twee categorieën. Er zijn aandachtspunten voor het algemene gebruik van BIM in de bouwsector en aandachtspunten die specifiek van invloed zijn op de overgang tussen de project- en beheerfase. De aandachtspunten zijn:

Wanneer men met BIM wil werken.....

.... moeten er afspraken worden gemaakt over de structuur van de informatie in zowel het BIM als het afzonderlijke as-built bestand.

.... wordt er aanbevolen om goed te communiceren en duidelijke afspraken te maken over het detailniveau van de informatie die gekoppeld is aan de objecten in het BIM-model.

.... moet men een beleid opstellen over hoe de informatie beheerd moet worden, hoe men deze actueel moet houden en hoe men de informatie compleet moet houden tijdens het project.

.... is het van belang om wijzigingen en correcte informatie bij te houden in zowel het as-built dossier als het BIM-model vanaf het begin van het project.

Wanneer men in de beheerfase met BIM wil werken, ...

.... dient men de facility manager in een vroeg stadium bij het project te betrekken en in het ontwerp rekening te houden met de noodzakelijke eisen voor de exploitatiefase.

.... is het belangrijk dat men zich bewust is van de verschillen in behoeften tussen het project- en de beheerfase.

.... wordt het aanbevolen om de organisatie van de transitiefase verplicht te stellen in het contract.

.... wordt geadviseerd om aan het begin van het project te definiëren waar het BIM-model aan moet voldoen voordat het kan worden gebruikt in de beheerfase.

Conclusie

Op basis van de bevindingen uit dit onderzoek kunnen verschillende conclusies worden getrokken (fase IV).

Wanneer de issues die uit de case studies naar voren komen worden geanalyseerd, kunnen een aantal conclusies worden getrokken. Ten eerste is er een grote tegenstrijdigheid in de implementatie van BIM naar voren gekomen. Enerzijds zorgt BIM voor een betere samenwerking. Het creëert de mogelijkheid om gemakkelijker samen te werken via een geïntegreerd platform. Anderzijds vraagt het werken met BIM om een betere samenwerking tussen de stakeholders. Dit

terwijl het verbeteren van de samenwerking op zich al als een uitdaging binnen de bouwsector wordt gezien.

Ten tweede zijn er twee soorten problemen die betrekking hebben op de implementatie van BIM geïdentificeerd. Een aantal van deze problemen kunnen als structureel worden beschouwd, terwijl andere als 'kinderziektes' van de implementatie van BIM kunnen worden gezien. De implementatie van BIM als nieuwe techniek is er zo een kinderziekte. De implementatie zorgt voor uitdagingen die altijd een rol spelen bij de implementatie van een nieuwe techniek. Echter, laten de case studies zien dat er ook structurele problemen zijn in de bouwsector. Dit zijn problemen die geïdentificeerd worden in bouw projecten met en zonder BIM. Door het gebruik van BIM worden deze inefficiënties echter onder een vergrootglas gelegd. Bijvoorbeeld de geringe betrokkenheid van de facility manager in een vroeg stadium van het project. Dit wordt gezien als een probleem in de bouwsector, met en zonder BIM. Daarnaast is het gebrek aan transparantie ook een probleem dat bestaat in bouw projecten met en zonder BIM.

Hieruit kan geconcludeerd worden dat alleen het werken met BIM niet de oplossing biedt voor de structurele problemen in de bouw die betrekking hebben op de transitie tussen de project en beheerfase. BIM is een tool dat ondersteuning kan bieden, maar het is geen op zichzelf staande oplossing voor de structurele problemen in de bouwsector. Als gevolg hiervan moeten, voordat de voordelen van het gebruik van BIM in de bouwsector volledig kunnen worden onderzocht, de structurele problemen van de bouw worden opgelost.

Uit dit onderzoek kan geconcludeerd worden dat de structurele problemen te maken hebben met de management van de informatieprocessen tijdens de bouw. Het lijkt er dus dat, voordat men kan onderzoeken hoe BIM ondersteuning kan bieden aan de overgang tussen de project en beheerfase, de informatiemanagementprocessen waarvoor BIM een ondersteunende tool is, moeten worden heringericht.

Aanbevelingen

Uit de analyse van de aandachtspunten kunnen vier categorieën worden onderscheiden. Deze categorieën hebben allemaal te maken met de organisatie van de informatiemanagement-processen in het begin van het project. De categorieën zijn: Het bepalen van de informatie behoefte; de rol van stakeholders met betrekking tot de informatie; de kwaliteit van informatie en; het bepalen van het proces waarin de informatie wordt gecreëerd.

Voor elke categorie zijn de aanbevelingen gericht op wat er nodig is bij de inrichting van het informatie management proces voor die specifieke categorie.

Vaststellen van de informatiebehoefte

- Zorg ervoor dat men zich bewust is van de verschillen in behoeften tussen de project- en beheerfase.
- Zorg ervoor dat er afspraken worden gemaakt over het detail niveau van het BIM-model in het BIM-protocol.

De rol van stakeholders met betrekking tot de informatie

- Wees ervan bewust dat de facility manager is opgenomen in de organisatiestructuur.
- Zorg ervoor dat in het contract beslissingen worden genomen over de wijze waarop documenten worden gedeeld tussen stakeholders.
- Wees ervan bewust dat alle stakeholders op de hoogte zijn van de documentatiestructuur.

De kwaliteit van de informatie

- Zorg ervoor dat in het BIM-protocol een documentatiestructuur voor het BIM-model wordt gedefinieerd.
- Neem de organisatie van de overgang tussen project- en beheerfase op in het contract.
- Bepaal vooraf wanneer wordt gecontroleerd of de informatie up-to-date en volledig is en of de overeengekomen structuur consistent wordt gebruikt.
- Controleer vanaf het begin op willekeurige basis of het BIM-model gelijk is aan as-built.

Het bepalen van het proces waarin de informatie wordt gecreëerd

- Creëer een strategie om ervoor te zorgen dat de gegevens in het BIM-model en het as-built dossier up-to-date blijven.
- Zorg ervoor dat vóór de overdracht wordt onderzocht of het BIM-model volledig in overeenstemming is met het BIM-protocol.
- Zorg ervoor dat alle wijzigingen in de exploitatiefase in het BIM-model worden opgenomen.

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1.

INTRODUCTION

This chapter contains the introduction of this research. At first, in paragraph 1.1 the research context will be described. This is followed by, in paragraph 1.2, the description of the problem statement. In paragraph 1.3, the research question with subsequent sub-questions will be presented. Followed by the research goal in paragraph 1.4 and the elaboration of the relevance in paragraph 1.5. The chapter will conclude with an overview of the structure of the research in paragraph 1.6.

Every year, 10 percent of turnover in the building industry is lost due to mistakes' is the headline in the NRC (Dutch newspaper) on August 18, 2017 (Houtekamer, 2017). The building industry recognizes this problem and is looking for ways in which these mistakes can be prevented. Stimulating the integration of information between the project phases and improving the collaboration between all stakeholders can possibly offer solutions. However, this asks for a new approach in the building industry.

With Building Information Modeling (BIM) this new approach came into existence. With BIM technology, a virtual (building) information model of a building is created. This 3D model of the building includes all relevant information about the construction of the building (Azhar, 2011; Eastman, Eastman, Teicholz, & Sacks, 2011; Hardin & McCool, 2015). Additionally, precise real-time information about the construction of the building supports the organizations within the project team to integrate their generated information and structure the project (Liu, Van Nederveen, & Hertogh, 2017).

The benefits that BIM promises ensure that organizations within the building industry are enthusiastic about the implementation of BIM. Nevertheless, there are also challenges that accompany the new way of working with BIM in the building industry. For instance, not all functions of BIM can directly be applied in the current design and construction activities. This is not only because of the technical challenges, but also has to do with the changing ratio between the technical and social elements of the construction project (Liu et al., 2017). The adoption of BIM, thus, asks for a change in the existing way of working. BIM requires more communication and collaboration between the organizations in the project, which means a more integrated way of working (Singh, Gu, & Wang, 2011). This challenge forms the basis for this research.

1.1 Research context

Based on literature and explorative interviews with four senior consultants from Brink Groep, the research context is established. The summary of the four interviews can be found in appendix I.

The building industry can be characterized by fragmentation both between organizations and processes (Becerik-Gerber & Rice, 2010). The increasing number of both professions and organisations involved in the building industry leads to fragmentation of tasks (Nawi et al., 2014). Each single organisation is focused on maximising the performance of its own business unit, but this does not result in a better overall performance. The fragmentation has a negative impact on the productivity in the building industry as a whole. In addition, the lack of integration is holding back possible improvements for the project performance (Howard, Levitt, Paulson, Pohl, & Tatum, 1989).

The fragmentation is also apparent in the transition between the project and operation phase. In many cases the building project is seen as the total of activities that is necessary for the completion of the building itself. As a result, the project is finished as soon as the building is ready for its use (Buijs et al., 2003).

Building Information Modeling is defined as the approach by which fragmentation in the industry will be reduced (Azhar, 2011; Bryde, Broquetas, & Volm, 2013; Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013; Eastman et al., 2011; Xu, Ma, & Ding, 2014). The integration in both the individual phases and between the project phases ensures that efficiency and effectiveness is increased and that interoperability will be improved (Succar, 2009). This sounds as the ideal solution for the

building industry, but implementing this new approach in the traditional building industry is complicated.

The fact that the implementation of BIM in the building industry is challenging, is also seen in the transition between the project and operation phase. In many cases, the BIM model is used in the design and construction of the building. However, during these projects, it appears that the BIM model cannot be used in the operation phase. In such cases, the information in the BIM model does not meet the information needs of the facility manager in the operation phase. The increase of integration between project phases, which is seen as the key value of BIM, is then negated.

This research provides insights on why the implementation of BIM in practice does not ensure the intended integration as described in literature. Therefore, the main issues of the use of BIM for the transition between the project and operation phase are investigated. These will be the basis for recommendations on how to deal with these issues and improve the implementation of BIM in the building industry.

1.2 Problem statement

The transition between the project and operation phase is a quality-oriented process, which aims to verify if the performance of the facilities, systems and components complies with the specified objectives and criteria. A proper transition ensures that the new building is at optimal productivity at the beginning of the operation phase. Besides it increases the probability that equipment maintains its level of performance during the entire lifetime. In addition, the transition between the project and operation phase is focused on the handover of information. The information from the project phase which is important for the operation and maintenance of the building must be handed over to the facility manager.

Despite the importance of this transition, both literature and practice show that the transition between the project and operation phase in building projects is not proceeding properly. The unstructured and incomplete two-dimensional documents that are handed over are inefficient and ineffective for use during the operation and maintenance of the building (Wu & Issa, 2012). It therefore causes friction between the stakeholders in the two phases and makes the transition towards the operational phase labour-intensive. In addition, a poor transition between the project and operation phase causes difficulties for correct verification of the performance of the facilities, systems and components, which ultimately results in otherwise avoidable financial expenses and delays.

Now that Building Information Modeling is changing the way of working during the entire building life cycle, the inefficiencies related to the poor transition between the project and operation phase can potentially be solved. BIM is a life cycle method that extends beyond the design and construction phase. It facilitates seamless exchange of information throughout the different stages of the building life cycle, which supports the transition between the project and operation phase. In practice, however, there is, despite the use of BIM, still no seamless exchange of information in the transition between the project and operation phase. While BIM is praised for its added value throughout the entire life cycle of a building, its potential is not realised in practice.

This problem mainly concerns the facility manager in the operation phase. The information needs for the facility manager to be able to carry out operation and maintenance activities is not met. As a result, the new building is not at optimal productivity at the beginning of the operation phase. This causes nuisance to the facility manager both in the short and long term. This long term disruption

also affects the client/ owner of the building. In order to correct and solve errors from the project phase unnecessary (repair) costs have to be made during the operation phase.

1.3 Research question

The main research question which will be answered in the report is as follows:

RQ	How can Building Information Modeling offer support in improving the transition between the project and operation phase in Dutch building projects?

In order to answer the main question, several sub-questions have been formulated. The sub-questions are as follows:

SQ1	How are current Dutch building projects organized and what is the possible role of BIM in this context?
SQ2	What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?
SQ3	How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?

1.4 Research goal

The purpose of this research is to understand the reason why the transition of information between the project and operation phase of a building project is not proceeding properly while using BIM. The study also seeks a way in which Building Information Modeling should be implemented so that it can support and prevent the flaws in information transfer during the transition between the project and operation phase.

1.5 Relevance

In this paragraph, the relevance of this research will be elaborated. First the scientific relevance will be explained (1.5.1), followed by the practical relevance (1.5.2).

1.5.1 Scientific relevance

As Eastman et al. (2011) describe, the transition from the project and operation phase is seen as a significant barrier in the building industry. The poor alignment between the supply and demand of information between the project and operation phase results in time-consuming and costly activities. If working with BIM ensures an integrated way of working (Liu et al., 2017), it should improve the transition between the project and operation phase. However, there is a lack of knowledge about why this fragmentation still occurs and how BIM should be implemented so that its potential can be realised. Research into the transition between the project and operation phase of projects where BIM is used can support the knowledge on exploiting the potential of BIM.

1.5.2 Practical relevance

As described in the research context, the building industry is known for its fragmented processes. Partly as a result of this, the transition between the project and operation phase in building projects are not proceeding properly. This ensures time consuming and costly activities that are prone to

errors and form a basis for dissatisfaction and conflicts between the contractor and the facility manager (Buijs et al., 2003; Eastman et al., 2011).

Building Information Modeling is an approach that theoretically eliminates the fragmentation in the building industry. In practice, however, it can be seen that despite the use of BIM, the building processes are still fragmented. As a result, the potential of BIM is currently nog being fully exploited. Research into what issues exist regarding the transition between the project and operation phase while using BIM is important to enable a better practical implementation of BIM. The results of this research contribute to the fulfilment of the potential of BIM.

For the facility manager, this implies that when this potential is realised, the use of BIM in the operation phase will be supported. The information needed for the operation and maintenance of the building is then available from the beginning of the operation phase. This ensures that delays and unnecessary costs for both the facility manager and the client/owner will be reduced.

1.6 Structure of research

This report is structured into three main parts: Introduction, Analysis and Conclusion (see Figure 1). The 'Introduction part' consists of two chapters. In chapter 1, the introduction of the research is given, followed by the research methodology in chapter 2. The 'Analysis part' has been divided into four chapters. The literature review is described in chapter 3. The case studies are performed in chapter 4, followed by the lessons learned in chapter 5. The synthesis is presented in chapter 6. The 'Conclusion part' thereafter consists of two chapters. The conclusion of this research is described in chapter 7. In this chapter the answer to the research question will be presented. Finally the discussion and recommendations are given in chapter 8.

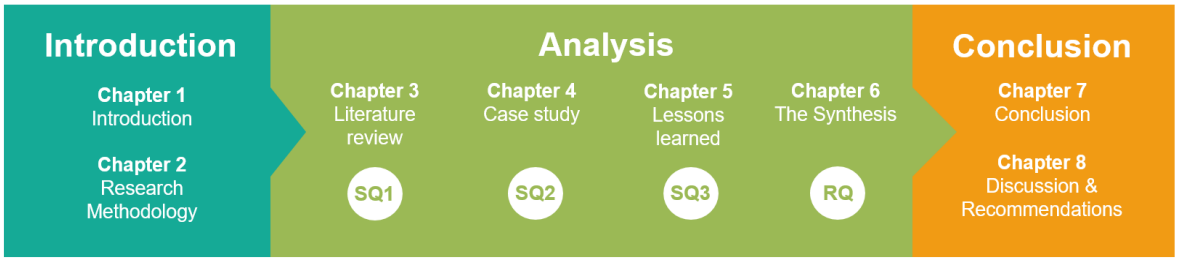

Figure 1: Structure of research

2.

RESEARCH METHODOLOGY

In this chapter, the research methodology is described. Therefore, in paragraph 2.1 the research strategy will be discussed. Thereafter, in paragraph 2.2, the scope of the study will be elaborated. The chapter will end with the presentation of the research framework in paragraph 2.3.

2.1 Research characteristics

In order to execute the research, a suitable research strategy must be chosen. Research strategies differ from each other in the way data are collected and analysed (Yin, 2009). By choosing the correct research strategy for this study the characteristics of each research strategy are compared. According to Yin (2009), the comparison is on three different levels:

Figure 2: Conditions for choosing a research strategy
Adopted from (Yin, 2009)

This research is an exploratory research in which the researcher has no control over the behavioural events. Beside transition between the project and operation phase is a contemporary event. In addition, as presented in paragraph 1.3, the research question is a "how" question. These three characteristics of this research jointly ensure that a case study research is the most suitable research strategy for this study.

The research aims to explore the implementation of BIM in the building industry and the issues and challenges that arise related to the transition between the project and operation phase. This is why the research can be characterized by a constructivist approach. This approach is known for learning and understanding the world around us through questioning and interpretation. The approach is also known as an approach for qualitative research. As this research focuses on understanding the issues involved with the implementation of BIM, it can be characterized as qualitative research (Creswell & Creswell, 2009).

In order to do so, the hierarchic method of a comparative case study will be performed. This implies that first each case will be analysed independently. A standard analysis method will be designed to ensure that all cases are analysed in the same way. Thereafter, the results of the independent analysis will be compared with each other. In this way, similarities and differences between the cases can be identified (Verschuren, Doorewaard, & Mellion, 2010). The design of the case study, which consists of defining the analysis method preparation and design of the interviews, determining of the data to be collected and defining how the data should be analysed once collected is done on the basis of the concepts of Yin (2009).

2.2 Scope of research

In this paragraph, the scope of research will be presented. This is done on the basis of the following three topics: Dutch building projects, Transition between project and operation phase and Projects with Building Information Modeling.

At first, the Dutch building projects. The selected projects for the case studies (see chapter 4) are building project executed in the Netherlands. When all the projects are initiated in the same period of time and implemented in the same country, it enables one to compare the results of the projects. In addition, the focus of this research will be on public building projects. This because the projects with BIM in the entire life cycle that can be analysed are mainly publicly initiated.

Second, the focus of this research is on the implementation of BIM with regard to the transition between the project and operation phase. During building projects several transitions between phases occur, such as between the design and project phase. In order to ensure that the results of the case studies are comparable, it was decided to focus on only one transition. Based on literature findings and explorative interviews, it was decided to narrow the scope of research to the transition between the project and operation phase.

Third, since the aim of this research is to explore the implementation of BIM, all analysed projects are projects in which Building Information Modeling was used. For the analysis of the transition between the project and operation phase, it was in addition important that at the beginning of the project, the intention was to use BIM in both the project and the operation phase.

2.3 Research framework

In this paragraph, the research framework is presented. In order to be able to answer the main research question, the research is divided into four phases. An overview of the project phases and the goal of each phase is presented in figure 3. Thereafter, an elaboration of the approach for each phase is given.

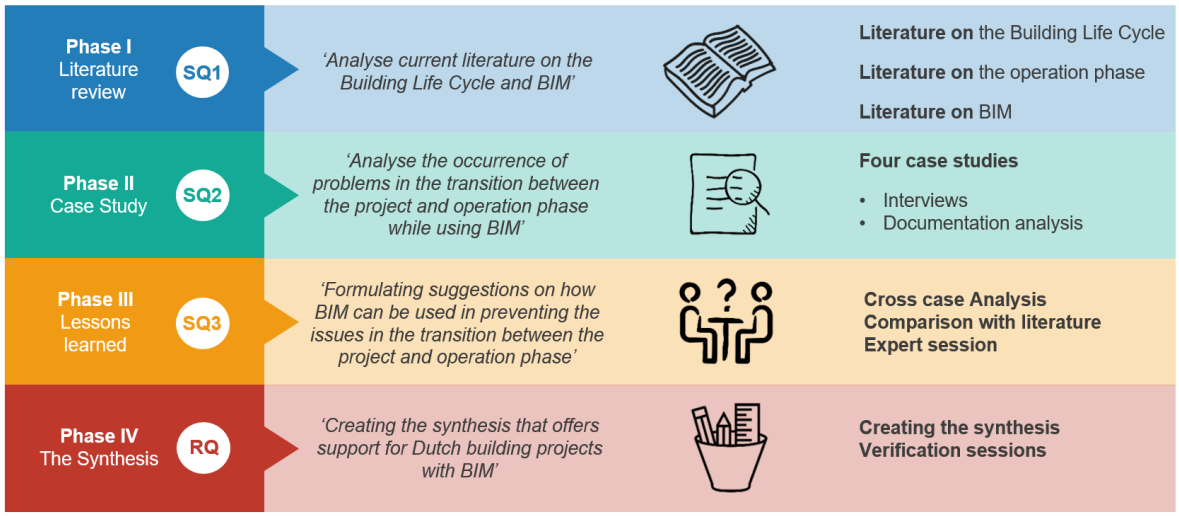

Figure 3: Research framework

Phase I

The first phase of this research is based on a literature study. On the basis of this study, inefficiencies in the building industry will be identified. In addition, the role of BIM in relation to these inefficiencies will be examined in theory.

This is done by first analysing the literature on the Building Life Cycle (BLC). By analysing the literature on the BLC, the aim is to gain insight into the structure of the building process and the information flow within the entire BLC. As a result of the scope of this study (see paragraph 2.2), special focus is given to literature about the operation phase. Both the literature on the BLC and the literature on the operation phase are used to identify the inefficiencies in the building industry that have a negative effect on the transition between the project and operation phase.

The literature on BIM will focus on the changes in the building industry that have emerged through the implementation of BIM and its potential added value. The added values that can have a positive influence on the aforementioned inefficiencies in the building industry will be examined.

Phase II

In the second phase, based on the findings from literature, case studies will be performed. Four cases are analysed in this study. In the case studies, it will be examined whether and how the potential added value in the context of the transition between the project and operation phase is also realised in practice. This involves exploring whether inefficiencies will disappear, which will continue to exist and whether new issues will arise.

The case studies will be carried out by conducting interviews with the stakeholders involved and by performing a documentation analysis. The purpose of this documentation analysis is to determine exactly what agreements have been made regarding the transition between the project and operation phase and whether and how these have been complied with in practice.

Phase III

The third phase focuses on identifying the lessons learned from the case studies and the literature study. Based on these lessons learned, suggestions on how to use BIM in such a way that the transition between the project and operation phase proceeds properly can be formulated.

In order to achieve this, first a cross case analysis is performed with the results from the case study in phase 2. The results of this analysis are thereafter compared with the findings from the literature study in phase 1. At last, an expert session is organised. The goal is aimed at identifying the reason behind certain issues that have been identified in the cross case analysis. This session makes it possible to verify the lessons learned and possibly add new ones.

Phase IV

The final phase includes the development of the synthesis. Based on the results of the literature study, the case studies and the generative session, a synthesis is generated. This synthesis provides support when it is decided on beforehand that BIM will be used in the operation phase. The lessons learned from this research provide support by providing points of attention for each phase of the project.

The synthesis is optimised on the basis of four verification sessions. These verification sessions are conducted with independent experts with regard to BIM in the transition between the project and operation phase.

3.

LITERATURE REVIEW

The aim of this study is to obtain an overview of the knowledge about the transition between the project and operation phase. This is first done through an analysis of the Building Life Cycle with specific attention to the operation phase. By analysing the literature on these subjects, inefficiencies in the building industry, which negatively influence the transition between the project and operation phase will be identified. Thereafter, the literature on Building Information Modeling is studied. This with the aim of identifying possible characteristics of BIM that could offer a solution to the inefficiencies in the building industry. The study is the basis for the continuation of this research. The following sub question will be answered in this chapter:

How are current Dutch building projects organized and what is the role of BIM in this context?

The chapter will consist of four different parts. In paragraph 3.1 an elaboration on the Building Life Cycle is given. This paragraph is followed up with an in-depth analysis of the operation phase in paragraph 3.2. In paragraph 3.3 an extensive analysis of BIM and its added value will be presented. The conclusion will be presented in paragraph 3.4.

3.1 The building life cycle

This paragraph is built up with a general description of the Building Life Cycle (3.1.1), a description of the important stakeholders (3.1.2) and an overview of the types of building organisation forms (3.1.3). Thereafter, an elaboration of the information flow throughout the entire Building Life Cycle is given (3.1.4).

3.1.1 General description

Within the literature, the project phase of a building and the subsequent operation phase are seen as two separate parts in the building industry (William East, Nisbet, & Liebich, 2012). However, the Building Life Cycle (BLC) of Heijer and Voordt (2004) combines these two phases and presents the entire life cycle of a building. In figure 4 the combination of the two phases is shown. The project phase consists of the preparation and execution of the project and the operation phase entails the management of the building and the initiation of new projects or the adjustments/ extensions of the current building.

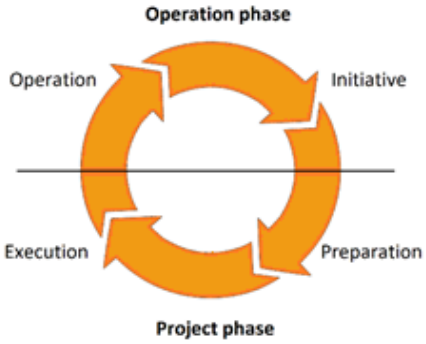

Figure 4: The Building Life Cycle
adopted from Heijer and Voordt (2004)

In order to start the project phase, the perceived or desired need for a new or more efficient building is initiated by an owner or the current/future users. In this first step of the construction project, the project preferences are defined and the necessary location information is gathered (Bennett, 2007; Winch, 2010). These preferences are the basis for the construction project and will provide an input for the design of the building, the planning and the obtaining of loans and funds for the construction. In order to be able to elaborate the preferences, the user will specify the building requirements in a specification (Wamelink, 2009). The specification document is the basis of all requirements which are essential for the design, verification and maintenance of the building (MIL-STD-961E, 2003). The initiation ends when actual programming, planning and designing starts.

In the preparation phase, the preliminary specification supports the sketch design, which then helps the user to adjust and rethink the design and make it final. With the final design and the approval of the client, the execution phase can start. During the execution phase, the general implementation plan from the preparation phase is converted to a detailed implementation plan. Thereafter the contractor can actually build the project. The budget, which is acquired in the preparation phase is used for the execution of the building assignment (Wamelink, 2009).

When a project nears completion, the emphasis is on the final delivery of the building. In order to do so, the contractor needs to carry out some specific activities. These activities can be subdivided in the closure of the construction project (the project phase) and the start of the operations (the operations phase). Closure activities are such as testing and start-up tasks, terminating supplier

contracts, the final clean up and the closing of the construction office. While the start of the operations is more focused at handing over the project documentation to the business, transferring and archiving project records and the finalization of the as-built drawings containing all changes to the original design (Bennett, 2007; Watt, 2013). These closure and start-up activities are both carried out simultaneously.

After the project is completed and handover is done, the operation phase starts. From that moment the user/ owner starts using and living in the building. The operation and management of the building are being done by a facility manager which is responsible for the continuity of the building (Construction Specifications Institute, 2011). This phase continues until new initiatives arises. They require adjustments on the current building or perhaps a completely new building. In that case, the cycle starts again.

Although the Building Life Cycle is described as a continuous process, the way in which the building projects are organised is not oriented towards this continuity. According to Eastman et al. (2011) the facility delivery process of the building industry is divided into fragments. This ensures that the continuous process as described about, does not apply in practice. As a result, the integration between the various phases in the Building Life Cycle are not proceeding properly.

3.1.2 Stakeholders in the Building Life Cycle

During the different phases of the Building Life Cycle, different stakeholders are present. In order to ensure a good transition between the various phases of the Building Life Cycle, it is important to know which stakeholders are at stake when. In addition, it is good to know who has to make choices when and how communication between the stakeholders in the different phases is organized. According to Wamelink (2009), there are nine types of stakeholders in the project phase of the Building Life Cycle:

1. *The client* – A distinction can be made between clients who occasionally have to deal with building processes (non-professional clients) and clients who more often have to deal with building processes (professional clients).
2. *The Architect* – The architect translates the requirements of the client from the specification into the drawings of the building. By using both an engineering and design approach, the architect is able to translate technical wishes into a design.
3. *Consulting firm* – Consulting firms can be involved at different stages of the building process but also by different stakeholders of the building process.
4. *Building management agencies* – These agencies perform as advisors both on the demand as on the supply side of the market. They support clients with generating specifications and guiding the building processes, but also support the executing businesses with controlling complex processes.
5. *Contractors and sub-contractors* – The contractor is responsible for the construction of the building project. They hire sub-contractors, such as installers, plasterers and plumbers to fulfil elements of the construction process.
6. *Producers and suppliers* – Contractors and sub-contractors ask producers and suppliers to supply materials that are used for the construction of the building. These materials can be raw materials, but also completely manufactured elements of the building.
7. *Broker* – A broker mediates in the purchase/ sale and rent/ rental of houses and offices. A broker is an intermediary whose main job is to facilitate between a buyer and a seller.

8. *Tenant/ user / owner* – The tenant/ user/ owner is the stakeholder who will finally move into the building. The tenant/ user can be an anonymous party, but can also be the client. If, at the beginning of the project, it is known who the user of the building will be, one can be involved in the decision making concerning the design of the building.
9. *Government* – The government can have the role of the client during the building process, but can also have a policy-making or supervisory role. The government always needs to consider the public interest and will accordingly adjust its building policy.

Wamelink (2009) only focusses on the stakeholders involved in the project phase of the Building Life Cycle. However, he does not include all stakeholders of the operation phase in his list. He does involve the tenant/ user of the building, but leaves the operation and management of the building out of his list. Nevertheless, this managing party is important for the operation and maintenance of the building and is therefore an important stakeholder in the Building Life Cycle. For this reason, a tenth stakeholder will be added to the list of Wamelink (2009) in this research:

10. *The facility manager* – The facility manager is involved in the transfer of the completed building for the owner's use. When the building is in use, the facility manager is responsible for the operation, maintenance and the continuity of the building and the people who make use of it (Construction Specifications Institute, 2011).

As described in the introduction, the building process is known on its fragmentation. This also influences the way in which stakeholders are related to each other in building projects. In these projects, each stakeholder is responsible for the deliverance of his/her phase in the project. The product, if it is the specification, the design or the building itself, will be handed over to the stakeholders in the subsequent phase, accompanied with the corresponding information,.

3.1.3 Building organisation forms

At the start of a building project, a choice is made about which form of building organisation will be used. On the basis of the chosen organisation form, the roles, responsibilities and tasks for the project are defined. Furthermore, the type of building organisation form is the foundation for the type of contract that is selected for the project.

Table 1 gives an overview of the types of building organisation forms. The organisation forms on the left side of the table are combined with the different tasks in the Building Life Cycle. For each building organisation form it is therefore determined in which phase who is responsible. As shown in the table, the construction task is the basis for examining the choice of a building organisation form. This means that the contractor is always responsible for the construction and may be given additional tasks/ responsibilities in other phases of the Building Life Cycle.

According to (Wamelink, 2009), the influence that the client wants to exert on the project is one of the most important reasons for choosing a specific building organisation form. In addition, it will be examined whether there is a separation between the project and operation phase.

Table 1: Responsibilities in building organisation forms

	Specifications	Design	Construction	Maintenance	Financing	Operation management
Build			■			
DB		■	■			
BM			■	■		
DBM		■	■	■		
DBFM		■	■	■	■	
DBFMO		■	■	■	■	■

■ Responsibility contractor ■ Responsibility client

3.1.4 Information in the Building Life Cycle

Within building projects, the exchange of information between the various stakeholders is a continuous process. According to Wamelink (2009), the management of this information is based on four aspects. It encompasses *what* information is given, *by whom*, *to whom* and at *what time*. In this research the focus will be on the transition of information between the project phase and the operation phase. In this transition (time) information is shared between the construction company and the building management team (by whom and to whom). The information is generated and provided from the project phase and which will be used in the operation phase (what).

Information flow

Figure 5 shows the information flow in traditional building processes. It is apparent that the information from the initiation phase does not flow directly to the operation phase. The information in the initiation phase, which consists of the needs of the client, is first translated into requirements in a specification. The requirements of the specification are then used for the design of the building. Before this design is build, the preliminary design is tested against the requirements of the specification. Once this has been approved, the information, this time in the form of drawings, is converted into a building (Wamelink, 2009). Eventually, the final building is tested against the design of the building. If the design of the building has been changed and/or adapted, this must be included in the drawings of the building. In this way, as-build drawings will be created. Instead of the information thus being transferred from the construction phase to the operation phase, the final design is first made up-to-date. After that it will subsequently be transferred to the operation phase.

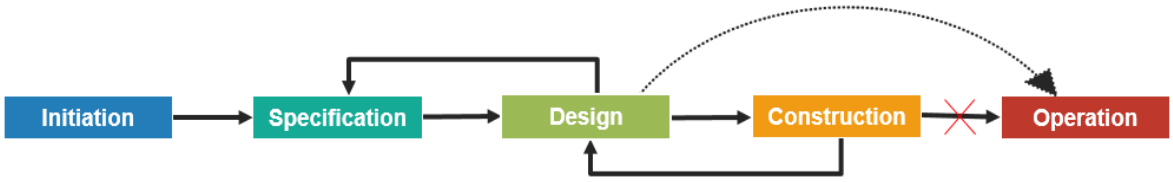

Figure 5: Information flow in Building Life Cycle

Generation of information

In addition to the way information flows through the Building Life Cycle, it is important to examine the way information is created. The information which is used in the operation phase is generated and collected during the project phase (Smith & Tardif, 2009). Figure 6 shows how all information created in the phases before the handover can be used in the operation phase. During the operation phase new information will still be created. This is because adjustments or renovations can be applied to the building (Bosch, Volker, & Koutamanis, 2015).

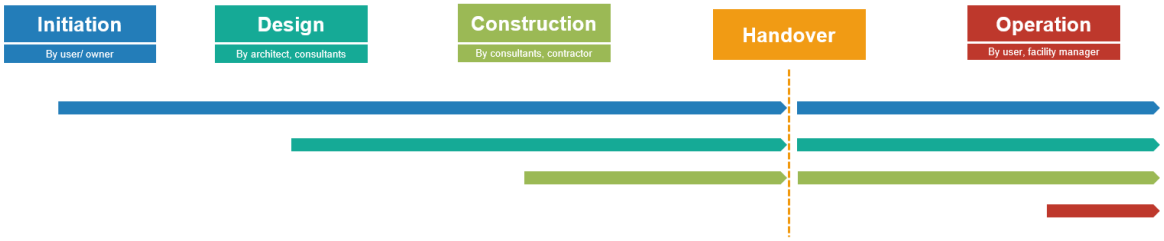

Figure 6: Information creation in Building Projects (theory)
Adopted from Bosch, Volker, and Koutamanis (2015)

It can be concluded that the information needed for the management of the building is generated from the information which has been created in the different building phases. This is also known as the supply of information. However, the transfer of information also depends on the information derived from the needs for the execution of the operation phase. This is called the demand of information. This means that in order to be able to offer good information from the project phase, the project manager must be aware of the demand of the operation management team. In this way the project and operation phase are dependent on each other.

This sounds logical, but in practice it is seen that matching the supply and demand and therefore also the direct transfer of information is not properly aligned. The transition process is seen as a significant barrier which is caused by time consuming and costly activities that are prone to errors (Eastman et al., 2011).

The information that is generated in the initiation, design and construction phase is often not or not fully used in the operation phase (Smith & Tardif, 2009; van Wassenaar & van Hulten, 2015). In figure 7 the situation in practice is shown. Instead of complete information from all previous phases, in practice it often happens that the information flow is fragmented and incomplete. As a result of the fragmented information, it is not clear in the course of the project, which choices have been made in previous phases, whether the information is up to date and if the documents are complete. These problems create friction, additional financial expenses and delays (Eastman et al., 2011). In addition, it happens in practice that the definition of supply and demand between both phases takes place late in the building process. Because of this, some decisions can no longer be adjusted and unnecessary mistakes are made.

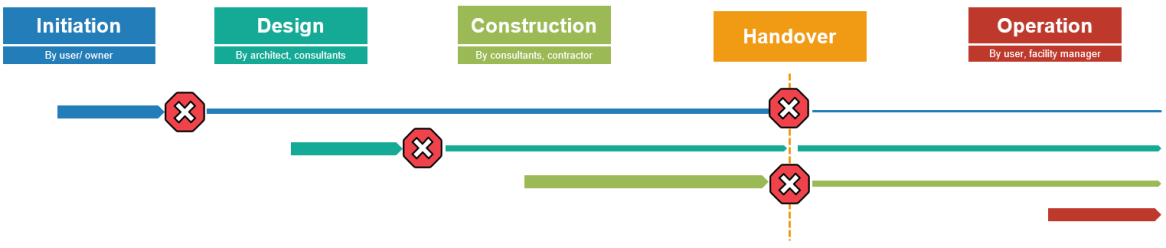

Figure 7: Fragmented information flow in building projects (practice)

3.2 The operation phase

In this paragraph, first a general description of the operation phase is given (3.2.1). Thereafter, the aspects that are important for facility management (3.2.2) and the systems that support the facility management (3.2.3) will be discussed.

3.2.1 General description

Once the building has been completed, the construction activities are finalised and commissioning will take place. The completed building will be used, maintained and managed with the project data which is obtained at the handover of the project (Wamelink, 2009). In the transition phase, the final contracts and drawings are made to generate an as-build overview. These drawings are together with all manuals transferred to the facility management team (Eastman et al., 2011).

The operations and maintenance of the building are done by the facility management team. According to the International Facility Management Association (IFMA), Facility Management is '*a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology'* ("Definition of facility Management," 2018). NEN 15221-1 (2006) adds that this integration is focused on supporting and promoting the effectiveness of the primary process of the mother organization, which is operating in the specific building.

This integration of people, places, processes and technology is not only focused on the operations phase. It includes activities from the start of the project until the operations and maintenance of the building. By taking the operation phase into account at the beginning of the project, the needs for managing a building can be integrated into the decision-making and execution of the construction (Construction Specifications Institute, 2011; Nackaerts & Janssens, 2017).

While it is known that integrating the Facility Manager in the design phase is an important aspect of the execution of the operation and maintenance of the building, the involvement of the Facility Manager in the design phase is often absent of minimal (Nackaerts & Janssens, 2017). Facility Management is seen as a post-constructive service. This again confirms the fragmentation between the project and operation phase (Meng, 2013).

In addition, at the handover of the building, it often turns out that the information which is delivered from the project phase is unstructured and incomplete. The information that is important for the facility managers in the operation phase is then divided into scattered documents such as construction specifications, warranty certificates and operation manuals (Gu & London, 2010).

The definition of Facility Management, which is stated by the IFMA, indicates that both the operations and maintenance of the building are part of Facility Management. According to NEN 15221-1 (2006), it is a product or service with an identifiable value, which supports the organization in question. This is the reason why in this study the term 'Facility Management' refers to all activities relating to the operation and maintenance of a building.

3.2.2 Aspects of facility management

According to NEN-EN-15221-1 (2006), facility management can be subdivided into two main categories:

- People and Organisation
- Space and Infrastructure

These two categories both contain specific aspects which can be related to specific activities (see figure 8). Each category and their aspects will be explained.

Figure 8: Aspects of facility management

People and Organisation

The first part of Facility Management is the category 'People and Organisation'. This category focuses on everything that supports the needs of the organisation and the people who are working for that organisation. There are many elements that are part of the People and Organisation category. Such as the indoor temperature, fire safety and personal computer support. In this research, these elements are summarized in four aspects that describe the category of People and Organisation. These four aspects are:

Safety

This aspect encompasses all the elements that are part of the safety of the people in the building. The demand for safety comprises both the protection of internal risks and the assurance of health and well-being of the people in the organization. Examples of safety elements are fire safety, prevention and occupational health services.

Security

In this research a distinction is made between safety and security. The security element focusses on everything that has to do with burglary safety. This means both the security of the building and the IT security/protection. How this security is managed and what preventive measures have been taken are part of the security element.

Indoor climate

The well-being of the people who are working in the organisation is also partly based on the indoor climate of the building. The indoor climate can be influenced by different elements such as humidity, the temperature and the way in which the ventilation is used.

ICT

The last element of the People and Organisation aspect is the ICT operations in the building. The ICT element encompasses everything that has to do with the use, the support and continuity of the ICT system. Examples of ICT elements are data and telephone network operations, personal computer support and the update of the operating systems.

Space and Infrastructure

Space and Infrastructure is the part of Facility Management that focuses on the accommodation and the infrastructure both inside and outside the building. For this category also applies that there are many different elements that are part of Space and Infrastructure. Think about car parking, but also the use of lightning and cleaning of the windows. For the purpose of this study, these elements have been summarized in four aspects that describe the category Space and Infrastructure. These four aspects are:

Technical infrastructure

The first aspect of the Space and Infrastructure is the technical infrastructure. This aspect has to do with the operation, maintenance activities and the management of the technical infrastructure. This includes elements such as maintenance of lighting, the operation and management of energy and environmental aspects and the management of utilities.

Motion

The motion aspect is a wide aspect and includes every motion within and outside the building. Improving and maintaining the movements within and around the building affects the well-being of the people utilising the building. The motion aspect therefore encompasses car park, walking routes, elevator rides, but also the availability of working space.

Cleaning

The third aspect of the Space and Infrastructure category is the cleaning aspect. People in the building have a request for hygiene, which is met by services that maintain a clean working environment. This again is not only focused on the inside of the building, but also includes outdoor space cleaning and winter services. Other elements that are part of the cleaning aspect are workplace/ machinery cleaning and cleaning and maintenance of equipment provision.

Energy

The fourth and last aspect of the Space and Infrastructure category is the energy aspect. The facility manager monitors and evaluates the energy consumption and tries to identify potential savings. This supports the compliance with environmental regulations and ensures that operating costs decrease (Construction Specifications Institute, 2011).

3.2.3 Systems that support the operation

In order to manage the before described aspects of facility management, different systems have been developed. According to Sinopoli (2010) the different software that supports the operation and management of the building can be divided into four categories (see figure 9).

Figure 9: Systems that support the operation

Facility Management Systems (FMS)

FMS is an overarching name for all systems that support the planning and execution of the facilitating processes (Sinopoli, 2010). FMS creates an integral environment between people, processes, systems and technologies which help to realise the operational, tactical and strategic goals of a facility manager ("FMIS: wat is het en wat kun je ermee?," 2018).

Building Management Systems (BMS)

Building management systems are computer-based operating systems which are used to monitor all mechanical and electrical elements in a building. In addition, the systems are used to control and support the mechanical and electrical elements in the most efficient way (AECOM, 2015). The BMS are very similar to the FMS. The main difference between the BMS and FMS is the fact that FMS is more focused on business processes, such as asset management and procurement management, while BMS is focused on the operational processes, such as the fire alarm and indoor climate systems (Sinopoli, 2010).

Energy Management Systems (EMS)

According to Sinopoli (2010) systems that relate to the EMS are systems that generate information on energy usage and the related costs. However, Darnall, Jolley, and Handfield (2008) describe the EMS not as Energy Management Systems, but as Environmental Management Systems. In this way they include not only the systems that generate information on energy usage, but see EMS as *'strategic management approaches that define how an organization will address its impacts on the natural environment'* (Darnall et al., 2008*).* The EMS can be seen as a stand-alone software module, but belongs in some cases also to the FMS or the BMS (Sinopoli, 2010).

Computerized Maintenance Management Systems (CMMS)

The fourth and last type of systems are the Computerized Maintenance Management Systems. In order to control the maintenance of a building, a clear overview of the building is required. CMMS are computer programs that support the control and analysis of the maintenance activities of a facility manager (Wireman, 1994). Just like the EMS, the CMMS can be seen as both stand-alone systems and as part of the FMS or the BMS (Sinopoli, 2010).

3.3 Building Information Modeling

In this paragraph, first a general description of Building Information Modeling will be given (3.3.1). Thereafter, the differences with the traditional way of working will be elaborated (3.3.2). This is followed by a description of the benefits of BIM and its added value for the different stakeholders in the entire Building Life Cycle (3.3.3).

3.3.1 General description

In recent years, the developments have led to a new way of working and collaborating in the building industry. This is mainly caused by the emerge of Building Information Modeling (BIM). As stated in the introduction, BIM technology is used to realise a virtual model, the building information model, of a building. This results in a detailed model of the building to be realised. The BIM model contains all information relating to the construction of the building (Eastman et al., 2011). The information that the model possesses about the construction of the building helps the organisation to integrate the information and give structure to the project (Li, Wu, Shen, Wang, & Teng, 2017).

BIM can be seen as a socio-technical system. On the one hand BIM is focused on the technical aspects, such as the 3D model of the building. This can be combined, on the other hand, with social aspects of the building process, such as process reengineering (Liu et al., 2017).

Since the early 2000's, BIM has been introduced in the construction industry. The building information model enables stakeholders throughout the Building Life Cycle to communicate with each other. The model is a central database in which all relevant information about the project is created, used, adapted and stored. BIM is aimed at integrating the information flows from various phases of the construction project. This therefore allows users to request information at any time in the project (Eastman et al., 2011).

According to ISO 29481-1 (2017), BIM is the *'use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operational processes to form a reliable basis for decisions'*. BIM is not only a tool in which a 3D model is constructed, but it also facilitates the use of digital construction data throughout the life cycle of a construction project. This creates the ability for information management and life cycle analysis (Azhar, 2011).

In order to make BIM accessible for all stakeholders in the Building Life Cycle, an international IFC-standard is created. The Industry Foundation Classes (IFC) is a neutral open file format which can be used with different software providers. In this way, all stakeholders can communicate about the same building data. All stakeholders involved can continue to work with their own software, when supported with this IFC-standard (Martens, 2008).

3.3.2 Changes in the building industry due to the introduction of BIM

With the introduction of BIM, changes in the building industry have occurred. These changes are both technically oriented as well as organisational/ process oriented. In this section the main differences between the traditional building industry and the building industry with BIM will be discussed.

Differences with traditional CAD

The development of 3D modeling in the construction industry, in the 1970s, was based on the emergence of computer-aided design (CAD) technology. By that time, this technology was already used in several other industries such as the petrochemical, automotive and shipbuilding industry. While these industries where developing manners to integrate analysis tools (basic concept of BIM), the construction industry was lagging behind in these developments and worked for a long time with the traditional 2D design (Volk, Stengel, & Schultmann, 2014).

BIM differs from the conventional 3D CAD because BIM describes a building by integrated 3D views, while 3D CAD describes a building with independent views (Azhar, Khalfan, & Maqsood, 2015; Kensek, 2014) (see figure 10). The integrated 3D model of BIM supports visualization of both the construction process and the design details. This makes it possible to review constructability issues, to discuss design decisions and to prevent potential conflicts in early stages of the process (Aksamija & Iordanova, 2010; Chan, 2014).

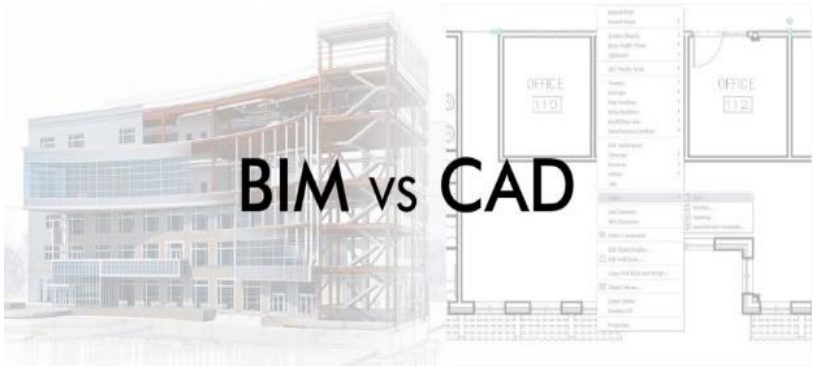

Figure 10: BIM vs. CAD
(retrieved from http://www.iceboatstudio.com)

The components that are used in the BIM model are called parametric objects. Eastman et al. (2011) describes the concept of working with parametric objects as a central concept for understanding BIM and its differences from 2D drawings.

The parametric objects are described as:

- Consisting of geometric definitions and associated data and rules.
- Geometry is integrated non-redundantly, and allows for no inconsistencies.
- Parametric rules for objects automatically modify associated geometries when inserted into a building model or when changes are made to associated objects.
- Objects can be defined at different levels of aggregation.
- Object rules can identify when a particular change violates object feasibility.
- Objects have the ability to link to or receive, broadcast or export sets of attributes to other applications and models.

Though it must be said that not all objects in a BIM model all parametric objects. When objects do not vary with the context, such as objects with a fixed dimension, the objects are called 3D object models (Panaitescu, 2014).

Differences for operation support systems

The use of a BIM model in the operation phase provides detailed information which is beneficial for the operation and maintenance of the building. Adjustments can be quickly visualized, an overview-list can be generated and information about the objects in the building can be easily retrieved.

As described in paragraph 3.3.1, an IFC-standard is used to make BIM available to all stakeholders. This IFC-standard is used with BIM in the project phase. Such an open source standard has also been developed to exchange information between the software packages used in the project phase on the one hand and the operation phase on the other. These systems are linked to the BIM model. In this way information can be used both via the BIM model as the operation support systems (Nackaerts & Janssens, 2017).

An important part of the application of BIM in the operation phase is the level of detail with which the BIM model is handed over at the end of the project phase. The model should include all information relevant to the operation phase. In general, it can be considered that the model need to be structured and coded consistently (Nackaerts & Janssens, 2017).

Differences for collaboration

According to Liao and Ai Lin Teo (2018) the implementation of new technologies or technological processes, is influenced by the people who are obliged to work with the technology. This also applies to the implementation of BIM. With the use of BIM in building projects, differences in the collaboration between the involved stakeholders emerge. The fragmentation between stakeholders and the hierarchical structure of the traditional building industry changes in a more integrated way of collaboration. This causes that with BIM tighter collaboration and closer communication among the stakeholders working in the cross-organizational projects is generated (Homayouni, Neff, & Dossick, 2010).

The tighter collaboration has several consequences for the stakeholders in the building industry. With BIM, there might be new roles in the project team, such as BIM managers and BIM modellers (Liu et al., 2017). The BIM manager has the responsibility of monitoring the different model activities of each organization. A challenge that comes with the emergence of new roles is the adaptation and change of responsibilities for the companies in the inter-organizational team. It is therefore required to establish clear roles and responsibilities at the beginning of the project (Merschbrock & Munkvold, 2015). In addition, team members must be provided with training and sufficient information to enable them to participate and contribute to the new working environment (Singh et al., 2011).

The tighter collaboration is also seen in the transparency of the building process. As presented in paragraph 3.3.1, BIM serves as a platform for the integration between the stakeholders in the whole Building Life Cycle. The BIM model becomes the common denominator, which requires insights across the stakeholders and their information during the project (Eastman et al., 2011). In this way the transparency of the building process will be increased (Babič, Podbreznik, & Rebolj, 2010). In order to achieve this transparency, it is therefore expected of the stakeholders working with BIM that they adhere to this transparency and share necessary information with other stakeholders. Close relationships, mutual trust and openness will ensure that the possible added value of BIM will be exploited (Liu et al., 2017).

In addition, it is expected that stakeholders will be involved early in the project. The involvement of stakeholders in the project phase through BIM can generate benefits by saving costs and time in terms of design, construction, building quality and communication (Ratajczak, Malacarne, Krause, & Matt, 2015). By getting involved in the early stages, stakeholders are able to support by developing and plan the construction project through BIM and optimize the efficiency of the construction and operation.

Besides the fact that with BIM tighter collaboration is required, it also has influence on the way in which is communicated during the project. BIM is a communication tool that can be used to generate, control, share and collect. The use of BIM affects the information flow throughout the Building Life Cycle and therefore the way in which stakeholders communicate (Alreshidi, Mourshed, & Rezgui, 2017). Once the client's wishes and needs have been converted into requirements in the specification, it can be added to the BIM model. From that time onwards, all information is made, updated, used and stored in the model (McArthur, 2015). This information is available to the stakeholders in the entire Building Life Cycle and does not need to be transferred directly between

the stakeholders in the different phases (Xu et al., 2014). By doing so, the information from all stakeholders is communicated via the BIM model.

The latter causes the main difference between the traditional information flow and the information flow with BIM. Because all information from the specification onwards is processed in the BIM model, the information can be controlled more easily and the risk of errors and misunderstandings is considerably reduced (Miettinen & Paavola, 2014). Thereby, organizations become aware of how their information is related to others and the whole construction project (Chen, Nunamaker, Romano, & Briggs, 2003; Phelps, 2012).

The changing information flow is also a challenging aspect of BIM. It requires new agreements about the exchange of data (Eastman et al., 2011) and, as with the increase in transparency in the building process, employees need to be willing to share information. This requires trust of the employees in the building process with BIM (Alreshidi et al., 2017).

3.3.3 Benefits of BIM

In this section the benefits of Building Information Modeling will be elaborated. On the basis of the literature research, seven main benefits are identified. The benefits are:

- Scheduling and cost estimation tool
- Increased integration and collaboration
- Continuity of information
- Visualization support
- Reduction error and rework
- Effort created in the beginning
- Improve energy efficiency and sustainability

The before mentioned benefits of BIM can all be seen as an individual benefit of BIM. However, it should be noted that the seven main benefits are interdependent at a given point in time and therefore affect each other.

Scheduling and cost estimation tool

With the introduction of BIM in the building industry, BIM-based scheduling and cost estimation software programs have also been developed. By including the time dimension to the building information model, a "4D" model is created (see figure 11). Using the scheduling function of BIM can help users to optimize the project planning in a 3D environment (Jiang, 2011). A "5D" building information model can also be generated when the cost estimation is included (Aksamija & Iordanova, 2010). With the information stored in the BIM model it is, for example, possible to automatically calculate material quantities (Lee, Kim, & Yu, 2014). This allows one to easily make a cost estimation.

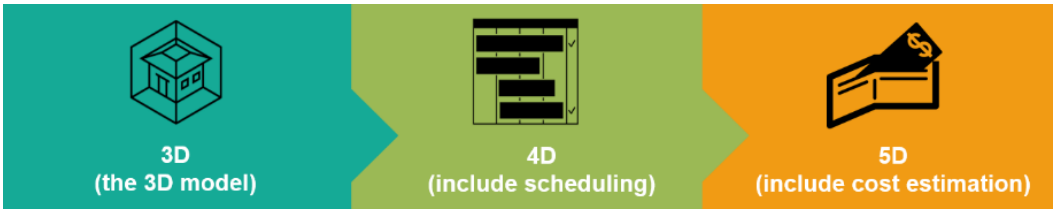

Figure 11: 3D, 4D, 5D Building Information Model

Increased integration and collaboration

Another advantage of BIM is the increased integration and collaboration. Because BIM creates an integrated platform throughout the stages of the Building Life Cycle, it gives the stakeholders the possibility to collaborate more easily. By increasing this collaboration, design mistakes will be reduced and the productivity of the construction industry will increase (Miettinen & Paavola, 2014).

Collaboration in construction projects is closely linked with the communication between the stakeholders in the project (Oraee, Hosseini, Papadonikolaki, Palliyaguru, & Arashpour, 2017). According to Zhang, Azhar and Nadeem (2017), better communication within teams will significantly limit the amount of error and rework of a model. Communication with BIM has two different purposes. The first purpose is the communication by human-to-computer and the second, more traditional purpose, is the human-to-human communication (Liu et al., 2017). Human-to-computer, also named as communication technology, is focused on how fabricators and component retailers deliver their design input, in what way reviews are coordinated and how scheduling is done (Solnosky, 2016). Human-to-human communication is despite the replacement from offline to online activities still an important element of communication. It helps with the coordination of achieving project goals, motivates practitioners and is needed when complex problems have to be discussed (Ma, Zhang, & Li, 2018). In addition, effective communication helps with understanding the needs of members within a team in order to perform their tasks (Dainty, Moore, & Murray, 2006).

Increased collaboration also positively influence the engagement between team members (Rahman, Endut, Faisol, & Paydar, 2014). Important to notice is the fact that teamwork is based on the motivation, commitment, experience, knowledge and willingness of the individual actors in the team (Alreshidi et al., 2017). These practitioner factors are mostly personal characteristics. This ensures that an organization or other members of a team can hardly influence these practitioner factors. The implementation of BIM is thus not necessarily a success. It depends partly on the motivation, commitment and willingness of the actors who will work with it.

Continuity of information

Working with BIM ensures continuity of the information flow through the Building Life Cycle (S. Zhang, Teizer, Lee, Eastman, & Venugopal, 2013). During the whole Building Life Cycle, BIM can be used for information management (Xu et al., 2014). BIM supports information management because it offers an interface, which includes all information about a building and the operational performance (McArthur, 2015). The information which is stored and maintained during the project is now useful for later use. This ability to support the facility manager with their work is seen as one of the important benefits of working with BIM (Gu & London, 2010).

Information management is, on the one hand, a selling point of BIM. The stimulation of information sharing supports the willingness to collaborate between organizations (Rahman et al., 2014). Sharing information ensures a data environment to which all organizations have access. In this way all organizations have a real-time version of the model at hand. Thereby, organizations become aware of how their information is related to others and the whole construction project (Chen et al., 2003; Phelps, 2012).

On the other hand, information management is also a challenging aspect of BIM. When a project team works with BIM a new information flow between the organizations emerges (Alreshidi et al., 2017). It requires new agreements about the exchange of data (Eastman et al., 2011) and employees need to be willing to share information, which also is combined with trust issues (Alreshidi et al.,

2017). It is, therefore, important to manage the information flows during the whole life cycle of a construction project (Xu et al., 2014).

Visualization support

A BIM model can be seen as a digital representation of a building. Working with BIM supports parametric modelling and causes a new way of spatial visualization. In addition, BIM supports the simulation of the behaviour of the building (Miettinen & Paavola, 2014). The integrated 3D model supports visualization of both the construction process and the design details. This makes it possible to review constructability issues, to discuss design decisions and to prevent potential conflicts in early stages of the process (Aksamija & Iordanova, 2010; Chan, 2014).

Reduction error and rework

Bryde et al. (2013) did research into the main project benefits of BIM. They studied 35 construction projects that used BIM and found that the main benefits of BIM were related to the cost reduction and control to the project life cycle. Azhar (2011) and Masood, Kharal, and Nasir (2014) confirm this statement. This reduction in costs is mainly due to the reduction of errors and rework.

Working with BIM ensures that the building information model will be developed in a more structured manner and that modification is possible during the project (Gu & London, 2010; Ma et al., 2018). This on the one hand is a benefit of using BIM, but on the other hand also a challenging aspect. When the updated versions of BIM are not controlled and checked properly, there is a chance that one makes adjustments in wrong documents. This negatively influences the modification process (Lin & Yang, 2018).

A positive element of the more structured manner of modification is that it reduces error and rework in a later stage of the project (Solnosky, 2016). Errors are also prevented by the model's ability to immediately and automatically check for conflicts, malfunctions or collisions (Azhar, 2011).

Effort created in the beginning

The use of BIM also changes the workflow of people working on the project (Hardin & McCool, 2015). As seen in figure 12, in the traditional way of working (black line) the most effort is put into the construction phase of the project. This while at that moment, the possibilities of adjusting elements are low (blue line) and the cost thereby, are relatively high (red line). When working with BIM, the effort lies more in the design phase of the project (green line). This makes it possible to analyse more alternatives. The costs involved in this analysis at the start of the project are relatively low (Strafaci, 2008).

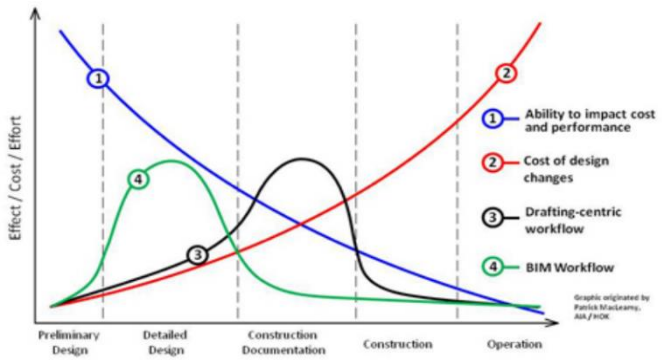

Figure 12: Effect/ Cost/ Effort in Building Life Cycle (Strafaci, 2008)

Improve energy efficiency and sustainability

According to Eastman et al. (2011) and Azhar (2011) a BIM model can also be used for energy analyses. Early in the design phase an evaluation of the future energy performance and the energy consumption of a building can be done. In this phase of the design, necessary adjustments based on the improvements of the energy performance can be done.

With the use of the traditional 2D models, the energy evaluation in an early stage of the design phase is not possible. This can only be done when the final design has been made. However, it is then almost impossible to apply modifications to the design (Eastman et al., 2011).

3.4 Conclusion

The aim of this chapter was to generate an overview of the body of knowledge about the Building Life Cycle, with special emphasis on the operation phase and Building Information Modeling. This is done by answering the following sub question:

How are current Dutch building projects organized and what is the role of BIM in this context?

Dutch building projects can be divided into different phases. These phases can be seen as individual phases in which different stakeholders are responsible for the result of that specific phase. Once a phase has been completed, the results with the associated information are transferred to the next phase of the building project. In this new phase, other stakeholder will continue with the information created.

At the end of the project phase, the facility manager receives the necessary information about the project phase from the project manager. The facility manager will use this information to carry out all activities related to the operation and maintenance of the building. These activities are people, organisation, space and infrastructure oriented and will support the organisation in the building at all times.

By analysing the literature study, several inefficiencies in the building industry, which negatively influence the transition between the project and operation phase are identified. These are:

- The facility delivery process of the building industry is divided into fragments.
- The Facility Manager is not/ hardly involved in the project phase.
- The transition process is seen as a significant barrier which is caused by time consuming and costly activities that are prone to errors.
- Information that is generated in the project phase is often incomplete or unstructured at handover.
- The definition of supply and demand between both phases takes place late in the building process.
- Design decisions can no longer be adjusted and unnecessary mistakes are made.

The literature study has shown that in theory BIM offers added value for a variety of different inefficiencies in the building industry. This also applies to the transition between the project and operation phase. Appendix II shows all the added values that have been described in the literature study. These are presented diagrammatically against the problems that arise in relation to the transition between the project and operation phase. Some added values are able to solve, theoretically, the problems and some do not apply to this case. The applicable added values

combined with the problems of the transition between the project and operation phase are shown in table 2 on the next page.

As can be seen in table 2, there are a number of inefficiencies for which BIM does not offer a functional solution. These inefficiencies relate to the organisational aspects which play a role in the implementation of BIM.

From literature, it seems that the implementation of BIM is mainly related to the functional aspects of the model and the way in which the project with BIM is organised. However, in literature, trust, openness, willingness and transparency are assumed to be the standard behaviour of the employees that work with BIM. According to Liao and Ai Lin Teo (2018), these aspects influence the success of the implementation of BIM in the building industry. Because the behaviour of employees has an influence on the organisational processes, behavioural factors will be taken into consideration as a part of the case study analysis on organisational factors.

The case study examines whether BIM in practice offers the functional solution that it purports to offer in literature. In addition, it will explore how is dealt with the organisational aspects of BIM. In this way, the results of the literature study are compared with practice. This makes it possible to determine to what extend literature is in line with practice.

Table 2: Benefits BIM combined with Inefficiencies in Building Industry

	Inefficiency in building industry	Fragmentation between project and operation phase	Transition consist of time consuming and costly activities.	Missing information at handover.	Unstructured information at handover.	Facility Manager is not/ hardly involved in project phase	Operation phase not included in design.	Definition of supply and demand takes place late in project	Unnecessary mistakes in the design are made.
Benefit of BIM	Source	(Eastman et al., 2011)	(Eastman et al., 2011)	(Gu & London, 2010)	(Gu & London, 2010)	(Meng, 2013)	(Meng, 2013)	(Eastman et al., 2011)	(Eastman et al., 2011)
Design mistakes will be reduced.	(Miettinen & Paavola, 2014)								**X**
Integration of information and documentation.	(Xu et al., 2014; S. Zhang et al., 2013)	**X**	**X**	**X**	**X**				
There is one central information source	(Chen et al., 2003; McArthur, 2015; Phelps, 2012)	**X**	**X**	**X**					
Organizations become aware of how their information is related to others.	(Chen et al., 2003; Phelps, 2012)	**X**					**X**		
Check whether all information is added to the model.	(Azhar, 2011)		**X**	**X**					
Less data gets lost.	(Azhar, 2011)		**X**	**X**					
Review constructability issues.	(Aksamija & Iordanova, 2010; Chan, 2014)								**X**
Discuss design decisions.	(Aksamija & Iordanova, 2010; Chan, 2014)						**X**		**X**
Building will be developed in a more structured manner.	(Solnosky, 2016)		**X**		**X**				
Adjustments can be easily done.	(Azhar, 2011; Eastman et al., 2011)								**X**

4.

CASE STUDIES

In this chapter, the results of a case studies conducted with four building projects will be discussed. On the basis of the results from the literature study, this case study will examine whether the implementation of BIM offers the functional and organisational solution that BIM purports to offer in literature. In this way, it is explored whether inefficiencies will disappear, which will continue to exist and whether new issues arise. The sub question which will be answered in this chapter is:

What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?

In order to do so, first the case study approach is elaborated in paragraph 4.1. Thereafter, in paragraph 4.2, a description of the general case study results is given. This is followed by a presentation of the results of each case and a cross case analysis in paragraph 4.3 t/m 4.7 In paragraph 4.8 the conclusions are drawn.

4.1 Case study approach

In this paragraph an elaboration of the case study approach is given. This first starts with the goal of the case study (4.1.1), followed by the case selection criteria (4.1.2). Thereafter, the data retrieving approach is presented (4.1.3). The paragraph will end with a description of the interview set up (4.1.4).

4.1.1 Goal

The goal of the case studies is to explore how the transition phase is organized in practice when one makes use of BIM. By doing so it is hoped to identify the problems and challenges that arise during the transition phase with BIM. The identification of the problems and challenges will be the basis for finding possible solutions that improve the use of BIM in building projects.

4.1.2 Case selection criteria

The cases are selected on the basis of the following criteria:

1. Dutch building projects
2. Finished projects
3. Projects with BIM
4. Public organizations
5. Different types of organization forms

Dutch building projects

As described in the scope (chapter 2) this research focuses on Dutch Building projects. Therefore, it is important that the cases, which will be analysed during the case study, are also Dutch Building projects. With a Dutch building project is a project meant that has been carried out on the basis of Dutch building legislation and regulations.

Finished projects

In order to be able to analyse the transition phase it is important that the full transition between the project and operation phase took place. In this way the effects of activities, before and during the transition phase, on the operation phase can be discussed. In addition, it is important that the interviewee did experienced the entire transition phase themselves. Projects in which the facility manager did not experience this phase or were no longer available in the project are considered unsuitable.

Projects with BIM

In order to analyse the effect of BIM on the transition between the project and operation phase, it is important that BIM is used in all cases. In addition, it is important that the BIM model has been sufficient for the project phase. If this is not the situation, the case is not considered relevant for this research into the transition between the project and operation phase while using BIM.

Public organizations

In the scope definition, it is defined that the project has a public perspective. This is because the projects with BIM in the entire life cycle that can be analysed for this study are mainly publicly initiated. Therefore, this case study only focuses on projects that are publicly initiated.

Different types of organization forms

The projects that are selected for the case study are all based on different organizational forms. In this way it hoped that as many as possible facets of problems, causes and consequences are included in the study.

4.1.3 Data retrieving approach

As shown in the conclusion of the literature study (paragraph 3.4), there are a number of ways in which BIM offers added value for solving the problems in the transition between the project and operation phase. In addition, there are a number of organisational aspects that influence the implementation of BIM in the building industry. The functional and organisational aspects of BIM will be the two main pillars of the case study. There should be noticed that behavioural factors will be taken into consideration as a part of the case study analysis of organisational factors.

The two aspects are subdivided into five topics. For each topic, based on the literature study and the explorative interviews, several indicators are identified. With the analysis of the 'type of information', the aim is to determine if the information has been delivered in one source. By doing so, the fragmentation between the project and operation phase will be reduced, time consuming activities during the transition will be reduces and there would be no missing information. In order to verify this, the 'suitability of information' is examined to ensure that no information was actually missing. In addition, it is examined whether no unnecessary design mistakes were made and a standard information structure has been used. In this way, it is analysed whether the information was of sufficient quality for the operation phase. Furthermore, it is examined when the 'aspects for the operation phase were defined', and when the 'facility manager was involved' in the project. These two topics, together with the division of 'roles and responsibilities' are seen as organisational aspects. This latter topic examines whether and how agreements about the transition between the project and operation phase were made and if these were complied with.

The interview questions are based on these indicators. The topics in combination with their indicators for the case study are shown in table 3.

Table 3: Case study topics and indicators

		Topic	Indicators
Functional	1	Type of information	• Information is delivered in one source.
	2	Suitability of information	• Information at handover is sufficient for the operation phase. • No missing information at the handover. • A standard documentation structure has been used.
Organisational	3	Definition of aspects for operation phase	• Definition of aspects for the operation phase is at the beginning of the project.
	4	Involvement Facility Manager	• The Facility Manager has been involved from the start of the project.
	5	Roles and responsibilities	• Agreements have been made on the organisation of the transition between the project and operation phase. • The agreements have been complied with.

4.1.4 Interview set up

The interviews which are conducted are recorded and transcribed as approved by the interviewees. The transcripts of these interviews can be obtained on request. The interviews had a semi-structured character and were structured as follows:

The sequence of the aspects that were discussed during the interviews is based on backwards reasoning. This means that the interview started with questions about how the current operation and maintenance of a specific building is organized. In this phase, questions about the operation and maintenance aspects of literature (paragraph 3.2.2) and how they are defined in practice were asked.

Thereafter the interview questions went back in time. First questions about the provision of information on the operation and maintenance aspects were asked. These questions were focused on the supply of information and whether the provided information was suitable for the operation phase. The last phase of the interview was about the involvement of the facility manager in the project phase and the agreements which were made on how the transition phase was organized.

The reason for the backwards reasoning strategy, which is used in the interviews, was to keep focused on the operation and maintenance aspect that are discussed in the first phase of the interview. By focussing on these aspects it is assured that no availability bias on the events happened in the transition phase occurred. The full interview guideline is shown in appendix III.

In order to be able to analyse and compare the results of the interviews, the transcript of each interview is coded in excel. By doing so, patterns can be found in the results of the cases and one is able to compare the cases with each other (Clifford, French, & Valentine, 2010). The coded interviews and the coded cross case analysis can be found in appendix IV.

4.2 General case study results

In this paragraph the general information about the case study is presented. First, in paragraph 5.2.1, an outline of the static characteristics of the cases is given. Second, in paragraph 5.2.2, an overview of the interviewees and used documentation is presented.

4.2.1 Selected cases

In table 4, an overview of the static characteristics of the cases is shown. In the table the name of the client is not shown, because this will directly lead to the specific case. Therefore the type of client as described by Wamelink (2009) is shown. Because of the fact that for all clients it applies that the project was a one-off project, all clients are seen as non-professional clients. With the ‘facility manager’ heading is not the specific facility management company meant. However, it is shown which party is responsible for the operation and management of the building. In case 1 and 4 it therefore holds that the facility management of the building is internally taken care of.

As can be seen in table 4, the cases meet the requirement that they all must have different organizational forms. In case 1 it should be mentioned that the interviewee preferred not to mention the project type. However, it can be mentioned that the contract type was an integrated contract.

Table 4: Static description of cases

	Case 1	Case 2	Case 3	Case 4
Client	Non-prof.	Non-prof.	Non-prof.	Non-prof.
Contractor	VolkerWessels	Heijmans	Heijmans	BAM
Facility manager	Internally	Rjiksvastgoedbedrijf	Rijksvastgoedbedrijf	Internally
Organization form	Design Build	Build Maintain	DBFMO	Build
Contract type	-	UAV 2012	DBFMO	UAV 2012
Size (m2)	56000	19000	1500	18000

As described in the case selection criteria (paragraph 5.1.2), BIM is used in all cases. However, it should be noted that in addition to the BIM model, a document management system (DMS) was used in all cases. A DMS is an external system that users use in for the exchange of all documentation of the project between the different stakeholders (Hajmiragha, 2001). The information in the DMS is not separated from the BIM model, but is linked. In this way, the important information for the model is from the DMS attached to the BIM model.

4.2.2 Retrieved data

For the analysis of the cases, four interviews were conducted and 28 documents were analysed (see table 5 and table 6). The information emerged from the interviews is confirmed with the documentation available for the cases. An evaluation of the data obtained data can be found in paragraph V.

In this report, no names of the cases, interviewees and documents will be included. As seen in table 6 and table 7, the cases are ranked from one to four and each interviewee and document got its own code. In the results of the case study, reference is made to these codes. In table 6, the function and years of experience of each interviewee are also shown. The complete analysis in which the results of the interviews are combined with the documentation analysis is presented in appendix V.

Table 6: Interviewees per case

	Function	Years exp.	Code
Case 1	Facility Manager Engineer	>15	FM.C1
Case 2	Head Facility Management	>20	FM.C2
Case 3	Customer Manager	>20	FM.C3
Case 4	Manager Real Estate Operation and Services	>15	FM.C4

Table 5: Documents per case

Case	Type	Document name	Code
1	Certificate	Take over certificate – As-Built Documentation	D1.1
	Contract	PM for Transition - Annex	D1.2
	Protocol	Project Information Protocol	D1.3
	Contract	Engineering and Construction contract	D1.4
	Letter	Proposal BIM model – a final	D1.5
	Manual	Project manual – version 3	D1.6
	Report	Works Information	D1.7
2	Contract	BM contract – New premises 'project name'	D2.1
	Tender instructions	Aanbestedingsleidraad Build Maintain New premises 'project name'	D2.2
	Presentation	'Project name' – IM maintain	D2.3
	Evaluation report	'Project name' Evaluation	D2.4
	Letter	Opdracht Ibis4Projects 'project name'	D2.5
	Evaluation report	Management review directievoering contractbeheersing 'project name'	D2.6
	Report	Deelbestek process	D2.7
3	Contract	DBFMO overeenkomst	D3.1
	Report	Outputspecificatie – Algemeen	D3.2
	Report	BIM plan	D3.3
	Report	Definitief Plan 6 (Best and Final offer)	D3.4
	Report	Voortgangsrapportage 08-2014/09-2014	D3.5
	Report	Activiteit Beheer en onderhoud	D3.6
	Evaluation report	Memo evaluatie 'project name'	D3.7
4	Progress report	BIM overleg januari 2015	D4.1
	Specification	Programma van Eisen 'project name'	D4.2
	Contract	Aannemingsovereenkomst	D4.3
	Report	Oplevering- en overdrachtsprocedure 'project name'	D4.4
	Report	SHE assessment 'project name'	D4.5
	Excel file	Checklist overdracht beheerder	D4.6
	Report	Project Informatie protocol	D4.7

4.3 Results case I

The first case is an office building with room for over 1200 employees. The company, which is housed in the building is a large international company. For the operation and maintenance of the building, both the technical infrastructure and the safety of the building are of great importance. These aspects are seen as main aspects because they guarantee the continuity of the company in the building at all times.

4.3.1 Stream of events

In 2009 the decision was made to build a new office building. The construction works started three years later in 2012 (see figure 13).

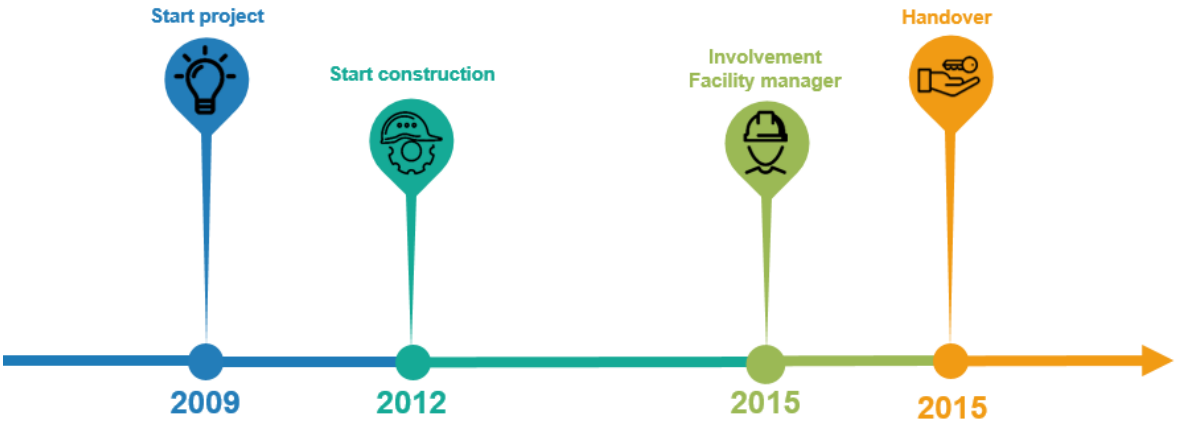

Figure 13: Stream of events case 1

Before moving to their current premises, the company was located in a different building. In order to be able to deliver the new building and at the same time ensure that the current activities continue to run smoothly, it was decided to hire an external team. Because of the large size and the complexity of the project, the project management team was involved from the initiation phase up to and including the transition phase.

This temporary project team was responsible for the project management of the new building. In addition to managing the construction activities of the new building, they were also responsible for considering how the facility management would be set up. By incorporating the temporary project management team partly into the organization, it was ensured that both the construction and operation phase were involved in the process. Therefore, the transition between the two different phases and the way in which they could be integrated had to be considered.

4.3.2 Results

Type of information

A separate document management system is used in this project. In this system, the documentation was kept during the project and finally delivered as one as-build dossier (FM.C1; D1.7; D1.1).

Suitability of information

According to the Works Information, the as-built dossier had to contain the BIM model with the as-built information (drawings and text) and all the dossiers (D1.7). However, the at the handover many documentation and data was missing (FM.C1; D1.1). In addition, the standards for drawings and documentation, as discussed in the beginning of the project, were not met (FM.C1; D1.3).

The owner of a specific document was held responsible for the structure and coding of that document, but this was not sufficiently maintained throughout the project (D1.3). This made it almost impossible to find a drawing or a document when it is needed (FM.C1).

Definition of aspects for operation phase

Almost one year before finishing the construction phase, the planning of the transition between the project and operation phase started. This planning contained also the definition of aspects for the operation phase (FM.C1).

Involvement of the facility manager

The facility manager was involved in making decisions on the design, engineering and construction works (FMC.1). Thereby, during the design phase, consideration was given to general aspects of the operation phase, such as ICT and security (D1.6). These aspects were incorporated into the final design (D1.7).

Roles and responsibilities

In the contract it was agreed that BIM would be used for the entire life cycle and that a separate document management system was to be used for the sharing of documentation between different stakeholders (D1.4).

According to the contractor, the agreements on the delivery of documentation and information in the transition between the project and operation phase were met (D1.1). Although the facility manager described that the standards as discussed were not in the as-built dossier, but in the BIM model only (FM.C1).

Furthermore, during the transition it turned out that the model was not suitable for the operation phase. A specialized BIM company was hired to make, together with the facility management team, the BIM model ready for the operation (FM.C1; D1,2).

4.3.3 Findings case I

Various findings can be deduced from the results of the analysis. The main findings of case I are as follows:

- Many documents and data were missing
- Not all documentation was delivered on time, but the information that was provided was sufficient for the operation phase.
- The company had to hire an external team to prepare and adjust the BIM model for the use in the operation phase.
- Agreements on the structure of documentation and drawings were not met. Caused by:
    - Components had different names in the BIM model.
    - Drawings in the as-built dossiers had different names
- Owner of a document was responsible for a proper structure of the document.
- The facility manager is involved from the design phase.

4.4 Results case II

The building which was built in case 2 is an office building for around 400 employees. Business continuity is for the facility manager the main priority. When one translates business continuity into operation and maintenance aspects, well-organized motion, the technical infrastructure and the security of the building are in this case seen as the main priority for the facility manager.

4.4.1 Stream of events

The start of the project was in 2014 and after the design period Heijmans (the contractor) started the construction in 2015. Before that time the facility manager of the building was already involved in the project (see figure 14). This was partly because of the contract. A separate partnership (in Dutch: VOF) was set up to carry out the project. In addition, organisation form was Build Maintain with a maintenance period of at least 15 years. In the contact is stated that the contractor is next to the regular maintenance also responsible for the replacement of (technical) elements in the building.

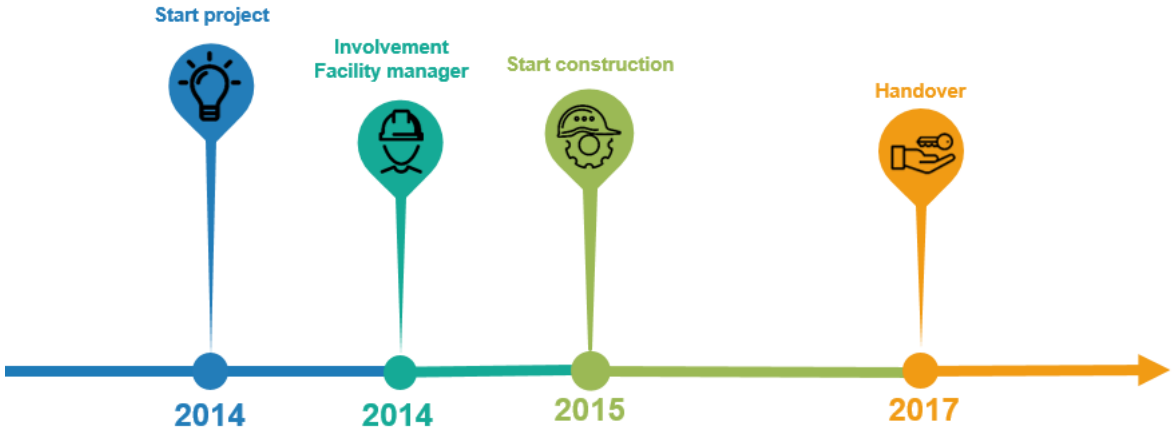

Figure 14: Stream of events case 2

4.4.2 Results

Type of information

An external document management system was used to manage and share documentation of the project. Herein a revision dossier in which all aspects the building can be found. This is presented in a very detailed and structured way (FM.C2; D2.5).

Suitability of information

One of the main positive elements of the projects was the structure in which information and documentation were kept and finally delivered (FM.C2). At the beginning of the project, the coding of documents and the detail level was determined (D2.3). As a result, at handover, each document had the same structure and a clear overview of the location of each document was made (FM.C2).

It must be said, that not all the documentation was present in the revision dossier at handover. However, according to the facility manager, the information and documentation was at handover more than sufficient for the use in the operation phase (FM.C2; D2.6).

Definition of aspects for operation phase

From the beginning of the project, consideration was given to the aspects for the operation phase (FM.C2; D2.1). Het Rijksvastgoedbedrijf was asked to show some reference buildings to the facility management team. In this way the team was able to speak with other facility managers and learn from their experiences.

Despite these actions, the facility manager appointed that the design phase was one of the parts of the projects where improvements could have been achieved. The translation from the aspects of the operation phase in the final design was insufficient (FM.C2; D2.3).

Involvement of the facility manager

The facility manager has been an integral part of the development and design of this project (FM.C2; D2.7). In addition, it was decided at the beginning of the project that is was desirable to take the application of BIM in combination with a building management system (BMS) into account (D2.7). With this, the operation phase included in the project from the beginning.

Roles and responsibilities

The contract required the contractor to organise the transition between the project and the operation phase (D2.1). At the beginning of the project, clear agreements were made about this transition and nine months before handover the actual transition phase started. The transition phase was achieved in the same way as it was stated in the contract (FM.C2; D2.1; D2.2).

At the beginning of the project, there was a lack of clarity between the different stakeholders of the project and operation phase about each other's needs. Despite the fact that agreements were made, it was not self-evident that one was aware of each other's needs. This caused friction between the various parties. When this happened, everyone was put together around the table and discussed with each other about their needs and expectations. This supported the alignment between the various stakeholders (FM.C2).

4.4.3 Findings case II

Various findings can be deduced from the results of the analysis. The main findings of case II are as follows:

- Information was handed over in one as-built dossier. Dossier did not include all the information, but the information was sufficient for it to be used in the operation phase.
- The contract required a transition phase to be set up.
- Agreements on the transition phase have been complied with.
- The facility manager was involved from the beginning of the project.
- The specific operation and maintenance aspects were clear at the beginning of the project, but are not sufficiently included in the design.

4.5 Results case III

The project in case 3 is the building of a museum in the Netherlands. The management and operation of the building, therefore, have specific requirements. Indoor climate is for this building one of the main aspects. This is because it can very easily negatively influence the pieces in the museum. In addition, recovery times of the technical systems are very important. This causes the fact that a well-organized technical infrastructure is also seen as one of the main aspect of the operation and maintenance of the building.

4.5.1 Stream of events

Heijmans, the contractor, has two different branches within the company. Both a team that specializes on the project phase and a team the focuses on the operation phase of the building life cycle. For the DBFMO contract, in which the contractor had to bind to an operational phase of at least 25 years, Heijmans was therefore seen as suitable contractor.

However, the fact that one party had to carry out both the project and operation phase did not mean that the transition between these two phases was well organized. As seen in figure 15, the facility management team was involved in the project only six months before the handover. In these six months the building had to be verified by the facility manager in order to make it suitable for the operation phase.

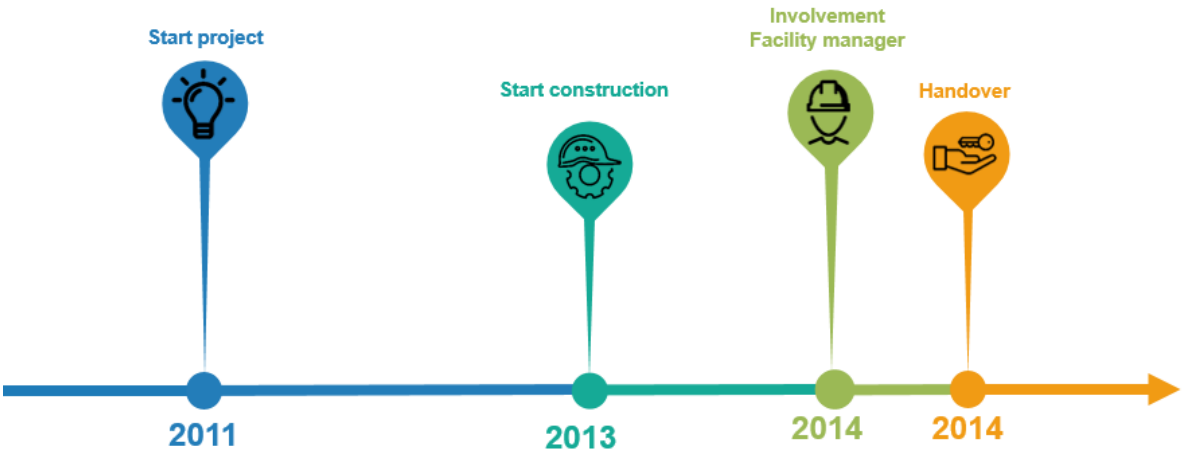

Figure 15: Stream of events case 3

4.5.2 Results

Type of information

At the beginning of the project, there was decided by the contractor to use the BIM model as a basis for both the project and operation phase (D3.3). Eventually, the BIM model was only used in the project phase. In Relatics, all 2D drawings and construction calculations were delivered (FM.C3).

Suitability of information

The BIM model, which was created, was sufficient for the design and construction of the building, but did not met the requirements for the operation phase (FM.C3). This was mainly because the BIM model was not kept up to date during the construction phase.

According to the output specification, all documents had to be structured and easily retrievable at handover. Thereby, was the contractor obliged to maintain an overview of all documentation location (D3.2). However, at handover, it turned out that the structure of the documentation was sufficient,

but the structure of documentation names and codes were missing (FM.C3; D3.5). This makes it still impossible to find documents when it is needed (FM.C3). In addition, it was discovered that not all documentation was available after the handover (FM.C3; D3.7).

Definition of aspects for operation phase

The contractor did already identify the general aspects of the operation phase, such as security, fire safety and motion, in the project tender (D3.4). The specific activities for the operation and maintenance of the building were identified one year before completion (FM.C3; D3.6).

Involvement of the facility manager

The facility manager was involved from the design phase of the project, but there was insufficient focus on jointly selecting/ generating design solutions (D3.7; D3.3). Partly because of this, many design flaws were made. The facility management team had to adjust these mistakes at het beginning of the operation phase at their costs (FM.C3).

After the involvement in the design phase, the facility manager was not involved in the project any longer, until six months before the handover. Because of the fact that one had decided to discontinue the BIM model, the facility management team had to check whether what was agreed in the contract and design phase also was delivered (FM.C3).

Roles and responsibilities

In the contract, no agreements were made on the transition between the project and operation phase (D.33). Heijmans, the contractor, decided by themselves to execute both the project and operation phase with BIM. As described before, the BIM model was discontinued six months before the handover. By doing so, their agreements on the handover of documentation and information were automatically not met. In addition, at handover a hard cut arose in responsibilities. The employees who were responsible for the project phase left the project completely from the moment the handover took place. This despite the fact that some tasks had not yet been carried out and information was still missing for the operation phase (FM.C3).

During the construction phase, several decisions were made with regard to the cost-cutting of several elements in the building. One did not reflect on the effects these decisions had on the operation phase. This ensured that the costs in the construction phase were reduced. However, it negatively influences the activities in the operation phase (FM.C3).

4.5.3 Findings case III

Various findings can be deduced from the results of the analysis. The main findings of case III are as follows:

- BIM was initiated for the entire life cycle, but it has been stopped 6 months before the handover. Because of this:
    - Agreements on how information was transferred were not met.
    - Handover documentation was insufficient for the operation phase.
- Contractor was obliged to keep documents easily retrievable, but at handover names and codes were missing.
- Aspects for the operation and maintenance were identified in the project tender (logistic-, fire safety- and security- plan).
- Facility manager was involved in the design phase, but there was insufficient focus on jointly selecting/ generating design solutions. As a result, design flaws have been made that negatively influence the operation phase.

4.6 Results case IV

The fourth case is about the building of a Dutch university campus building. Preferences for the operation phase were taken into account in both the design and construction of the building. These preferences were mainly focussed on the most important aspects of the operation and maintenance of the campus building. For this building these main aspects where safety, security, and motion in the building. This is mainly caused by the number of persons in the building on a daily basis and the fact that there are also research areas in the campus building.

4.6.1 Stream of events

The project of case IV started in 2013 and is part of a larger project where several more buildings will be and have been built. The construction started in 2015 and was executed by BAM. From the moment the design of the building started, the facility manager was included in the project (see figure 16).

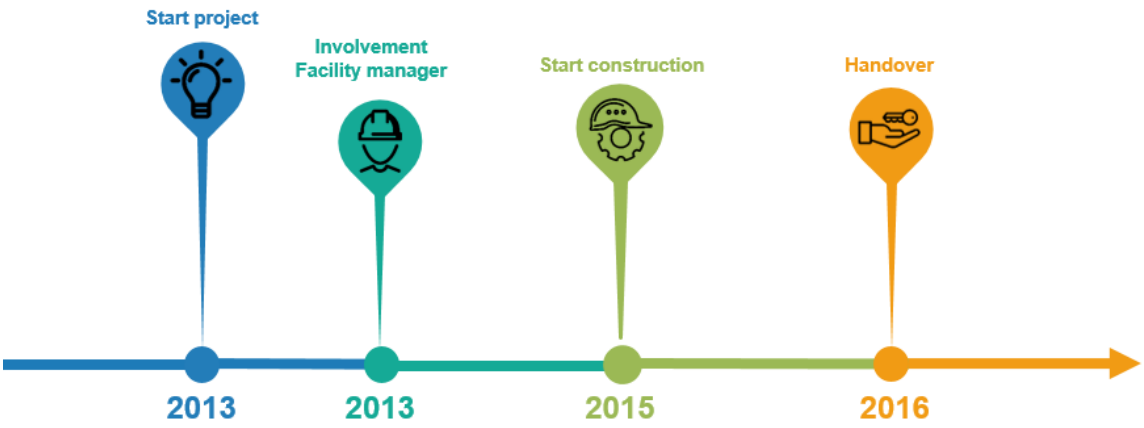

Figure 16: Stream of events case 4

4.6.2 Results

Type of information

At the start of the project, it was decided to use BIM only for the project phase (FM.C4). An external document management system was thereby used to manage the information an documentation between the various stakeholders (D4.3).

Suitability of information

In the project information protocol a description of the structure of how the documentation had to be structured was given. It also contained the requirements for the documentation names and codes (D4.7). However, at handover, the structure and naming of documentation were insufficiently maintained (FM.C4). In addition, many documents were missing at handover. Now, 1.5 years after the handover, still not all documents are available (FM.C4; D4.6).

Definition of aspects for operation phase

The general aspects of the operation phase were defined early in the project (D4.2). The specification did include design requirements, such as logistic routes and catering facilities, which were related to the operation phase. The specific aspects were determined late in the project. This was not possible until the facility management team was in possession of the asset list (FM.C4).

Involvement of the facility manager

The facility management team in the project of case 4 is a team that focuses on the operation and maintenance of this and the other buildings of an overarching project. Because of the fact that the team often has to deal with the commissioning of a new building, and therefore the design of the transition phase, they have the ability to evaluate and improve this process (FM.C4).

The facility management team was intensively involved in the design of the building (D4.5). This involvement was established from the lessons that were learned from previous projects. Both with the preparation of the specifications and with the drawings of the design of the building, the facility management team was asked about their opinion and possible adjustments. In this way design flaws that1 could have had a negative effect on the operation and maintenance were prevented (FM.C4).

Roles and responsibilities

On the basis of previous projects, the facility management team has created a document that states what information is needed when in the project. Some documents need to be delivered six months before the handover, others at handover and again others may be delivered six months after handover (FM.C4; D4.4). At the beginning of this project the document was reviewed and signed by the contractor (BAM) of this project (D4.1).

Despite these agreements, the supply of information did not go well during the transition phase and beyond. A lot of documentation was handed over without structure, naming, with different formats and not at the agreed moment in time. There were no real consequences for the contractor for the non-/late delivery of information (FM.C4).

4.6.3 Findings case IV

Various findings can be deduced from the results of the analysis. The main findings of case IV are as follows:

- A standard structure of documentation was required, but at handover documents were without a naming, with different formats and incomplete.
- There were no consequences for the non-/late delivery of information.
- Facility manager was involved from the design phase of the project.
- In the contract requirements for the transition were made, but the agreements were not adhered to.

4.7 Conclusion

In this paragraph the conclusions of the case study conducted for this research are presented. With the case study it was aimed to identify the issues and challenges that arise during the transition between the project and operation phase in the building life cycle. In this chapter the following sub question will be answered:

What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?

In order to be able to identify the issues that are related to the transition between the project and operation phase, four case studies are performed. In each case, several findings are determined. An overview of the identified issues and challenges is presented in table 7.

Table 7: Findings case studies

Case	Findings

Case I	• Many documents and data were missing
	• Not all documentation was delivered on time, but the information that was provided was sufficient for the operation phase.
	• The company had to hire an external team to prepare and adjust the BIM model for the use in the operation phase.
	• Agreements on the structure of documentation and drawings were not met. Caused by:
	  ○ Components had different names in the BIM model.
	  ○ Drawings in the as-built dossiers had different names
	• Owner of a document was responsible for proper structure of the document.
	• The facility manager is involved from the design phase.

Case II	• Information was handed over in one as-built dossier. Dossier did not include all the information, but the information was sufficient for it to be used in the operation phase. • The contract required a transition phase to be set up. • Agreements on the transition phase have been complied with. • The facility manager was involved from the beginning of the project. • The specific operation and maintenance aspects were clear at the beginning of the project, but are not sufficiently included in the design.

Case III	• BIM was initiated for the entire life cycle but it has been stopped 6 months before the handover. Because of this:
	  ○ Agreements on how information was transferred were not met.
	  ○ Handover documentation was insufficient for the operation phase.
	• Contractor was obliged to keep documents easily retrievable, but at handover names and codes were missing.
	• Aspects for the operation and maintenance were identified in the project tender (logistic-, fire safety- and security-plan).
	• Facility manager was involved in the design phase, but there was insufficient focus on jointly selecting/ generating design solutions. As a result, design flaws have been made that negatively influence the operation phase.

Case IV	• A standard structure of documentation was required, but at handover documents were without a naming, with different formats and incomplete. • There were no consequences on the non-/late delivery of information. • Facility manager was involved from the design phase of the project. • In the contract requirements for the transition were made, but the agreements were not adhered to.

In chapter 5, these issues will be discussed by means of a cross case analysis. The results of this analysis will be compared with the findings from the literature study and subsequently used an input for the synthesis. In addition, the findings are used in the generative session. The purpose of this session is to explore how BIM could have provided support and which organisational actions are needed to prevent the identified issues of table 7.

5.

LESSONS LEARNED

The literature study and case studies together provided the opportunity to compare the literature on BIM with the practical implementation of BIM in Dutch building projects. In order to draw lessons from the analysis, this chapter discusses the results from the research carried out. For this purpose, first a cross-case analysis will be carried out in paragraph 5.1. Hereby, the results will be compared with the findings from the literature study. Thereafter, a generative session was held to explore how BIM could have provided support and what organisational actions are needed to prevent the identified issues from the case studies. In paragraph 5.2, the results of the generative session are presented.

By performing the cross-case analysis and the generative session, the following sub question will be answered:

How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?

5.1. Cross case analysis

In this paragraph, the cross-case observation of the four cases is presented (5.1.1). By doing so the observations of the cases can be classified and compared. In appendix IV, the coded overview of the cross-cases analysis is shown. Thereafter, the results of the cross case analysis will be compared with the results of the literature study (5.1.2), followed by an elaboration of the lessons learned from the cross case analysis (5.1.3).

5.1.1 The results

The results of the cross case analysis have been, in the same way as the design of the case study, divided into the following two main pillars:

- Functional issues
- Organisational issues

In the cross case analysis, the overlapping issues of the cases have been identified. The functional issues involve issues relating to the functional outcome of BIM. These are the issues that are linked to the BIM model at handover. The organisational issues concern the issues relating to the process and the people as well as their behaviour with regard to BIM. The issues of both categories are presented in figure 17.

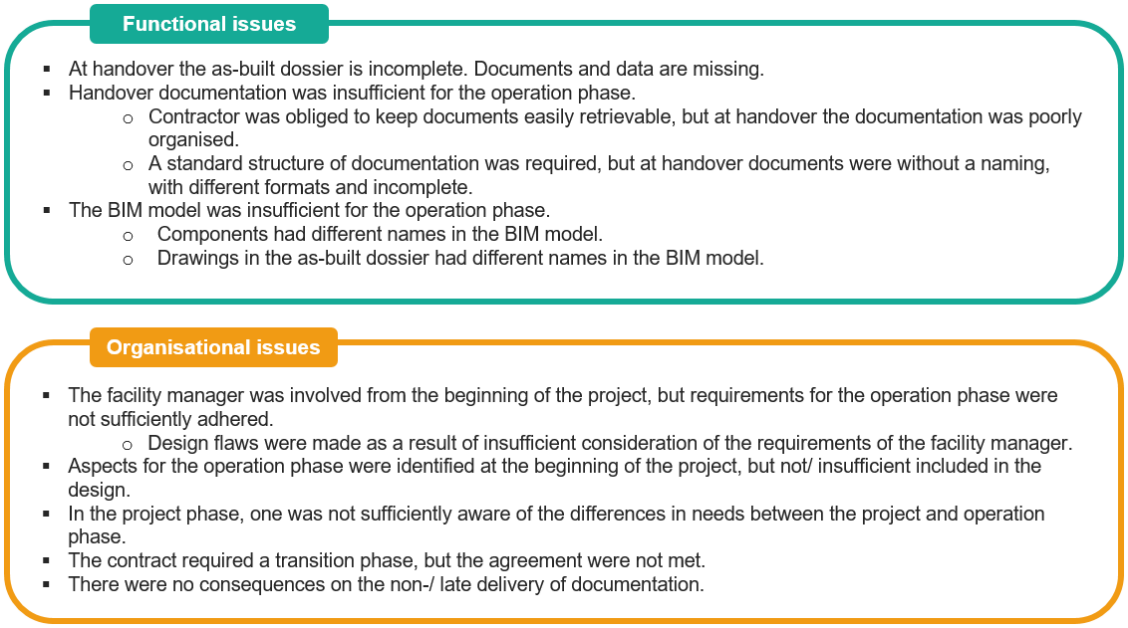

Figure 17: Functional and organisational issues

5.1.2 Comparison with literature

In this section, the issues that have emerged from the cross case analysis are compared with the results from the literature study. This involves examining which similarities and differences can be found between literature and practice. The comparison will be performed for both the functional and organisational issues.

Functional issues

When one is working with BIM a central information source is used during the project. This ensures the integration of information and documentation. According to Xu et al. (2014), S. Zhang et al. (2013), Chen et al. (2003), McArthur (2015) and Phelps (2012), this will result in no missing information about the project phase at handover. However, in all four cases at the handover information was missing despite the use of BIM. According to Eastman et al. (2011), it is important that if one does not want to

miss out on information at handover, new agreements about the exchange of data should be made. In case 3 and case 4 it became clear that these agreements were made, but not complied with during the project. It transpires here that, as Alreshidi et al. (2017) said, some employees do not want to share their information which could possibly have to do with trust issues. Ultimately, this could cause that at handover information still misses despite the use of BIM.

The cross case analysis also revealed that both the documentation and the BIM model itself were unstructured in several cases. In case 1 and case 3, the BIM model itself was insufficient for the operation phase. For these two cases, this was due to the fact that components in the model had different names and were the drawing in the as-built file had different names than in the BIM model. This contradicts with the expectations which emerged from the literature study. According to Solnosky (2016), with BIM the building will be developed in a more structured manner which should prevent the issue of an unstructured model. As Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018)Lin and Yang (2018) describe, the unstructured way of working may have occurred because the model was not properly checked and controlled during the process. Both in case 1 and case 3 this was indeed the situation. FM.C3, concluded that it did not happen because of incapacity or unwillingness of the employees, but because of time pressure during the project phase.

What is not mentioned in the literature study as an added value of BIM, is the way in which BIM offers support to the organisation of documentation. From the cross case analysis, it emerged that this is even seen as an issue related to the use of BIM. In cases 1,3 and 4, at handover the documentation was not clearly organised and easily retrievable.

Organisational issues

Because with BIM an integrated platform throughout the stages of the Building Life Cycle is generated, collaboration between the stakeholders will be increased. According to Miettinen and Paavola (2014), the increased collaboration ensures that design mistakes will be reduced. Besides, Nackaerts and Janssens (2017) describes that the integration of stakeholders in the decision-making and design phase enables requirements for the operation phase to be easily integrated. From the case study it emerged that in practice, despite the use of BIM, this described situation will not always be achieved. In all cases the facility manager was involved from the beginning of the project. However, in case 2 and case 3 not all the requirements of the facility manager were incorporated in the design. This resulted in design flaws that negatively influenced the work of the facility manager in the operation phase.

According to Merschbrock and Munkvold (2015), this may be related to the fact that in addition to the increased collaboration, there is also a change in roles in the project team. A challenge that comes with the emerge of new roles is the adaption and change of responsibilities in the inter-organisational teams. In case 3, the identification of the new roles and responsibilities was insufficiently done. According to FM.C3 this was one of the main issues of the project. However, in case 2, the roles and responsibilities were clearly established and the facility manager was involved in the design phase. Although this situation design mistakes were still made.

Another reason for the insufficient consideration of the requirements of the facility manager is the fact that in the project phase, one was not sufficiently aware of the differences in needs between the project and operation phase. As was the situation in cases 1,2 and 4. This while Chen et al. (2003) and Phelps (2012) describes that when one works with BIM organisations become more aware of how their information is related to others and the whole construction project.

In the literature study nothing is indicated about the organisation of the transition between het project and the operation phase. However, it is recommended from the case studies to make the organisation of the transition mandated in the contract. Despite this obligation, it can be seen in cases 1,2 and 4 that these agreements are not always (fully) complied with. It is therefore recommended to consider the possible consequences of the non-/ late delivery of documentation in the contract.

5.1.3 Lessons learned cross-case analysis

The following lessons have been learned from the cross case analysis and the subsequent comparison with the literature:

With BIM…

- … the ideal situation is that at handover no information on the project phase is missing. However, this is despite the use of BIM still an issue. It could possibly has to do with the fact that stakeholders are not willing to share their information.
- … the building will be developed in a more structured manner. In this way components are correctly specified and information, which will cause that at handover the model is of sufficient quality for the operation phase. Nevertheless, it still occurs that components in de BIM model have different names and documentation names differ.
- … it is ideal that documentation is at sufficient quality at handover. This means that it is easily retrievable and a standard structure is used. Nevertheless, it still happens that at handover information and documentation is unstructured, incomplete and therefore insufficient for the operation phase.

When one wants to work with BIM in the operation phase…

- … one should involve the facility manager early in the project and include the necessary requirements for the operation phase into account in the design. However, in practice it occurs that despite the fact that the facility manager is included early in the project, the required specifications were not always translated in the design.
- … it is important that one is aware of the differences in needs between the project and operation phase. In practice, it still occurs that these differences are unclear, which can cause that the project and operation phase are not in conformity with one another.
- … it is recommended that the organisation of the transition phase is made compulsory in the contract. In practice, however, it appears that this agreements is not being complied with. It is therefore advisable to consider possible consequences of the non-/ late delivery of documentation in the contract.

5.2 The generative session

In this paragraph, the results of the generative session will be presented. For this purpose, a comparison will first be made between the issues presented and the ideal situation (5.2.1). Hereafter the approach of the generative session will be explained (5.2.2), followed by a presentation of the results (5.2.3). The paragraph will end with an elaboration on the lessons learned from the generative session (5.2.4).

5.2.1 The ideal situation

In paragraph 5.1.1, functional and organisational issues were identified that hinder the transition between the project and operation phase while using BIM. Based on the comparison with literature in paragraph 5.1.2, for each issue and ideal situation from literature could be identified. In the generative session, the ideal situations are verified by the experts. An overview of the issues combined with the ideal situations is presented in figure 18.

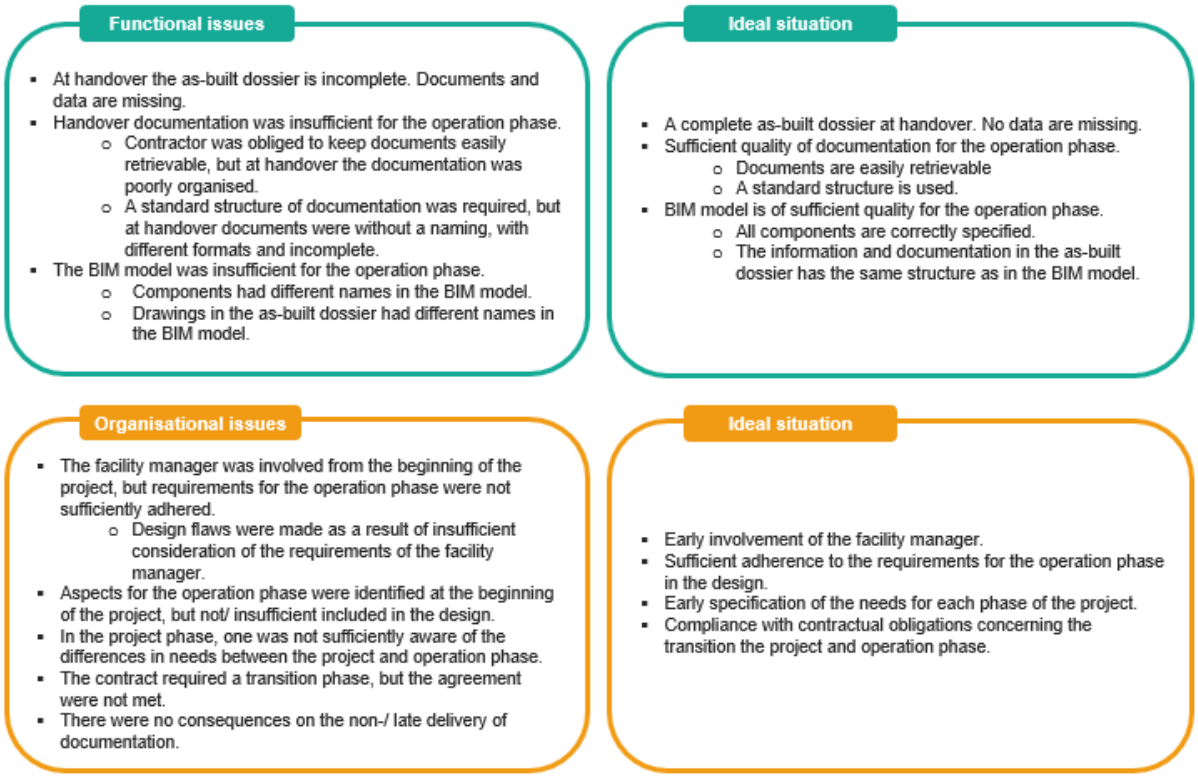

Figure 18: Issues combined with ideal situation

From the overview of the ideal situations for the functional and organisational issues, it can be concluded that the ideal situation of the organisational issues can be achieved by modifying the behaviour or actions of the people involved in the project. Achieving the ideal situation of the functional issues is more complex. Behind these issues, the technical challenges of BIM may be hidden or organisational issues may (re)-appear.

In order to find out how BIM should provide support for achieving the ideal situation of the functional issues and which organisational aspects are related to this, a generative session was set up. In this session, the functional ideal situations were presented to experts and possible solutions were generated.

5.2.2 Approach generative session

In this section the approach for the generative session will be elaborated. First the goal of the generative session will be presented, thereafter the design of the session will be explained.

Goal

For every issue that emerged from the case study, an ideal situation is identified. However, at this moment, a gap exists between the issues and the ideal situation (see figure 19). The goal of this generative session is to explore how BIM should support in achieving this ideal situation and which organisational actions must be present. The participants in the session will examine whether BIM can offer support in realising the ideal situation and, if so, how this can be implemented in practice.

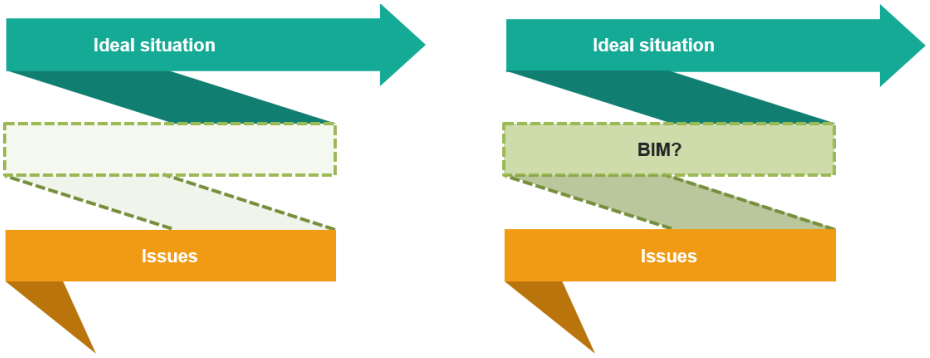

Figure 19: From issue to ideal situation

Design generative session

The basis for the generative session are the ideal situations which are presented in paragraph 5.1. The generative session is conducted with three senior consultants from Brink Groep. For each ideal situation, the three questions, as presented in figure 20, are asked. The first question is a closed question. This question was asked in order to verify whether the problem referred to is actually a functional issue of BIM. Thereafter, it was examined which competencies of BIM should offer support in achieving the ideal situation and how this should be implemented in practice. With this latter question, the focus has been placed on possible behavioural actions.

An overview of the participants and the program of the generative session is presented in appendix VI.

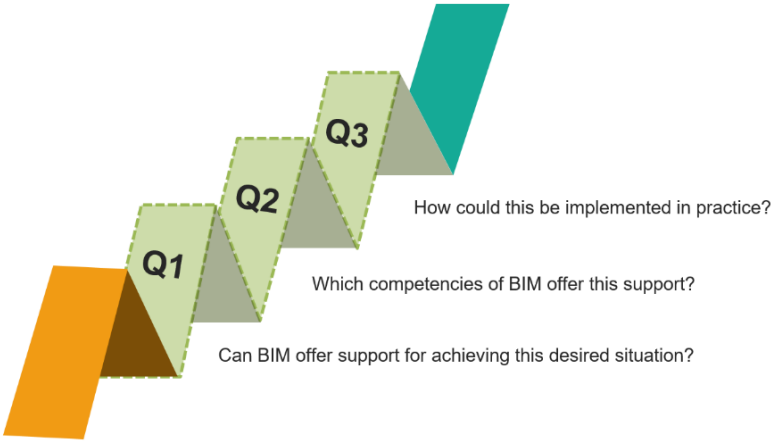

Figure 20: Overview questions generative session

5.2.3 The results

In the generative session, the focus is on the functional ideal situations defined in paragraph 5.1. The ideal situations are:

- A complete as-built dossier at handover. No data are missing.
- Sufficient quality of documentation for the operation phase.
    - Documents are easily retrievable
    - A standard structure is used.
- BIM model is of sufficient quality for the operation phase.
    - All components are correctly specified.
    - The information and documentation in the as-built dossier has the same structure as in the BIM model.

In this paragraph a description of the competencies of BIM that should support in achieving the ideal situation will be presented. In addition, the session also focussed on the practical implementation and the behavioural actions. These two elements will be discussed per ideal situation.

A complete as-built dossier at handover. No data are missing.

Working with BIM ensures that data is object oriented (Eastman et al., 2011). The experts appoint this as one of the main features of BIM that support with the prevention of missing data. Because BIM is object oriented, information about each object in a model can be directly linked to that specific object. This object then can easily be compared with same or similar objects. This allows one to quickly check whether all necessary information has been added to the objects in the model. For example, with BIM it is possible to look at the fire resistance of walls within the model and check whether all necessary information is added to all different walls.

Another element that helps avoid missing data at handover, is the continuity of information. With the continuity of information is meant that in the whole Building Life Cycle information about the building and the operation performance is accessible (McArthur, 2015). In addition, all information is stored in one model which ensures that less data is lost. These two aspects together position BIM as a solution for the missing data at handover.

As described by Gu and London (2010), it often turns out at handover that information, which is delivered from the project phase, is missing. BIM should offer a solution for this issue, but as shown in the case study, with BIM it still happens that data is missing at handover. For that purpose, the experts describe an important condition that must be fulfilled to ensure that the as-built dossier is actually complete at handover. The experts said:

- For the practical implementation it is important to keep track changes and correct information from the beginning. BIM does make it easier to prevent that data is missing, but there is a great responsibility for the users.
- The ideal situation can be achieved with good communication and clear agreements about the level of detail of information that is linked to the objects in the model.
- Within a project, one should together create policies on how to manage the information, keep it up-to date and about how to keep the information complete during the project.

Sufficient quality of documentation for the operation phase.

According to Miettinen and Paavola (2014), BIM is an integrated platform that supports throughout the whole Building Life Cycle. This means that all information is centralized and information can be retrieved more easily. In addition, BIM can support the collaboration between stakeholders and design mistake may thus be reduced. In the generative session, it was agreed that increased integration helps to create high-quality documentation. In practice, this integration mainly ensures that the development of documentation is structured. Because it is easier to process the information with BIM in a more structured way, this may also positively influence the quality of documentation at handover. In addition, with BIM it is easy to see whether the right and sufficient information is coupled to all objects. In this way working with BIM supports the development of documentation and its quality.

The second area in which BIM supports the quality of the documentation is the way in which the quality of documentation can be tested. This has once more to do with the fact that all information is integrated and collected in one model. Besides, the visualisation support also ensures that testing of the documentation becomes easier. This is because BIM supports parametric modeling and causes a new way of spatial visualisation (Miettinen & Paavola, 2014). In the generative session it emerged that in practice BIM causes that one no longer has to check drawings and documentation with a red pen. BIM ensures that the documentation can be easily viewed and that one is able to look at the connection between different disciplines and spaces.

Despite the fact that BIM should support the quality of documentation, the case study shows that the quality of documentation is at handover often insufficient for the operation phase. To this end, the experts have identified the following practical requirements:

- In order to ensure the sufficient quality of documentation at handover, experts recommended that it is necessary to define the level of detail of the BIM model and the information of its components. This definition then needs to be included in the BIM protocol at the beginning of the project. By doing so, a basis will be created with which the documentation can be built and at handover being tested.
- Another practical requirement for ensuring the quality of documentation, according to the experts, is the definition of the needs for the operation and maintenance of the building. By doing so, and the agreements are consistently executed, the BIM model will be ready for use in the operation phase at handover.

BIM model is of sufficient quality for the operation phase

As was shown in the case study, it occurs that at handover the BIM model is not suitable for the use in the operation phase. As a result, it was decided whether to convert the BIM model at the end of the project phase and make it suitable for the operation phase of the quit the whole BIM model. However, the BIM model is presented as a life cycle model which from the project phase would be immediately ready for the operation phase.

According to the experts, this is also possible. The BIM model ensures that instead of separate 2D drawings there is a model that integrates the entire building. This ensures that the right information can easily be extracted from the model during the operation phase. There is also a better overview of how a component relates to the other components in the model. This allows the facility manager to carry out a clash detection when new modifications are made to the building.

The experts agreed on the fact that the achievement of this ideal situation lies mainly in the agreement made regarding the BIM model. This results in the following actions:

- It is important to define at the beginning of the project what the BIM model must comply with before it can be used in the operation phase. This prevents that at the end of the project phase the model still needs to be converted for the use in the operation phase.
- In addition, it is important that the information is kept up-to-date during the project. Agreements about how this will be assured during the project and what the consequences will be if this is not properly carried out are important for the success of the project.
- As a last aspect, it is important that agreements are made about the structure of information in both the BIM and the separate as-built file. Naming and structure of the documentation are of great importance for the use of the model in the operation phase.

5.2.4 Lessons learned generative session

The following lessons have been learned from the generative session:

When one wants to work with BIM in the operation phase, …

- … it is important to keep track changes and correct information in both the as-built dossier and the BIM model from the beginning of the project.
- … good communication and clear agreements about the level of detail of information that is linked to the objects in the BIM model are recommended.
- … one should create policies on how to manage the information, keep it up-to date and … it is advised to define at the beginning of the project what the BIM model must comply with before it can be used in the operation phase.
- … Agreements must be made about the structure of information in both the BIM and the separate as-built file.

5.3 Conclusion

The aim of this chapter was to explore how BIM should support in achieving this ideal situation and which behavioural actions must be present. This is done by answering the following sub question:

How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?

From the cross case analysis and the generative session several lessons learned have emerged. The lessons learned can be seen as points of attention, which are important when one decides to work with BIM in the operation phase. The points of attention can be divided into two categories. There are points of attention of the general use with BIM in de building industry and points of attention that specifically affect the transition between the project and operation phase. It should be noted, however, that the general points of attention for BIM will also positively influence the transition between the project and operation phase. The points of attention are as follows:

When one wants to work with BIM…

- … agreements must be made about the structure of information in both the BIM and the separate as-built file.
- … good communication and clear agreements about the level of detail of information that is linked to the objects in the BIM model are recommended.

- … one should create policies on how to manage the information, keep it up-to date and about how to keep the information complete during the project.
- … it is important to keep track changes and correct information in both the as-built dossier and the BIM model from the beginning of the project.

When one wants to work with BIM in the operation phase, ….

- … one should involve the facility manager early in the project and include the necessary requirements for the operation phase into account in the design.
- … it is important that one is aware of the differences in needs between the project and operation phase.
- … it is recommended that the organisation of the transition phase is made compulsory in the contract.
- … it is advised to define at the beginning of the project what the BIM model must comply with before it can be used in the operation phase.

The identified points of attention will be the input for the synthesis in the next chapter. The synthesis will combine all findings from the literature study, the case studies and their lessons learned. When one wants to work with BIM in the operation phase, the synthesis provides an overview of the building process with all important points of attention per project phase, that have emerged from this research.

6.

THE SYNTHESIS

In this chapter, the synthesis is presented. The synthesis combines all the findings from the various phases of this research. These form an overview of the most important point of attention for building projects in which one will make use of BIM in the operation phase. For this purpose, first a description will be given on the synthesis input (6.1), thereafter the goal will be presented (6.2), followed by the presentation of the synthesis (6.3).

6.1 Synthesis input

The literature study, case studies and generative session provided insights into the aspects which are important during building projects with BIM. These aspects influence the way in which the transition between the project and the operation phase. The literature provides a strong basis on how BIM in theory can support the inefficiencies that occur in relation to the transition between the project and operation phase. The empirical research subsequently provided the basis for the comparison between literature and practice. With the results of the various cases, a cross-cases analysis is carried out. This section of the study has identified issues that cause that the potential of BIM, as described in literature, may not be realised in practice. These issues are both functional and organisational related. Thereafter, the generative session provided insight into how BIM could have been used so that the functional issues of the case study could have been prevented. This part both identified organisational as behavioural points of attention. The lessons learned from the difference research phases form the basis for the synthesis. In order to create an overview of the points of attention in the building process with BIM, the synthesis is visualized in figure 21. The synthesis has been critically analysed and complemented by an expert validation. The consultations also included the translation of the points of attention into practical implementation. The elaboration of this expert consultation is presented in appendix VII.

6.2 Goal

The goal of this research is to understand what the reason is behind the fact that the transition between the project and operation phase is still fragmented despite the use of BIM. The issues that have arisen in this study provide input for point of attention in the various phases of the building project. The aim of the synthesis is to generate an overview of the building phases and the main points of attention that need to be taken into account in order to hand over a BIM that is suitable for the operation phase.

6.3 The synthesis

The visualisation of the synthesis is shown in figure 21 on the next page. The figure is divided into three parts, both horizontally and vertically.

Horizontally, the Building Life Cycle is divided into three phases. First, there is the initiation phase, which includes all the activities before the design is made. Second, there is the project phase. As described in paragraph 2.2, the transition between the design and construction phase falls outside the scope of this research, it was decided to merge these two phases in the figure under the project phase. The third and final phase is the operational phase. Vertically, the project phase is a 3-level review of the project phases. The first, the input and output of each phase are displayed. Subsequently, the process steps in each process phase are presented. These process steps include actions for the client, contractor of the facility manager. Lastly, for each process step and each stakeholder, points of attention are described that emerged from this study.

A more detailed explanation of the various process steps, whit input/output and points of attention, are given after the presentation of the figure.

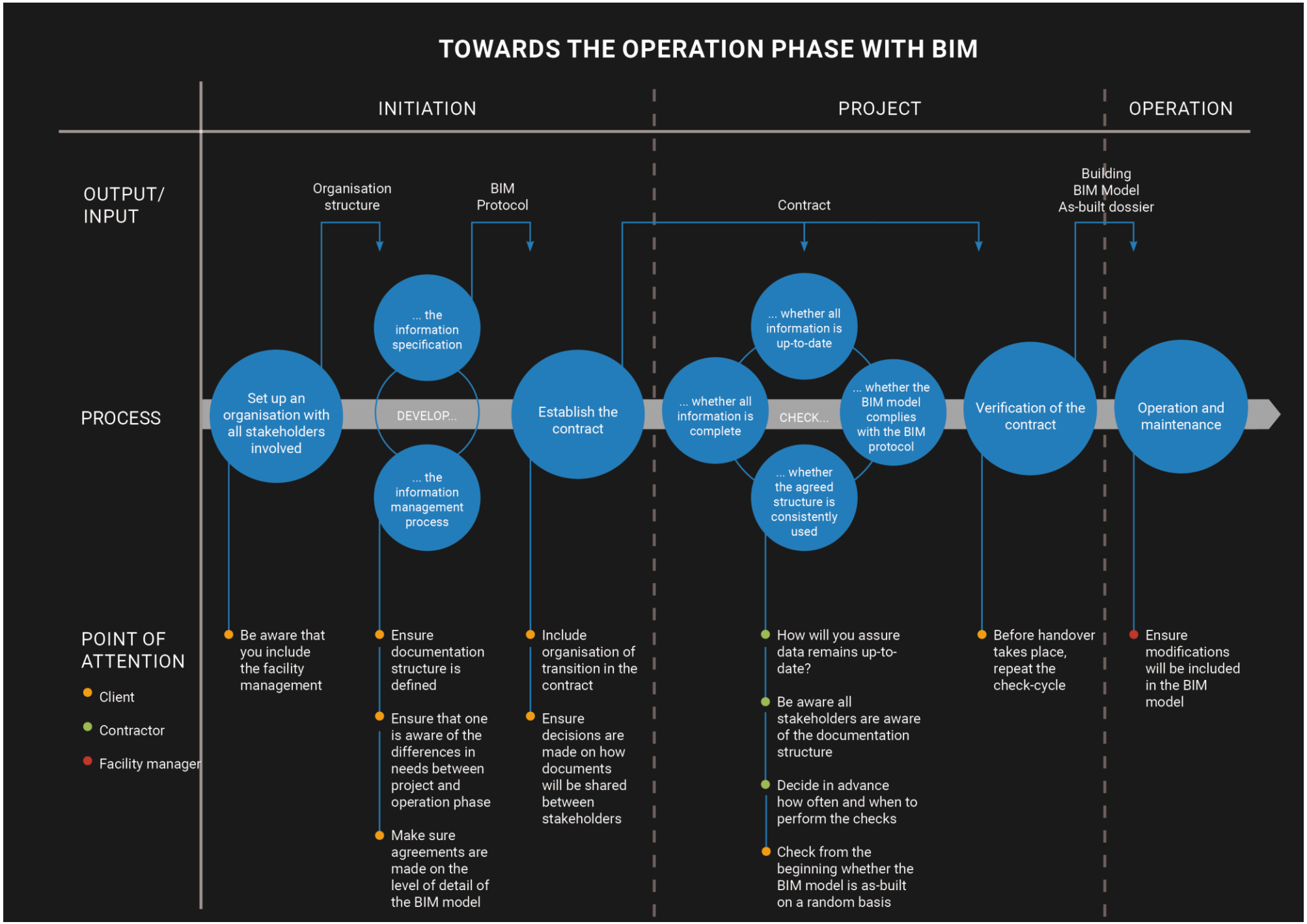

Figure 21: The Synthesis

PHASE I – THE INITIATION

In the initiation phase, the development of the three documents is central. The organisation structure, the BIM protocol, which consists of an information specification and an information management process, and the contract. The organisational structure is used as input for the BIM protocol, which then is added as a section in the contract. The client is responsible in this phase. He or she must consider whether BIM will be used in the operation phase. When this is decided, the following points of attention are important in the initiation:

1. *Be aware that the facility manager is included in the organisation structure.*

By including the facility manager in the organisation structure, a connection is made between the project and operation phase from the beginning of the project.

2. *Ensure that one is aware of the differences in needs between the project and operation phase*.

The physical involvement of stakeholders from different phases of the building life cycle is important to ensure that people are aware of their differences in needs. By defining each stakeholder's needs it is possible to determine what should be required of the BIM model in terms of function and level of detail of the objects in the model. Another advantage of sharing each other's needs is that it creates mutual understanding. It ensures that people can better understand the choices of each other. To facilitate this, it is necessary to organise sessions with involved stakeholders at an early stage of the project.

3. *Ensure that a documentation structure for the BIM model is defined in the BIM protocol.*

In order to ensure that documentation is easily retrievable and that an overview of all documentation can be created, it is important that a documentation structure is agreed at the beginning of the project. This structure must be laid down in the BIM protocol.

4. *Make sure agreements are made on the level of detail of the BIM model in the BIM protocol.*

A part of the information needs of the facility manager is the level of detail in which the objects in the BIM model must be delivered. For the construction phase a different level of detail is needed than for the operation phase. For example, in the construction phase it is not important what the life span of a specific lamp is. However, for the operation phase this information is important. For this reason it is important that agreements are made about the level of detail in the BIM protocol.

5. *Include the organisation of the transition between the project and operation phase in the contract.*

A client should stimulate that the transition between the project and operation phase is thoroughly organised. In order to achieve this, the organisation of the transition must be included in the contract. This ensures that the contractor is obliged to establish a plan on how the transition is going to be organised. This will strengthen the connection between the project and operation phase.

6. *Ensure that in the contract decisions are made on how documents will be shared between stakeholders.*

At the start of the project, it must be laid down in the contract of documentation is shared. This is connected to the structure in which documentation is built and the associated coding of documents.

PHASE II – THE PROJECT

For the project phase, the input of the contract, including the organisational structure and the BIM protocol, is of great importance. Based on these documents, the design will be made, the BIM model will be set up, the building will be built and eventually the verification will take place. In order to ensure that the requirements in the contract are met during the project, it is important that the contractor continuously checks whether the information generated is complete, whether the agreed structure is used consistently and whether the data is up to date.

It is the responsibility of the client to check whether the BIM model complies with the BIM protocol during the project. This will include requirements on how the information ultimately be delivered. In order to prevent problems from being identified just before handover, it is recommended to perform this check several times during the project phase. Both the BIM protocol and the contract should be verified before real handover takes place.

The following points of attention are important for the project phase:

7. *Create a strategy on how it will be assured that the data in the BIM model and the as-built dossier remains up-to-date.*

In order to ensure that the as-built dossier remains up-to-date, one should create a strategy on how this will be assured. It is thereby important that a strategy is made, which is feasible and can be checked over the entire course of the project. The responsibility for defining this strategy lies with the contractor.

8. *Be aware that all stakeholders are aware of the documentation structure.*

If the documentation structure is only laid down in the BIM protocol, there is a high chance that not all stakeholders are aware of the prescribed structure. To prevent the occurrence of different documentation structures being used, it is important to communicate about this subject clearly. This must be done from the beginning of the project and must be monitored throughout the building life cycle.

9. *Decide in advance how often and when it will be checked if the information is up-to-date, complete and whether the agreed structure is consistently used*.

Keep track of the as-built model from the beginning of the project. When the BIM protocol is part of the contract, agreements will have been made about the documentation structure and the incorporation of adaptions to the model. It is de contractor's task to ensure that these agreements are met.

10. *Check from the beginning whether the BIM model is as-built on a random basis.*

In order to prevent as-built adjustments from not being implemented in the BIM model, it is important that the client checks on a random basis whether the BIM model is correctly maintained. This will prevent that during the transition between the project and operation phase many alterations have to be made before the model is suitable for the operation phase.

11. *Before the handover, ensure that it is examined whether the BIM model fully complies with the BIM protocol.*

Conduct a check of the BIM model before it is handed over to the operation phase. It is in this respect impossible to check the entire BIM model. To this end, it is advised to check those objects that needed to be improved during interim checks or objects that have been adapted for the as-built model.

PHASE III – THE OPERATION

The last phase in the synthesis figure is the operation phase. The information which is necessary for the operation and maintenance of the building will be obtained from the BIM model. The following point of attention is important in this respect:

12. *Ensure all modifications in the operation phase will be included in the BIM model.*

As during the project phase, it is important that all modifications are included in the BIM model. Only in this way the BIM model can be used when, for example, adjustments on the current building or perhaps a completely new building needs to be built.

7.
CONCLUSIONS

In this chapter, the conclusions of this research are presented. For this purpose, the research question and the corresponding sub-questions will be answered.

The main research question which will be answered in this report is as follows:

RQ	How can Building Information Modeling offer support in improving the transition between the project and operation phase in Dutch building projects?

In order to answer the main research question, several sub-questions have been formulated. The sub-questions are as follows:

SQ1	How are current Dutch building projects organized and what is the possible role of BIM in this context?
SQ2	What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?
SQ3	How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?

First, the answer to each sub-question will be presented, followed by the answer on the main research question.

1. ***How are current Dutch building projects organized and what is the role of BIM in this context?***

Dutch building projects can be divided into different phases. These phases can be seen as individual phases in which different stakeholders are responsible for the result of that specific phase. Once a phase has been completed, the results with the associated information are transferred to the next phase of the building project. In this new phase, other stakeholder will continue with the information created.

At the end of the project phase, the facility manager receives the necessary information about the project phase from the project manager. The facility manager will use this information to carry out all activities related to the operation and maintenance of the building. These activities are people, organisation, space and infrastructure oriented and will support the organisation in the building at all times.

By analysing the literature study, several inefficiencies in the building industry, which negatively influence the transition between the project and operation phase are identified. The literature study has shown that in theory BIM offers added value for a variety of different inefficiencies in the building industry. This also applies to the transition between the project and operation phase. In figure 22, an overview is given of the identified added values of BIM which will theoretically offer a solution for the identified inefficiencies in the building industry.

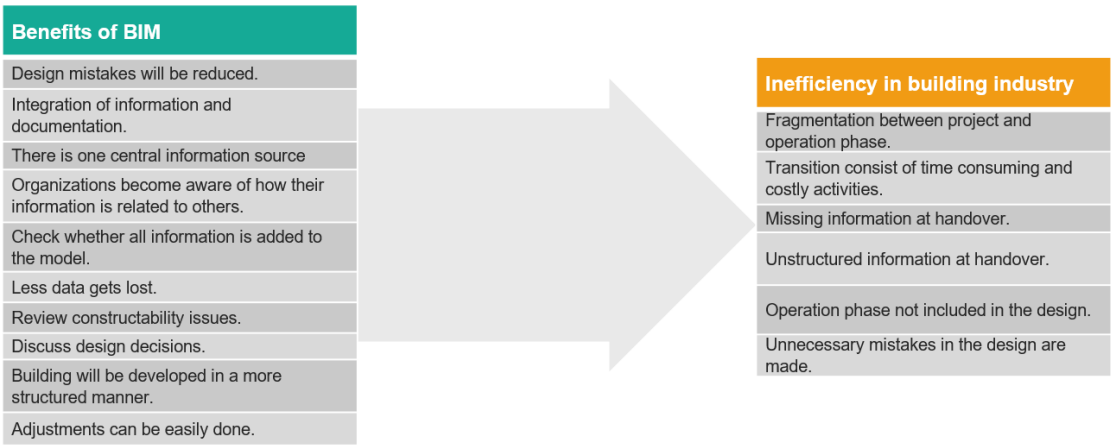

Figure 22: Benefits BIM combined with Inefficiencies in Building Industry

Besides identifying the benefits of BIM in relation to the inefficiencies in the building industry, it is important to be aware that with the implementation of BIM, a number of aspects of the building industry are changing. These changes are in terms of both functional and organisational changes. The functional changes are mainly due to the fact that with BIM the building is described by integrated 3D views, while with 3D CAD one describes a building with independent views. In addition, working with BIM requires the use of a neutral open file format which can be used by different software providers. This also applies for the use of BIM in the operation phase. For the operation phase an open source standard has also been developed to exchange information between the software packages used in the project phase on the one hand and the operation phase on the other. Besides that, there are also changes for the organisational aspects of the building process. By using BIM, an integrated platform is generated that is used by all stakeholders in the building life cycle. This ensures tighter collaboration between the stakeholders and, at the same time, require more transparency from the users. This entails willingness, openness and trust on the part of stakeholders in working with BIM.

2. ***What problems and underlying causes exist within the aspects that influence the transition between the project and operation phase in Dutch building projects while using BIM?***

In order to generate an answer on this question, four case studies have been performed. The case studies examined whether the described benefits of BIM provide a solution in practice for the described inefficiencies in the building industry as shown in figure 23.

The results of the case studies show that despite the use of BIM, a number of issues still affect the transition between the project and operation phase. The issues that arise can be divided into two main categories: Functional issues and Organisational issues. The functional issues involve issues relating to the functional outcome of BIM. These are the issues that are linked to the BIM model at handover. The organisational issues concern the issues relating to the process and the people as well as their behaviour with regard to BIM. The issues of both categories are presented in figure 23.

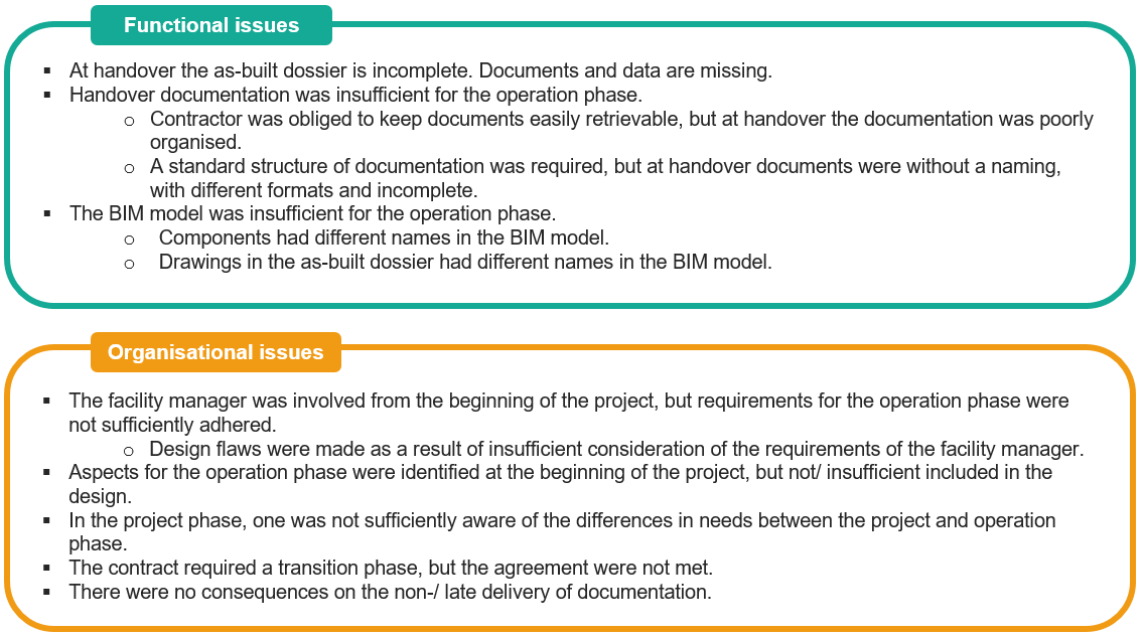

Figure 23: Functional and organisational issues

3. ***How can BIM offer support in preventing the problems and underlying causes in the transition between the project and operation phase in Dutch building projects?***

From the cross case analysis and the generative session several lessons learned have emerged. The lessons learned can be seen as points of attention which are important when one at the beginning of the project decides to work with BIM in the operation phase. The points of attention can be divided into two categories. There are points of attention of the general use with BIM in de building industry and points of attention that specifically affect the transition between the project and operation phase. It should be noted, however, that the general points of attention for BIM will also positively influence the transition between the project and operation phase. The points of attention are as follows:

When one wants to work with BIM…

- … agreements must be made about the structure of information in both the BIM and the separate as-built file.
- … good communication and clear agreements about the level of detail of information that is linked to the objects in the BIM model are recommended.
- … one should create policies on how to manage the information, keep it up-to date and about how to keep the information complete during the project.
- … it is important to keep track changes and correct information in both the as-built dossier and the BIM model from the beginning of the project.

When one wants to work with BIM in the operation phase, ….

- … one should involve the facility manager early in the project and include the necessary requirements for the operation phase into account in the design.
- … it is important that one is aware of the differences in needs between the project and operation phase.
- … it is recommended that the organisation of the transition phase is made compulsory in the contract.
- … it is advised to define at the beginning of the project what the BIM model must comply with before it can be used in the operation phase.

RQ: How can Building Information Modeling offer support in improving the transition between the project and operation phase in Dutch building projects?

Several inefficiencies in the building industry cause that the transition between the project and operation phase in Dutch building projects is not proceeding as desired. Specifically, in this transition, unstructured and incomplete two-dimensional documents are handed over. These documents are inefficient and ineffective for the use during the operation and maintenance of the building. Working with Building Information Modeling (BIM), theoretically, provides several solutions for the inefficiencies that contribute to the poor transition by facilitating seamless exchange of information throughout the different stages of the building life cycle. However, research shows that only the implementation of BIM does not offer the solution for all inefficiencies regarding the transition between the project and operation phase in Dutch building projects. In addition, new issues and challenges arise as a result of the use of BIM in the building industry.

By performing this study, it is aimed to explore ways to support the implementation of BIM in the building industry. By doing so, the potential of BIM, an integrated way of working throughout the whole building life cycle, will be achieved.

Through the execution of a literature study, case studies and a generative session, this study explored whether and how BIM offers a solution for the current inefficiencies in the building industry. The literature shows that working with BIM requires both the implementation of a new technique and the improvement of collaboration between stakeholders. This latter relates to the fact that when one works with BIM it is expected to involve stakeholders early in the process. In addition, BIM requires the implementation of new roles and responsibilities and stakeholders are required to be transparent in sharing their information.

When the issues that emerge from the case studies are analysed, a number of conclusions can be drawn. First, a major contradiction in the implementation of BIM became apparent. On the one hand, BIM ensures improved collaboration. It creates the possibility to work together more easily via an integrated platform. On the other hand, working with BIM asks for improved collaboration between the stakeholders. This while the improvement of collaboration is in itself seen as a challenge within the construction industry.

Second, two types of issues with the implementation of BIM were identified. A number of these issues can be seen as structural, while others can be considered ‘teething problems’. The implementation of BIM as a new technique poses challenges. These are challenges that invariably come into play when implementing a new technique and are therefore are seen as teething problems. However, the case studies also reveal structural problems in the building industry. These issues are identified as problems in the building industry with and without BIM. However, the use of BIM puts the inefficiencies related to the transition between the project and operation phase under a magnifying glass. For example, the lack of involvement of the facility manager at an early stage of the project. This is seen as an issue in the building industry, that is not mitigated with the use of BIM. In addition, the lack of transparency between stakeholders causes problems during building projects with and without the use of BIM.

One can conclude from this analysis that only working with BIM will not provide the solution for the issues that relate to the transition between the project and operation phase. BIM is a tool that can provide support but it is not a stand-alone solution for the structural problems in the building industry. Figure 24 illustrates this. As a result, before the full benefits of using BIM can be examined, the

structural problems of the building industry need to be solved. The analysis of this research also shows that the structural problems are all related to the management of information processes during the building life cycle. It thus seems, that before one can examine how BIM can offer support to the transition between the project and operation phase, the information management processes for which BIM is a supportive tool, must be redesigned.

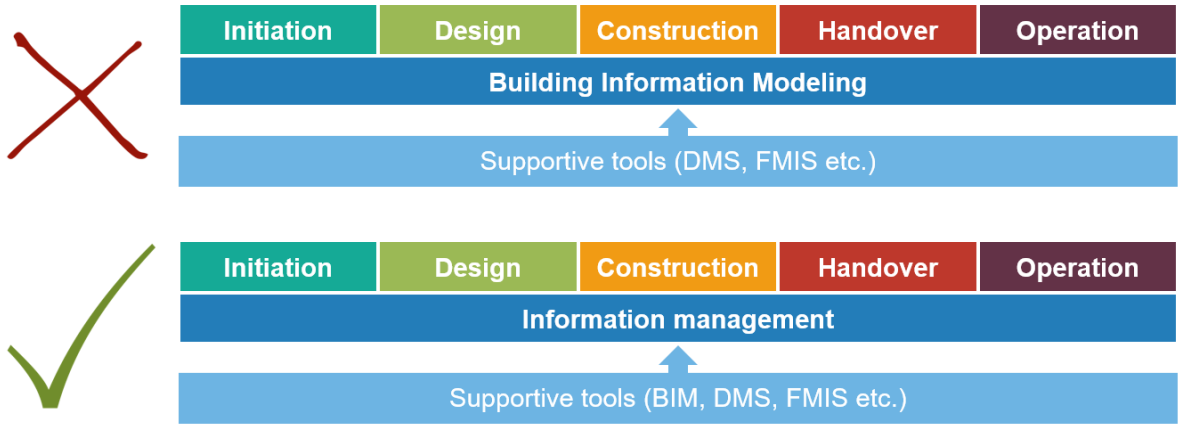

Figure 24: BIM as a support tool

8.

DISCUSSION & RECOMMENDATIONS

In this chapter, the discussion and recommendations of the research are presented. This is done by first discussing the recommendations and their managerial implications in paragraph 8.1. Thereafter, in paragraph 8.2, the limitations of the study are described. Based on paragraph 8.1 and 8.2, suggestions for future research are presented in paragraph 8.3. In paragraph 8.4 the validity is discussed, followed by the reliability in paragraph 8.5.

8.1 Recommendations & managerial implications

The answer to the research question, as presented in the conclusion, indicates that BIM is not a stand-alone solution for the structural problems in the building industry. BIM is a tool, which offers support to the information management processes in the building industry. The analysis of this research also shows that the emerged structural problems in the building industry are all related to the management of information processes during the building life cycle. This research therefore suggests a redesign of the information management process for which BIM is a supporting tool. In this paragraph the recommendations and suggestions of this redesign in the form of managerial implications are presented.

From the analysis of the points of attention in the synthesis, two observations have emerged. First, nearly all points of attention are related to what must be organised in the beginning of a building project. It is becoming more and more clear that the start of the project is the key moment for the rest of the whole building life cycle. Besides the fact that the client has to decide at the beginning of the project whether the BIM will be used in the operation phase, the success of the use of BIM in the operation phase also lies in this beginning.

Secondly, from the analysis of the points of attention, four categories are identified. These categories are all related to the organisation of the information management processes in 'the beginning' of the project. The categories are about how the information management process is organised and not directly about how it should be executed during the building project. The categories are:

- Determining the information needs;
- the role of stakeholders with regard to the information;
- the quality of the information and;
- Determining the process in which the BIM model is generated

Based on these two observations, this discussion will focus on the beginning of the information management process. The discussion will be structured according to the above mentioned categories. Each category will be discussed on the basis of two topics. These are:

1. **Recommendations** – The recommendations focus on what is required when organising the information management process for that specific category. This is done on the basis of the points of attention that emerged from this research.
2. **Managerial implications** – With the managerial implications, it is discussed how the recommendations can be achieved.

8.1.1 Determining information needs

Recommendations

In order to achieve a clear definition of the information needs of stakeholders the following recommendations need to be taken into account:

- *Ensure that one is aware of the differences in needs between the project and operation phase.* The early involvement of stakeholders from different phases of the building life cycle is important to ensure that people are aware of their differences in needs. By defining each stakeholder's needs it is possible to determine what is required of the BIM model in terms of function and level of detail of the objects in the model. Another advantage of sharing each other's needs is that it creates mutual understanding. It ensures that people can better understand the choices of each other.

- *Make sure agreements are made on the level of detail of the BIM model in the BIM protocol.* A part of the information need of the facility manager is the level of detail in which the objects in the BIM model must be delivered. For the construction phase a different level of detail is needed than for the operation phase. For example, in the construction phase it is not important what the life span of a specific lamp is. However, for the operation phase this information is important. For this reason, it is necessary that agreements are made about the level of detail in the BIM protocol.

Managerial implications

A clear definition of the information needs for the facility manager can be guaranteed by drawing up general guidelines for facility management. The information needs should be described as dispositional requirements. By doing so, the requirements describe what is expected of a certain area of object. This, on the one hand, gives the architect the freedom to materially fulfil these requirements. On the other hand, the general requirements give the facility manager the certainty about the quality of the information and the building itself for the operation phase. The involvement of the facility manager in the design phase will in this respect be as an expert. He or she can be engaged for specific requirements, preferences and value assessments/ evaluations.

If, at the start of the project, the client decides that he or she wants BIM to be used in the operation phase, it is important to create a continuous link between the two phases from the beginning of the project. This connection is not only created by defining the level of detail in the BIM protocol or including the organisation of the transition in the contract, but also by incorporating all general facility management requirements in the tendering process.

8.1.2 Relation between stakeholder and information

Recommendations

In order to achieve a clear definition of how the relation between stakeholders and the project information is organised the following recommendations need to be taken into account:

- *Be aware that the facility manager is included in the organisation structure.* By including the facility manager in the organisation structure, a connection is made between the project and operation phase from the beginning of the project.

- *Ensure that in the contract decisions are made on how documents will be shared between stakeholders.* At the start of the project, it must be laid down in the contract how documentation will be shared between stakeholders. This is connected to the structure in which documentation is built and the associated coding of documents.

- *Be aware that all stakeholders are aware of the documentation structure.* If the documentation structure is only laid down in the BIM protocol, there is a high chance that not all stakeholders are aware of the prescribed structure. To prevent the occurrence of different documentation structures being used, it is important to communicate about this subject clearly. This must be done from the beginning of the project and must be monitored throughout the building life cycle.

Managerial implications

A solution to increase the relation between stakeholders and the project information is to connect requirements and information to specific stakeholders. When changes to the BIM model are to be applied, the connected stakeholders must be informed.

This connection already exists in the operation phase itself. If one wants to move a pillar in the design, the engineer is involved to provide advice. This sounds quite logical. However, the case studies in this research show that when adjustments that relate to the operation phase are applied, these decisions are *not* being reported to the facility manager. When a stakeholder is connected to a specific object ensures that when making an adjustment to the BIM model one not only considers the underlying requirement, but also the stakeholder for whom this change can have an impact.

8.1.3 The quality of information

Recommendations

In order to achieve an uniform degree of quality of information during the building life cycle, the following recommendations need to be taken into account:

- *Ensure that a documentation structure for the BIM model is defined in the BIM protocol.* In order to ensure that documentation is easily retrievable and that an overview of all documentation can be created, it is important that a documentation structure is agreed at the beginning of the project. This structure must be laid down in the BIM protocol.

- *Include the organisation of the transition between the project and operation phase in the contract.* A client should stimulate that the transition between the project and operation phase is thoroughly organised. In order to achieve this, the organisation of the transition must be included in the contract. This ensures that the contractor is obliged to establish a plan on how the transition is going to be organised. This will strengthen the connection between the project and operation phase.

- *Decide in advance how often and when it will be checked if the information is up-to-date, complete and whether the agreed structure is consistently used.* Keep track of the as-built model from the beginning of the project. When the BIM protocol is part of the contract, agreements will have been made about the documentation structure and the incorporation of adaptions to the model. It is de contractor's responsibility to ensure that these agreements are met.

- *Check from the beginning whether the BIM model is as-built on a random basis***.** In order to prevent as-built adjustments from not being implemented in the BIM model, it is important that the client checks on a random basis whether the BIM model is correctly maintained. This will prevent that during the transition between the project and operation phase many alterations have to be made before the model is suitable for the operation phase.

Managerial implications

The completeness and quality of information is, on the one hand, related with keeping all information up-to-date. However, on the other hand, it is connected to the background of that specific information. If during the construction of the building, modifications are needed, it should not only be considered whether this is constructively applicable, but also whether it does not negatively affect the underlying requirements. When these requirements from the specification are linked to the BIM model from the

beginning of the project, a continuous information flow is generated. This makes it possible to track back information and making substantiated decisions at any time during the project.

8.1.4 Determining the process in which the BIM model will be generated

Recommendations

In order to achieve a clear definition of the process in which the BIM model is established and maintained the following recommendations need to be taken into account:

- *Create a strategy on how it will be assured that the data in the BIM model and the as-built dossier remains up-to-date.* In order to ensure that the as-built dossier remains up-to-date, one should create a strategy on how this will be assured. It is thereby important that a strategy is made, which is feasible and can be checked over the entire course of the project. The responsibility for defining this strategy lies with the contractor.

- *Before the handover, ensure that it is examined whether the BIM model fully complies with the BIM protocol.* Conduct a check of the BIM model before it is handed over to the operation phase. It is in this respect impossible to check the entire BIM model. To this end, it is advised to check those objects that needed to be improved during interim checks or objects that have been adapted for the as-built model.

- *Ensure all modifications in the operation phase will be included in the BIM model.* As during the project phase, it is important that all modifications that occur during the operation phase are included in the BIM model. Only in this way the BIM model can be used when, for example, adjustments on the current building or perhaps, a completely new building needs to be built.

Managerial implications

The three themes described above converge in determining the process in which the BIM is developed and maintained. During the building life cycle a connection must be made in which the information needs are converted into actual information about the building in the different phases of the building life cycle. It is thereby important that stakeholders generate and maintain this information in a uniform manner. The guidelines for tis are included in the BIM protocol. However, the cases show that merely writing down these guidelines is not enough. It will therefore be necessary to create joint responsibility between stakeholders. This can be achieved by organising monthly sessions with representatives of each stakeholders. In these sessions, random data from the BIM model and the as-built file are checked on structure and completeness.

8.2 Limitations of the study

In this paragraph the limitations of the study will be elaborated. These are discussed on the basis of the limitations of the research methodology (8.2.1), limitations of the obtained data (8.2.2) and finally with the limitations of the generalisation of the results.

8.2.1 Limitations of research methodology

According to Liao and Ai Lin Teo (2018), the behaviour of employees, which make use of BIM has influence on the way the technology is implemented in the industry. With the behaviour, the perception of the practitioners and their willingness, openness and trust towards the use of BIM is meant. The this research was on the functional and organisational aspects of BIM. The behaviour of employees is taken into consideration as part of the case study analysis on organisational factors. However, the behaviour could have been taken into account as a separate pillar next to the functional

and organisational aspects. This might had provided more insights into the perception of the users in the various projects. It therefore could have potentially resulted in different and new insights into the projects. In addition, new point of attention could have arisen for projects in which BIM will be used in the operation phase.

Another limitation of the research methodology is that no specific attention is given to the functional challenges of the implementation of BIM in the building industry. The functional outcomes of working with BIM are examined, however the challenges the stakeholders faced with the new way of modeling and working with different standards are not included in this study. These challenges might have influenced both the functional and organisational results of the study, particularly because BIM was used for the first time in some cases.

8.2.2 Limitations of obtained data

As described in the validity of this research the number of interviewees for the case studies are limited. In addition, the interviews were only held with facility managers. This while multiple stakeholders in the projects were involved in the transition phase. These other stakeholders are not included in this research. In addition, all interviewees took part in the project. It can be argued that these people are influenced by their own evaluation and perception of the project. Although also documentation is used, it might be that points of attention are missing in the results.

Another limitation is the fact that in one case, six months before handover it was decided to quit with the BIM model. As a result, the way in which information was handed over at the end of the project phase was not as agreed in the contract. Outcomes on the organisation of the project are representative for this research, but outcomes on the actual transfer of information is not.

The last limitation of the obtained data is on the attendees of the expert consultations. The expert session, which was held at the beginning of the project and the generative session consisted only of employees of Brink Groep. Therefore, the results are potentially biased. However, since all attendees have worked on different projects and for different organisations over the years, they have acquired a broad perspective.

8.2.3 Limitations of generalisation of results

Finding a sufficient number of cases for this research was challenging. This due to the fact that the projects needed to be finished completely. In addition the use of BIM during the project was mandatory for the cases. In the end, four cases were analysed for this project. Although the cases were of sufficient quality for this research, the sample is not enough to generate representative results for the entire building industry.

Another limitation that emerged through the fact that all projects needed to be finished completely is the fact that some projects were initiated eight or nine years ago. The development of BIM was at that time not at the same level as it is now. For instance with Heijmans in case 3. Case 3 was their first project with BIM. The chance that errors would occur and that one would encounter functional and organisational issues were in this case almost self-evident.

It should also be noted that the size of the projects, which are analysed in the case studies, are not comparable. It is conceivable that the size of the projects has influenced certain decisions made during the design and construction process. The differences in project size are not included in the results of the study, which decreases the generalisation of the results.

Another limitation of the generalisation of the results is the fact that only projects with large contractors are analysed. The risk of implementing BIM is different for large contractors than for small-

sized contractors. The results of the research might have been different if only projects with small-sized contractors were analysed.

The fourth an last limitation of the generalisation of the results is concerned the economic situation which was present at the time the projects were executed. All projects were executed during the crisis. This might have influenced the research results.

8.3 Suggestions for future research

In this paragraph, the suggestions for future research are presented. The suggestions are based on the recommendations, managerial implications and limitations of this research which are presented in paragraph 8.1 and 8.2.

1. The role of BIM in the information management processes.
2. Effect of managerial implications on structural problems.
3. Quantitative research with regard to both the functional and organisational issues.
4. Comparison research with other industries using similar integrated tools.
5. Similar research in other countries
6. Behaviour of employees towards BIM in both the project and operation phase.

First, research must be done into the role of BIM in the information management processes. The recommendations now focus mainly on the redesign of the organisation of the information management processes. The explicit role of BIM is not yet included.

Second, the effect of the proposed managerial implications on the structural problems in the building industry must be assessed. This enables one to examine the effect of the proposed changes in the information management processes. In addition, one can examine how the transition between the project and operation phase is affected by these changes.

Third, quantitative research with regard to both the functional and organisational issues that have been identified in this research should be performed. By quantifying the issues, the results will be strengthened.

Fourth, a comparison with other industries using similar integrated methods is of interest for future research. As described in the literature review, other industries such as the automotive and shipbuilding industry, make use of similar integrated analysis tools. By conducting a comparative study with these industries, new lessons can be learned.

Fifth, similar research in the building industry in other countries should be subject for further research. In this way, the results can be compared internationally and insights can be generated.

Sixth, the behaviour of the employees towards BIM in both the project and operation phase should be investigated. In this way, it can be examined whether and how the behaviour and attitude of the stakeholders in the building industry towards the use of BIM influence the building projects with BIM.

8.4 Validity of research

When the validity of the research is discussed, both internal (8.1.1) and external (8.1.2) validity are considered.

8.4.1 Internal validity

By analysing the internal validity, the degree to which the reasoning within the study has been carried out correctly is discussed. In the research a well-structured framework was used. Each chapter ends with a conclusion that provides the input for the next chapter. This makes it clear how the results of

the study are connected and how they finally form a part in the synthesis. In addition, the interviews in this study were conducted in a semi-structured format. However, it was not possible to ask in all interviews the questions in the same order, since the interview was more organised as a dialogue. Furthermore, the interviews were not conducted in the same circumstances. Some interviews were conducted face to face, while others could only be conducted over the telephone. Performing an interview over telephone makes interpretation of the answers more difficult.

The different order of questions and the fact that the interviews are conducted in different circumstances results in a decreasing internal validity of this study. Another element that negatively influenced the internal validity is that only one interview has been conducted for each case. By interviewing more people and performing them all under the same conditions, the internal validity could have been increased.

8.4.2 External validity

With analysing the external validity, the extent to which results can be generalised to situations other than those in the research is examined. In order to generate this external validity, this research is based on both a literature study and case studies. Due to the limited number of both the case studies and the interviews, the external validity of the research has been lowered (Verschuren et al., 2010). In order to be able to improve the generalisation of the results, more cases will have to be analysed. In addition, more interviews per case will have to be conducted.

What increases the external validity in this research is the fact that the expert consultations were carried out in separate interviews. The single interviews ensure that the external validity is higher in comparison to when requested by a focus group. With a focus group it could have occurred that some respondents will take the lead and because of this, not all attendees are able to give their full opinion.

8.5 Reliability

With the analysis of the reliability, the extent to which comparable results are obtained during the repetitive execution of the study is examined. For this study, it can be concluded that the interviews that have been conducted to reduce the reliability of the research. This because the opinions and experiences of the interviewees have a role in the answers which they give. However, the analysis of the documentation ensures that reliability is increased. If this analysis is repeated, comparable results will be obtained. Because of the fact that the interviews have been verified with the documentation analysis, the reliability is positively influenced. But, despite the documentation analysis, the study would have become more reliable if more interviews had been conducted in each case. This would have strengthened the findings and subsequent the points of attention.

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Appendices

Appendix I – Summaries explorative interviews

In this appendix the summaries of the four explorative interviews is presented. The interviews are focused on the transition between the project and operation phase. The interviewees were asked about their personal experiences with the transition between the project and operation phase. This document provides an overview of the most important outcomes of the interviews.

Summary explorative interview Peter Timmermans
Function: Director of Brink Management en Advies
Date: April 18, 2018

According to Timmermans there are two main elements that influences the way in which needs about the transition between the construction- and operation phase are recorded:

1. **The type of organisation** – Before a project is stared, the organisation from must be chosen. This form results in a specific contract form and a procurement strategy. The method for cooperation between stakeholders, integrated or nog, depends on who is involved in the project and when the needs for each stakeholder are defined.
2. **Type of client –** It also differs whether the client is a one-time client of whether, as in the case of a housing corporation, projects are executed on a more regularly basis. A housing corporation is responsible for both the construction and the maintenance of the buildings. For them it is therefore automatically more important to think early in the project about the operation phase. For a one-time client this is different.
3. **Type of client –** Another difference between the projects, and therefore the way in which needs are defined is whether it concerns a real estate project of a corporate real estate project. With corporate real estate, the client will actually make use of the building when it is in the operation phase. Whereas with real estate, these two factors are separate.

According to Timmermans, the transfer of information between the project and operation phase is not properly aligned because many different stakeholders play a role in this transition. Since they are all different from each other, with different needs and expectations, they are not really concerned with each other. Timmermans said that stakeholders it often find their own tasks complicated enough.

Timmermans also explains that an effective project in practice is classified as a project which is finished within a certain time frame and within budget. This means that when construction is finished the project is finished and little to no attention is paid to the operation phase. Timmermans said: *"A project is never classified successful if it is delivered within time, budget and with good maintenance of 20 years."*

Summary explorative interview Hans Zaat
Function: Senior Manager/ Managing Partner Brink Groep Management en Advies
Date: April 23, 2018

According to Zaat, there are many different parties that are involved in the transition between the project and operation phase. One of the challenges involved in this transition is to know when, how and which parties will be included in the process. This has an great impact on how successfully the transition between the project and operation phase proceeds.

According to Zaat the construction and operation phase do not connect well with each other because of the different parties that are responsible in the two phases. The need for information is different and also the way both companies earn money differs. Zaat said these differences ensure that the process does not connect well. As a result, Zaat said, it often happens that upon completion of a project a hard cut between the project and operation phase happens. This is in spite of the fact that a smooth transition is desired for the facility manager.

In this projects, where a hard cut between the project and operation phase happens, all documents that are needed to operate and maintain the building are provided by the contractor to the facility manager and then leave of the project. The only thing that the facility management team then receives after completion, is a large pile of information with no structure.

Another challenge that Zaat mentioned, is to connect the needs between the two companies. In one of the projects he worked on, the contractor and the facilitator first had a clash. They were not aware of each other's needs and this caused friction between the various parties. According to Zaat, being aware of each other's needs and actually taking them into account when making decisions is very important for the success of the transition between the project and operation phase.

Summary explorative interview Pascal Kersten
Function: Managing partner at Brink Management en Advies
Date: April 25, 2018

In the interview with Pascal Kersten, he described that the building industry has always been a very traditional sector. For years, efforts have been made to fragment the market. Design at one party, realization at the other party, and operation and maintenance again the responsibility of another stakeholder. According to Kersten, the building industry has been responsible for this itself, while it is not efficient at all.

Kersten said that generally, the transition between the project and operation phase proceeds properly when the project and operation is the responsibility for one stakeholder. In these cases, the owner of the project also remains the owner of the building, even though the realisation has been completed. The contractor then realizes early in the project that he need to identify what is needed in the operation phase to manage the building properly. However, with non-residential buildings, things go often wrong. This is because the owner of the building is in these cases not always the user of the building. The owner can build the property, but the facility management can be organised by the user of the building. Because in these situations, various stakeholders have different interest, the bottleneck arises in the transition between the project and operation phase.

Kerstens adds to this, that is also happens that at handover, the facility manager is still not involved in the project. The constructor then knows how to develop the building, but is not aware of how the building will be maintained afterwards. This is then not the responsibility of the constructor, but it does cause errors in the operation phase.

In the interview, Kerstens also gave his opinion on the use of BIM. He explained that one needs to store information in one location and make use of this through all phases of the project. In this way, one is always able to find out which and why choices have been made. It is also possible to track back on how requirements from the specification have evolved in the design and construction.

What often happens, according to Kerstens, is that a BIM is created for different phases. Three separate models are then available for design, execution and operation. Working in this way makes no sense at all. The fragmented version of the building industry is then again reached and BIM becomes a different way of documentation management.

Summary explorative interview Erwin Verkooijen
Function: Senior manager and partner of Brink Management en Advies
Date: May 4, 2018

According to Verkooijen, the transition between the project and operation phase, always has been a weak point of the building industry. This is, according to Verkooijen, mainly because of the fact that with project a something is meant that has a beginning and an end. With the operation of a building, there is no end. Project managers therefore see the project phase as a real job. As soon as the building is completed, the job is over and it is time for the next job. In the eyes of Verkooijen this is not acceptable. The operation phase is the most important phase for the users. Although, he admits that it is very human to happen.

About the organisation of the transition between the project and operation phase, Verkooijen said the following: The paper work is needed. Protocols and manuals on how to set up this phase will always be written. But the organisational component is actually the most important. How will you organise the transition between the project and operation phase? How is it organised that people are incorporated? Are the tasks and responsibilities clear? It is important to be aware that there is more behind the documents and protocols.

Verkooijen also gave his opinion about the use of BIM in the building industry. BIM has a positive influence on the project phase. This is because a lot of construction errors are prevented through the use of BIM. However, if you want to make use of BIM in the operation phase, different needs are preferred. At this time, at the project where Verkooijen works, it often happens that the facility managers to not know how to work with BIM. They do not see the added value of BIM. Verkooijen said that in these projects it is not recommended to make use of BIM.

In the future, one will probably make use of BIM in the whole life cycle. However, at this moment, in my projects, it does not make sense. Once there are people who see this added value of BIM in the operation phase and can make use of it BIM will be used in the operation phase. They then need to be involved at the start of the project to ensure that there will eventually be a BIM model that supports in the operation phase.

Appendix II – Analysing the results from literature

		Inefficiency in building industry	Fragmentation between project and operation phase	Transition consist of time consuming and costly activities.	Missing information at handover.	Unstructured information at handover.	Facility Manager is not/ hardly involved in project phase	Operation phase not included in design.	Definition of supply and demand takes place late in project	Unnecessary mistakes in the design are made.
Topic	**Benefit of BIM**	Source	(Eastman et al., 2011)	(Eastman et al., 2011)	(Gu & London, 2010)	(Gu & London, 2010)	(Meng, 2013)	(Meng, 2013)	(Eastman et al., 2011)	(Eastman et al., 2011)
Scheduling an cost estimation	Optimize the project planning in a 3D environment.	(Jiang, 2011)								
	Easily make a cost estimation.	(Lee et al., 2014)								
Increased collaboration	Design mistakes will be reduced.	(Miettinen & Paavola, 2014)								**X**
	Productivity will increase.	(Miettinen & Paavola, 2014)								
Continuity of information	Integration of information and documentation.	(Xu et al., 2014; S. Zhang et al., 2013)	**X**	**X**	**X**	**X**				
	There is one central information source	(Chen et al., 2003; McArthur, 2015; Phelps, 2012)	**X**	**X**	**X**					
	Organizations become aware of how their information is related to others.	(Chen et al., 2003; Phelps, 2012)	**X**					**X**		
	Check whether all information is added to the model.	(Azhar, 2011)		**X**		**X**				
	Less data gets lost.	(Azhar, 2011)		**X**		**X**				
Visualisation support	Review constructability issues.	(Aksamija & Iordanova, 2010; Chan, 2014)								**X**
	Discuss design decisions.	(Aksamija & Iordanova, 2010; Chan, 2014)						**X**		**X**
	Testing documentation.	(Miettinen & Paavola, 2014)								
Reducing error and rework	Building will be developed in a more structured manner.	(Solnosky, 2016)		**X**		**X**				
Effort created in the beginning	Analyse more alternatives.	(Strafaci, 2008)								
	Adjustments can be easily done.	(Azhar, 2011; Eastman et al., 2011)								**X**
Improve energy efficiency and sustainability	Adjustments based on the improvements of the energy performance can be done more easily.	(Eastman et al., 2011)								

Appendix III – Guideline case study interviews

In this appendix, the guideline of the case study interviews is presented. There were both Dutch and English interviews. Because of this, a Dutch version and an English version of the guideline is given.

Dutch version

Introductie

Mijn onderzoek focust zich op de overgang tussen de constructie en beheer fase van een bouwproject. Om een goed beeld te krijgen over deze overgangsfase ga bij verschillende projecten zowel vanuit de aannemer/ projectmanager als vanuit het beheer kijken naar deze fase. Na dit interview wil ik een beter beeld hebben van de aspecten die belangrijk zijn voor het beheer en de manier waarop de overdracht is georganiseerd.

Het interview zal zich richten op drie verschillende topics: Beheer aspecten, informatie voorzieningen en informatie overdracht. Over elk topic zullen verschillende vragen gesteld worden. Deze zijn hieronder weergegeven.

Topic 1 – Beheer aspecten

1. Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?
2. Hoe worden de project specifieke aspecten gedefinieerd?
3. Wanneer worden de project specifieke aspecten gedefinieerd?
4. Welke beheer aspecten spelen er een rol in het beheer van gebouw X?
5. Welke van deze aspecten hebben de meeste prioriteit? En waarom?

Topic 2 – Informatie voorzieningen

1. Welke informatie is er vanuit de constructie fase aangeleverd voor het beheer?
2. Was de informatie die u verkreeg voldoende?
3. Hoe heeft u deze informatie geschikt gekregen voor het beheer?
    a. Is er een standaard structuur voor gebruikt?
    b. Zo ja: Is deze bekend binnen de organisatie?
    c. Zo nee: Wat zijn de beweegredenen daarvoor geweest?

Topic 3 – Informatie overdracht

1. Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?
2. Door wie en wanneer zijn deze afspraken gemaakt?
3. Zijn deze afspraken nageleefd? Waarom wel/ niet?
4. Hoe is het beheer betrokken bij het leveren van input over de overdracht?
5. Hoe waren de taken en verantwoordelijkheden tussen aannemer en beheerder verdeeld?
    a. En tussen projectmanager en beheerder?
6. Wat zijn de positieve ervaringen van het overgangsproces bij gebouw X?
7. Welke aandachtspunten zijn uit het proces naar voren gekomen?

Extra

Zijn er onderwerpen die wij nu niet besproken hebben, maar u wel belangrijk acht voor mijn onderzoek naar de overdracht tussen constructie en beheer?

English version

Introduction

My research will focus on the transfer of information from design and construct to operate and maintain. To generate a clear understanding of this transition phase, I will conduct several interviews at different companies. First I will talk with people who are responsible for the operate and maintenance phase and thereafter interviews with contractors will be held.

With this interview I hope to develop a clear understanding of the aspects, which are important for the operation and management of a building. Next to that I would like to get some insights on how the transition between design and construct to operate and maintain was organized for building X. The interview will be focused on three different topics: Aspects of the operate and maintenance phase, information provision and information transfer. Each topic will be discussed by several questions. These are:

Topic 1 – Aspects of the operate and maintenance phase

1. What aspects are in general important for the management of the building?
2. How are the project specific aspects defined?
3. When are project specific aspects defined?
4. Which management aspects play a role in the management of building X?
5. Which of these aspects are the most important? And why?

Topic 2 – Information provision

1. What information has been provided from the design and construction phase for the operation and maintenance phase?
2. Was the information you obtained sufficient?
3. How did you get this information suitable for management?
    a. Has a standard structure been used?
        i. If so: Is this known within the organisation?
        ii. If not: What have been the reasons for this?

Topic 3 – Information transfer

1. What were the agreements made about the transfer between the construction and operation/maintenance phase?
2. By whom and when were these agreements made?
3. Have these agreements been complied with? Why yes/no?
4. How is the management company involved in providing input for the transition?
5. How were the tasks and responsibilities divided between contractor and the management company?
6. What are the positive experiences of the transition phase of this project?
7. Which points of attention have emerged from the process?

Extra

Are there any subjects that you consider important for my research into the transfer between construction and management, but that we have not discussed yet?

Appendix IV – Results interviews

In this appendix the results of the interviews are presented. As described in paragraph 5.1.4, the interviews are coded in an excel sheet, in order to be able to identify categories and patterns. First, for each case the individual coding scheme is given. Thereafter, the cross-case analysis is shown.

Case I

Topic	Question	Explanation	Open code	Summary code	Translation
Definition of aspects for operation phase	Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?	-	-	-	-
	Hoe worden de project specifieke aspecten gedefinieerd?	*The facility management unit is responsible for the maintenance of the premises, and all other facilities related operations, which supports the primary processes of that company*	Voor de facility manager is het van belang altijd de bedrijfscontinuïteit te waarborgen.	Bedrijfscontinuïteit als basis voor de specifieke beheeraspecten.	Business continuity as a basis for specific operation and maintenance aspects.
	Wanneer zijn de project specifieke aspecten gedefinieerd? Dat is neem ik aan niet pas het moment dat het beheer echt startte?	*Almost one year before finishing the construction phase, the planning of transition phase started.*	Definitie beheeraspecten begon een jaar voor oplevering.	Late definitie van specifieke beheeraspecten.	Late definition of specific operation and maintenance aspects.
	Welke specifieke beheeraspecten spelen er een rol in het beheer van gebouw X?	*such as: cleaning, internal moves, furniture, catering.*	Schoonmaak, interne bewegingen catering.	Schoonmaak, interne bewegingen catering.	Cleaning, internal movements, catering.
Type informatie	Welke informatie is er vanuit de constructiefase aangeleverd voor het beheer?	*At the end of the project a folder was created by the management company, called the as-built dossier. The as-built dossier contained all the information required for the facility management unit of that particular company.*	De overdracht van de informatie uit de projectfase was één as-built dossier.	Een as-built dossier.	One as-built dossier

Suitablity information	Was de informatie die u verkreeg voldoende?	*Many documents and data were missing. It is still a challenge to find a document about a certain installation or its components.*	Bij de overdracht was structuur informatie niet zoals afgesproken en er mistte data.	Informatie onvoldoende voor het beheer.	Information insufficient for operation phase
	Hoe heeft u deze informatie geschikt gekregen voor het beheer?	*A BIM specialist company was hired to make the BIM ready for the maintenance.*	Een BIM specialist is ingehuurd om het BIM model geschikt te krijgen voor beheer.	BIM model is handmatig gestructureerd voor beheer.	Manually restructuring the BIM model.
	Is er een standaard structuur voor gebruikt?	*This company together with the facility management company had converted the BIM into the company standards.*	De facility manager moest de documentatie omzetten in de structuur van het bedrijf.	Er was geen standaard structuur over alle documenten.	There was no standard structure in documentation at handover.
Involvement Facility Manager	Wanneer is het beheer betrokken bij het leveren van input over de overdracht?	*Almost one year before finishing the construction phase, the planning of transition phase started. The transition phase also included how to deliver the information to the facility management*	Vanaf het moment dat de planning voor de overdracht begon is de facility manager betrokken bij het project.	Facility manager is één jaar voor oplevering betrokken bij het project.	FM is one year before handover involved in the project.
	Hoe is het beheer betrokken bij het leveren van input over de overdracht?	*The facility management unit was responsible for the maintenance of the interim premises. During the whole process they had a supportive role to the project office and they were also involved in some important decisions.*	De facility manager werd betrokken bij de inrichting voor de overdracht.	Facility manager was betrokken bij afspraken over de transitie.	FM was involved in the agreements about the transition.

Roles and responsibilities	Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?	*Almost one year before finishing the construction phase, the planning of transition phase started. The transition phase also included how to deliver the information to the facility management*	Facility manager kon aangeven hoe hij de informatie aangeleverde wilde hebben tijdens de transitie.	Er zijn afspraken gemaakt over hoe de informatie voor de operatie fase aangeleverd moest worden.	Agreements were made on how the information should be provided.
		In the initiation phase when the parameters were set up, it was decided to use BIM during the whole process.	In de initiatie was afgesproken dat BIM voor de gehel life cycle was.	BIM in de gehele life cycle.	BIM in whole Building Life Cycle
	Door wie en wanneer zijn deze afspraken gemaakt?	*Because of the size and the complexity of the project, a project management company was hired to manage the project from the initiation phase till the transition phase.*	Het externe project team was verantwoordelijk gesteld voor het gehele project inclusief de transitie.	Extern projectteam was verantwoordelijk van de start tot de transitie.	External project team responsible from start till the transition phase.
	Zijn deze afspraken nageleefd?	*The standards discussed with the BIM specialist company and the facility management unit were not in the as-built dossier but in the BIM model only.*	De standaarden waarin de documentatie opgeleverd zou worden was niet zoals afgesproken.	De afspraken over de transitie zijn niet volledig nageleefd.	Agreements on transition have not been complied with.
	Hoe waren de taken en verantwoordelijkheden verdeeld?	-	-	-	-

Case II

Topic	Question	Explanation	Open code	Summary code	Translation
Definition of aspects for operation phase	Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?	*Als je het puur vanuit het projectmatige bekijkt dan zit er geen verschil of je het beheerd doet of het project doet. Je wil kunnen sturen op tijd en geld en kwaliteit en informatie. De standaard beheer aspecten die gelden bij een project die gelden ook voor het beheerteam. Alleen bij het beheer moet je toch dingen intensiever bekijken van wat voor jouw organisatie specifiek van belang is*	In het algemeent stuur je op tijd, geld en kwaliteit. Alleen bij beheer zijn er nog specifieke aspecten die van belang zijn.	Tijd, geld en kwaliteit.	Time, money and quality.
	Hoe worden de project specifieke aspecten gedefinieerd?	*Voor ons is dat, en dat hebben ook gevraagd in de uitvraag, is de business continuïteit van de primaire processen van de Eurojust organisatie. En dat betekend dat het onderhoud zich moet vertalen naar: Oké, wat betekent dat voor mij?*	Alle aspecten die de business continuïteit waarborgen.	Business continuïteit als basis voor specifieke beheeraspecten	Business continuity as a basis for specific operation and maintenance aspects.
	Wanneer zijn de project specifieke aspecten gedefinieerd?	*Die zijn gedefinieerd al bij de uitvraag van de tender voor het Build-Maintain.*	De specifieke beheer aspecten zijn gedefinieerd voordat de vraag naar de markt ging.	Vroege definitie specifieke beheer aspecten.	Early definition of specific operation and maintenance aspects.

	Welke specifieke beheeraspecten spelen er een rol in het beheer van gebouw X?	*Voor ons is het heel belangrijk dat een aantal zaken goed geregeld zijn. En dat is alles met betrekking tot beveiliging. Dat is een hele belangrijke. Dat is niet alleen de fysieke beveiliging van het pand of de elektronisch beveiliging van de pand, maar het zit ook samen nog met het bewaken van informatie. Dus wat wij noemen de ICT Security kant.*	Beveiliging. Zowel op het gebied van fysieke beveiliging als ICT security.	Fysieke beveiliging	Physical security
			Beveiliging. Zowel op het gebied van fysieke beveiliging als ICT security.	ICT beveiliging	ICT Security
		Dus dat is heel belangrijk om te bewaken dat wij de grote groepen mensen, we krijgen er gemiddeld per dag zo'n 100/150 mensen naar binnen, dat dat goed gefaciliteerd is dat er badges klaar kunnen liggen, dat de stroom gecontroleerd is, dat we weten wie er in huis is bij een evacuatie. Dat is belangrijk.	Controle van stroom mensen die dagelijks door het gebouw beweegt.	Controle beweging in gebouw.	Control motion in building
Type information	Welke informatie is er vanuit de constructiefase aangeleverd voor het beheer?	*Ja er is een heel revisiedossier dat op Ibis staat waarin van alle aspecten van het van het pand, en niet alles voor ons is interessant, heel gedetailleerd is weergegeven. Daarbij is ook te vinden in welke file wat staat. Waar kan ik wat ophalen?*	Een riviesiedossier waarin de nodige informatie van alle aspecten van het pand is weergegeven.	Een rivisiedossier.	One revision register.

Suitability Information	Was de informatie die u verkreeg voldoende?	*Voor ons als gebruiker van het pand als beheerder zeg maar was er echt absoluut voldoende informatie te beschikking. En dat komt natuurlijk ook omdat we in die transitiefase gezorgd hebben dat dat allemaal al ongelijnd werd.*	De infromatie die uit de projectfase werd overgedragen was absoluut voldoende voor het beheer.	Informatie voldoende voor beheer.	Information sufficient for the operation phase.
	Hoe heeft u deze informatie geschikt gekregen voor het beheer?	*Het fijne was dat we samen een platform deelde waar dat op beheerd werd waarin wij ook zelf zeg maar al in die dossiers konden kijken. Als iets er dan iets niet geleverd was dan konden we het zelf ophalen.*	Vanaf het begin werkte project en operatie in hetzelfde platform. Hier kon nodige informatie te allen tijden uitgehaald worden.	Informatie uit gedeeld platform is gebruikt als basis voor beheer.	Information from shared platform has been used as a basis for the operation phase.
	Is er een standaard structuur voor gebruikt?	*En de structuur van elke file een beetje zelfde. Dat begint met tekeningen, documentatie tot en met onderhoudsvoorschriften. Ja, dat is eigenlijk de perfecte manier van het overhevelen van informatie.*	De structuur van de documenten op het platform is overal gelijk.	Ja er is een standaard structuur gebruikt.	Yes, a standard structure has been used.
Involvement Facility Manager	Wanneer is het beheer betrokken bij het leveren van input over de overdracht?	*Wederom, net zoals we in het hele project gedaan hebben, is dat alle partijen continu om tafel zaten.*	Beheerder is vanaf het begin van het project betrokken.	Beheerder is vanaf het begin van het project betrokken.	FM is from te beginning of the project involved.

	Hoe is het beheer betrokken bij het leveren van input over de overdracht?	*Of we nu met rvb of Brink Groep of met Heijmans om tafel zaten, 'wij' waren altijd aangesloten*	Organisatie werd betrokken gedurende het project en zat om de tafel met andere partijen om behoeften en belangen te delen.	Organisatie had de mogelijkheid om hun behoeften en belangen te delen.	Organisation had the possibility to share their needs and interests.
Roles and responsibilities	Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?	*Ze hebben ook geëist van partijen in het contract dat er een transitiefase moest komen. Dat er een warme overdracht kwam van realisatie naar onderhoud.*	Er is geeist dat de transitiefase ingericht moest komen.	Transitiefase is los ingericht.	The transition has been organised separately.
		Het proces wat we gekozen hebben is denk ik heel belangrijk geweest dat we aangegeven hebben dat 9 maanden voor de oplevering van het pand dat er een transitiefase moest beginnen.	9 maanden voor oplevering van het pand moest de transitiefase beginnen.	9 maanden voor oplevering moest de transitie beginnen.	9 months before handover, the transition had to start.
	Door wie en wanneer zijn deze afspraken gemaakt?	*Ze hebben ook geëist van partijen in het contract dat er een transitiefase moest komen.*	Bij het opstellen van het contract is meegenomen was de eisen waren voor de overdracht.	In het contract stonden de eisen voor de overdracht.	The contract contained the requirements for the transition.
	Zijn deze afspraken nageleefd?	*Het proces wat we gekozen hebben is denk ik heel belangrijk geweest dat we aangegeven hebben dat 9 maanden voor de oplevering van het pand dat er een transitiefase moest beginnen*	9 maanden voor oplevering is de transitiefase begonnen	Afspraken over transitie zijn nageleefd.	Agreements on the transistion have been complied with.

	Hoe waren de taken en verantwoordelijkheden verdeeld?	*Dat er een warme overdracht kwam van realisatie naar onderhoud.*	Dat er een warme overdracht kwam van realisatie naar onderhoud.	Geen harde knip tussen project en beheerfase.	No hard cut between project and operation phase.
		Ja dus altijd in die platforms van zegmaar operationeel, tactisch, strategisch. Die in piramide waren er op elk platform afgevaardigde van elke club. En dat vulde elkaar aan. En daar waar het nodig was maakte je bijvoorbeeld een apart projectteam	Vanuit de verschillende partijen werden steeds afgevaardigde bijelkaar geroepen. Deze zorgde ervoor dat iedereen altijd op de hoogte was van elkaars behoeften en belangen.	Gedeelde verantwoordelijkheden.	Shared responsibilities.

Case III

Topic	Question	Explanation	Open code	Summary code	Translation
Definition of aspects for operation phase	Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?	-	-	-	-
	Hoe worden de project specifieke aspecten gedefinieerd?	*We hebben pas gekeken van oke deze ruimte moet dan beheerd gaan worden, maar wat heb ik nodig om de KPI's die ik afgesproken heb, hoe ga ik die behalen?*	Aan de hand van de KPI's die in de projectfase zijn opgesteld.	KPI's als basis voor specifieke beheeraspecten	KPI's as a basis for specific operation and maintenance aspects.
	Wanneer zijn de project specifieke aspecten gedefinieerd? Dat is neem ik aan niet pas het moment dat het beheer echt startte?	*In 2012. Ja ik kan je een boekje laten zien. Wij noemen dat dp6. Daar staat tot achter de komma staan dingen genoemd hoe wij het bedacht hebben.*	Specifieke aspecten al gedefinieerd bij de inschrijving.	Vroege definitie specifieke beheer aspecten.	Early definition of specific operation and maintenance aspects.
	Welke specifieke beheeraspecten spelen er een rol in het beheer van gebouw X?	*Het zit meer op binnen klimaat, elektrotechnisch en museale aspecten zijn natuurlijk heel belangrijk.*	Het binnenklimaat is belangrijk voor.	Binnenklimaat	Indoor climate
		Hersteltijden zijn heel erg vastgelegd hier.	Hersteltijden van de technische apparatuur is belangrijk in het museum.	Hersteltijden	Recovery times
Type information	Welke informatie is er vanuit de constructiefase aangeleverd voor het beheer?	*Gewoon platte tekeningen. Dat staat gewoon ergens centraal bij ons op de server.*	Er worden 2D tekeningen overgedragen.	2D tekeningen	2D drawings

		Nouja, we hadden wel tekeningen en constructieberekeningen	Naast 2D tekeningen zijn er constructie berekeningen aangeleverd.	2D tekeningen en constructie-berekeningen	2D drawings and construction calculations
Suitability Information	Was de informatie die u verkreeg voldoende?	*Nee. Dat hebben wij hier zelf moeten regelen.*	Informatie was goed voor project fase maar niet voor beheer.	Informatie niet voldoende voor beheer	Information insufficient for operation phase
	Hoe heeft u deze informatie geschikt gekregen voor het beheer?	*We gaan weer gewoon naar de platte tekeningen. En op het moment dat ik nu iets nodig heb dan pak ik de tekening erbij.*	Beheerder heeft 2D tekeningen en berekeningen gebruikt als basis en daar een eigen beheersysteem mee ingericht.	De 2D tekeningen en berekeningen zijn gebruikt als basis voor het beheer.	The 2D drawings and calculations have been used as a basis for the operation phase.
	Is er een standaard structuur voor gebruikt?	*Daar hadden we Relatics voor en daar zaten we met z'n alle in te werken.*	Structuur gemaakt door Relatics te gebruiken.	Ja er is een standaard structuur gebruikt.	Yes, a standard structure has been used.
Involvement Facility Manager	Wanneer is het beheer betrokken bij het leveren van input over de overdracht?	*Toen wij in 2012 begonnen was er vanuit Heijmans nog geen klantmanager bij betrokken vanuit het beheer van denk eens met ons mee.*	Een half jaar voor oplevering is het beheer betrokken bij de overdracht.	Beheerder is zes maanden voor oplevering betrokken in het project.	FM is six months before handover involved in the project.
	Hoe is het beheer betrokken bij het leveren van input over de overdracht?	*En tussen juni en december zijn wij als service organisatie heel veel aan de verifiëren geweest en of dat ook werkelijk klopte.*	Organisatie moest het gebouw verifiëren en kon dit gebruiken na overdracht.	Organisatie heeft geen input geleverd over overdracht.	No involvement of the client in agreements about the transition.
Roles and responsibilities	Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?	*BIM was iets nieuws in de markt, dus wij wilden dat gaan gebruiken. Dan hebben we een project en kunnen we ook aan klanten laten zien hoe mooi en handig het is om met BIM te werken*	BIM gebruiken voor zowel het project als de	BIM in gehele building life cycle	BIM in whole Building Life Cycle

	Door wie en wanneer zijn deze afspraken gemaakt?	*Ja intern bij Heijmans.*	Afspraken over overdracht gemaakt intern bij opdrachtnemer.	Opdrachtnemer heeft zelf afspraken over overdracht gemaakt.	The Contractor has made its own agreements about the transition.
	Hebben jullie dan met Defensie ook afspraken gemaakt over BIM?	*Nee, dat is helemaal gekomen vanuit Heijmans.*	Afspraken over overdracht gemaakt intern bij opdrachtnemer.	Opdrachtnemer heeft zelf afspraken over overdracht gemaakt.	The Contractor has made its own agreements about the transition.
	Zijn deze afspraken nageleefd?	*Ja dat is helemaal over de kop gegaan. Wat we zijn met BIM begonnen en gezien de tijdsdruk is BIM een half jaar voor oplevering gestrand.*	BIM is vlak voor oplevering gestopt. Overgegaan op 2D tekeningen.	Afspraken over transitie zijn niet nageleefd.	Agreements on transition have not been complied with.
	Hoe waren de taken en verantwoordelijkheden binnen Heijmans verdeeld?	*Dat is een harde knip. Er is een oplevering van het gebouw. Je krijgt een opleveringscertificaat. En vanaf dat tijdstip was het gewoon verantwoordelijk.*	Verantwoordelijkheden worden overgegeven vanaf de oplevering.	Harde knip tussen project en beheerfase	Hard cut between project and operation
		Ja daar ben ik ook nog wel eens boos om geworden. Dat je collega's als je ze belt voor vragen gewoon niet opnemen en reageren.	Niet tot nauwelijks meer contact met project mensen na oplevering.	Geen gedeelde verantwoordelijk-heden.	No shared responsibilities

Case IV

Topic	Question	Explanation	Open code	Summary code	Translation
Definition of aspects for operation phase	Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?	-	-	-	-
	Hoe worden de project specifieke aspecten gedefinieerd?	*Wat wij eigenlijk nodig hebben voor het beheer, en dat geldt voor elk gebouw, is een fatsoenlijke asset lijst. Dan kunnen wij heel eenvoudig bepalen welke gebouw specifieke dossiers hebben we nodig? En welke algemene dossiers hebben we nodig?*	Aan de hand van de asset lijst wordt er gekeken welke beheer aspecten voor dat gebouw van belang zijn en welke documenten daarvoor nodig zijn.	Asset lijst als basis voor specifieke beheeraspecten	Asset list as basis for specific operation and maintenance aspects.
	Wanneer zijn de project specifieke aspecten gedefinieerd?	*Een paar maanden voor oplevering het liefst. Dan kunnen we er daar nog op sturen.*	Een paar maanden voor oplevering wordt aan de hand van de assetlijst gekeken welke aspecten belangrijk zijn en welke documenten nodig zijn.	Late definitie van specifieke aspecten voor het beheer.	Late definition of specific operation and maintenance aspects.
	Welke specifieke beheeraspecten spelen er een rol in het beheer van gebouw X?	*Eigenlijk alles wat met veiligheid te maken heeft. Die informatie wil je gewoon heel ruim van te voren hebben. Omdat wij een veiligheidsorganisatie op moeten tuigen.*	Alles wat met veiligheid te maken heeft is belangrijk voor het beheer.	Veiligheid.	Security.

Type information	Welke informatie is er vanuit de constructiefase aangeleverd voor het beheer?	*En heel praktisch wat je dan ziet is, Case 4 is een groot gebouw met heel veel tekeningen die worden als 1 brok over de muur geflikkerd.*	Na oplevering worden alleen de tekeningen ongestructureerd overgedragen.	2D tekeningen.	2D drawings
Suitability Information	Was de informatie die u verkreeg voldoende?	*2000 tekeningen op het laatste moment. Zonder enige structuur, zonder een naamgeving met allemaal een andere formats. Dat is echt ondoenlijk voor de beheerorganisatie.*	Informatie was goed voor project fase maar niet geschikt voor het beheer.	Informatie niet voldoende voor beheer	Information insufficient for operation phase
	Hoe heeft u deze informatie geschikt gekregen voor het beheer?	*Die zijn gewoon letterlijk een half jaar bezig om die structuur te brengen in de tekeningen.*	De beheerorganisatie is een half jaar bezig geweest om een eigen structuur aan te brengen in de overgedragen documentatie.	De 2D tekeningen zijn gebruikt als basis voor de beheer fase.	The 2D drawings have been used as a basis for the operation phase.
	Is er een standaard structuur voor gebruikt?	*Die zijn gewoon letterlijk een half jaar bezig om die structuur te brengen in de tekeningen.*	Beheerpartij heeft zelf een structuur in de documentatie gemaakt.	Er was geen standaard structuur van informatie bij oplevering.	There was no standard structure in documentation at handover.
Involvement Facility Manager	Wanneer is het beheer betrokken bij het leveren van input over de overdracht? Wordt er bijvoorbeeld aan begin van een project al gezegd wij willen het zus en zo opgeleverd hebben?	*Ja, we hebben het bij het project wat we net beschreven precies vastgelegd met elkaar van wanneer willen we wat en hoe willen we het aangeleverd hebben.*	Aan het begin van het project is beschreven wat wanneer aangeleverd moest worden in de transitie. Dit document is ondertekend door de betrokken partijen.	Beheerder is vanaf het begin van het project betrokken.	FM is from te beginning of the project involved.

	Hoe is het beheer betrokken bij het leveren van input over de overdracht?	*Ja, en daar hebben we eigenlijk een protocol voor opgesteld met elkaar, waarin we al die documenten benoemd hebben*	Aan het begin van het project heeft beheer een protocol geschreven	Organisatie heeft zelf eisen voor overdracht in een protocol opgeschreven.	Organization has written down requirements for transfer in a protocol.
Roles and responsibilities	Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?	*Ja, en daar hebben we eigenlijk een protocol voor opgesteld met elkaar, waarin we al die documenten benoemd hebben. En eigenlijk een soort van fasering in aangebracht hebben per document, van deze moeten we zoveel weken oplevering hebben, deze bij de oplevering en dit mag erna*	Er is een protocol gemaakt waarin stond welke documentatie wanneer aangeleverd moest worden.	Een overzicht van welke informatie en documenten wanneer aangeleverd moest worden.	An overview of which information and documents had to be delivered at what time.
	Door wie en wanneer zijn deze afspraken gemaakt?	*Ja, we hebben het bij het project wat we net beschreven precies vastgelegd met elkaar van wanneer willen we wat en hoe willen we het aangeleverd hebben.*	In het contract is beschreven welke informatie wanneer overgedragen moest worden.	In het contract stonden de eisen voor de overdracht.	The contract contained the requirements for the transition.
	Zijn deze afspraken nageleefd?	*En dan snappen wij natuurlijk wel dat je nog niet helemaal het protocol kan naleven qua timing et cetera, maar je weet zelf ook wel dat je dit en dit document echt moet aanleveren. Dus vanuit de exploitatie ontstaat dan de indruk van ja jullie weten het best wel, maar jullie hebben gewoon de ruimte om er mee weg te komen en dat doe je dan ook.*	Afspraken zijn gemaakt, maar tijdens de de transitie zijn niet de juiste documenten aangeleverd.	Afspraken over de transtitie zijn niet nageleefd.	Agreements on transition have not been complied with.

	Hoe waren de taken en verantwoordelijkheden verdeeld?	*Nou de aannemer is echt puur uitvoeringsgericht. En op het moment van oplevering dan moet dit allemaal overgedragen worden.*	Verantwoordelijkheden worden overgegeven vanaf de oplevering.	Harde knip tussen project en beheerfase	Hard cut between project and operation
			Verantwoordelijkheden worden overgegeven vanaf de oplevering.	Geen gedeelde verantwoordelijkheden	No shared responsibilities.

Cross-case analysis

Topic	Question	Case 1	Case2	Case 3	Case 4
Definition of aspects for operation phase	Welke aspecten zijn er in het algemeen belangrijk voor het beheer van een gebouw?		Time, money and quality.	-	-
	Hoe worden de project specifieke aspecten gedefinieerd?	Business continuity as a basis for specific operation and maintenance aspects.	Business continuity as a basis for specific operation and maintenance aspects.	KPI's as a basis for specific operation and maintenance aspects.	Asset list as basis for specific operation and maintenance aspects.
	Wanneer zijn de project specifieke aspecten gedefinieerd?	Late definition of specific operation and maintenance aspects.	Early definition of specific operation and maintenance aspects.	Late definition of specific operation and maintenance aspects.	Late definition of specific operation and maintenance aspects.
	Welke specifieke beheeraspecten spelen er een rol in het beheer van gebouw X?	Cleaning, internal movements, catering.	Physical security, ICT Security, Control motion in building	Indoor climate, recovery times	Security.
Type information	Welke informatie is er vanuit de constructiefase aangeleverd voor het beheer?	One as-built dossier	Revision register.	2D drawings and construction calculations	2D drawings
Suitability Information	Was de informatie die u verkreeg voldoende?	Information insufficient for operation phase	Information sufficient for the operation phase.	Information insufficient for operation phase	Information insufficient for operation phase

	Hoe heeft u deze informatie geschikt gekregen voor het beheer?	Manually restructuring the BIM model.	Information from shared platform has been used as a basis for the operation phase.	The 2D drawings and calculations have been used as a basis for the operation phase.	The 2D drawings have been used as a basis for the operation phase.
	Is er een standaard structuur voor gebruikt?	There was no standard structure in documentation at handover.	Yes, a standard structure has been used.	Yes, a standard structure has been used.	Yes, a standard structure has been used.
Involvement Facility Manager	Wanneer is het beheer betrokken bij het leveren van input over de overdracht?	FM is one year before handover involved in the project.	FM is from te beginning of the project involved.	FM is six months before handover involved in the project.	FM is from te beginning of the project involved.
	Hoe is het beheer betrokken bij het leveren van input over de overdracht?	FM was involved in the agreements about the transition.	Organisation had the possibility to share their needs and interests.	No involvement of the client in agreements about the transition.	Organization has written down requirements for transfer in a protocol.
Rollen en verantwoordelijkheden	Wat waren de afspraken die gemaakt zijn over de overdracht tussen constructie en beheer?	Agreements were made on how the information should be provided. BIM in whole Building Life Cycle	9 months before handover, the transition had to start. The transition has been organised separately.	BIM in whole Building Life Cycle	An overview of which information and documents had to be delivered at what time.
	Door wie en wanneer zijn deze afspraken gemaakt?	External project team responsible from start till the transition phase.	The contract contained the requirements for the transition.	The Contractor has made its own agreements about the transition.	The contract contained the requirements for the transition.

	Zijn deze afspraken nageleefd?	Agreements on transition have not been complied with.	Agreements on the transistion have been complied with.	Agreements on transition have not been complied with.	Agreements on transition have not been complied with.
	Hoe waren de taken en verantwoordelijkheden binnen Heijmans verdeeld?	-	No hard cut between project and operation phase.	Hard cut between project and operation	Hard cut between project and operation
			Shared responsibilities.	No shared responsibilities	No shared responsibilities.

Appendix V – Results case study

In this appendix an overview is given of the analysis of the interviews and the documentation which is used for the case study. The table below presents the documents per case together with the code that is used for the analysis.

For each case, the results are presented in a table. The comments of the interviewee are combined with information from different documents. For each indicator the specific description is given with thereby a short summary of that description and the corresponding document code.

Case	Type	Document name	Code
1	Certificate	Take over certificate – As-Built Documentation	D1.1
	Contract	PM for Transition - Annex	D1.2
	Protocol	Project Information Protocol	D1.3
	Contract	Engineering and Construction contract	D1.4
	Letter	Proposal BIM model – a final	D1.5
	Manual	Project manual – version 3	D1.6
	Report	Works Information	D1.7
2	Contract	BM contract – New premises ‘project name’	D2.1
	Tender instructions	Aanbestedingsleidraad Build Maintain New premises ‘project name’	D2.2
	Presentation	‘Project name’ – IM maintain	D2.3
	Evaluation report	‘Project name’ – Evaluation	D2.4
	Letter	Opdracht Ibis4Projects ‘project name’	D2.5
	Evaluation report	Management review directievoering contractbeheersing ‘project name’	D2.6
	Report	Deelbestek process	D2.7
3	Contract	DBFMO overeenkomst	D3.1
	Report	Outputspecificatie – Algemeen	D3.2
	Report	BIM plan	D3.3
	Report	Definitief Plan 6 (Best and Final offer)	D3.4
	Report	Voortgangsrapportage 08-2014/09-2014	D3.5
	Report	Activiteit Beheer en onderhoud	D3.6
	Evaluation report	Memo evaluatie ‘project name’	D3.7
4	Progress report	BIM overleg januari 2015	D4.1
	Specification	Programma van Eisen ‘project name’	D4.2
	Contract	Aannemingsovereenkomst	D4.3
	Report	Oplevering- en overdrachtsprocedure ‘project name’	D4.4
	Report	SHE assessment ‘project name’	D4.5
	Excel file	Checklist overdracht beheerder	D4.6
	Report	Project Informatie protocol	D4.7

Results case I

Topic	Indicator	Description	Summary	Source
Type of information	Information is delivered in one source.	At the end of the project a folder was created by the management company, called the as-built dossier.	One as-built dossier	FM.C1
		The BIM as built dossier as provided by the Constructor is in line with the Works Information. Nevertheless an upgrade is needed in order to make use of it during operations.	In the transition phase, the as-built dossier needed to be upgraded.	D1.2
		The As-built Information dossier must contain the following information: 1…..15. The 'BIM'model.	The as-built dossier must consist the BIM model.	D1.7
		The BIM model contains all the as-built information and is able to generate all the as-built information (drawings & text) and all the dossiers.	The BIM contains all information for the operation phase.	D1.7
		In accordance with the Works Information part 1 of the Engineering & Construction contract for the 'project name', the As Built dossier is handed over to the Project Directors Office (PDO) in the prescribed and agreed format.	One as-built dossier is handed over.	D1.1
Suitability information	Information is at handover sufficient for operation phase.	The as-built dossier contained all the information required for the facility management unit of that particular company.	Information sufficient for operation phase.	FM.C1
	No missing information at handover.	Many documents and data were missing. It is still a challenge to find a document about a certain installation or its components.	Many documents were missing.	FM.C1
		A small number of documents are still pending will be handed over not later than 21 July 2016.	Documents were missing at handover.	D1.1
	A standard documentation structure is used.	This company together with the facility management company had converted the BIM into the company standards.	There was no standard structure in documentation at handover	FM.C1
		Furthermore we adjusted the BIM and selected all necessary information regarding maintenance.	From the BIM model the information for maintenance was derived.	D1.5
		This was the reason that no assets list could be produced with the help of BIM or Revit.	No standard name structure used.	FM.C1
		The owner of the document is responsible for proper placing, proper input of metadata and agreed notification. Status and revision have to be determined in a proper way.	Owner of document is held responsible for structure documentation	D1.3

		Because the drawings have different names, it is almost impossible to find a drawing or a document which is needed at that particular moment.	Information itself is complete but structure is missing.	D1.3
Definition of aspects for operation phase	Definition of aspects is at beginning of the project.	Almost one year before finishing the construction phase, the planning of transition phase started.	Late definition of specific operation and maintenance aspects.	FM.C1
Involvement facility manager	The FM has been involved form the start of the project.	The facility management unit was responsible for the maintenance of the interim premises. During the whole process they had a supportive role to the project office and they were also involved in some important decisions.	FM is involved to support the project office and with important decisions.	FM.C1
		The draft result will be functionally assessed by the user team with special attention to: ICT, facility, security.	Draft design was already tested on aspects for operation phase	D1.6
		An important aspect of the design process is the interaction with the Employer, who must approve the choices made during the engineering and construction works and who can provide input for the design. The Employer's involvement consist of … Facility Management Unit (FMU)	The Facility manager had de ability to provide input for the design.	D1.7
Roles and responsibilities	Agreements have been made on the organisation of the transition between the project and operation phase	In the initiation phase when the parameters were set up, it was decided to use BIM during the whole process.	Agreements were made on how the information should be provided.	FM.C1
		In the contract, no clause is added for the organisation of the transition between the project and operation phase.	No agreements were made on how the transition should be organized.	D1.4
	Agreements have been complied with.	The standards discussed with the BIM specialist company and the facility management unit were not in the as-built dossier but in the BIM model only.	Agreements on transition have not been complied with.	FM.C1
		In accordance with the Works Information part 1 of the Engineering & Construction contract for the 'project name', the As Built dossier is handed over to the Project Directors Office (PDO) in the prescribed and agreed format.	According to the contractor, the agreements have been complied with.	D1.1

Results case II

Topic	Indicator	Description (Dutch)	Summary	Source
Type of information	Information is delivered in one source.	Ja er is een heel revisiedossier dat op Ibis staat waarin van alle aspecten van het van het pand, en niet alles voor ons is interessant, heel gedetailleerd is weergegeven.	One revision register.	FM.C2
		De informatie-uitwisseling van alle documenten betreffende het werk geschiedt via een workflow gestuurde projectwebsite.	An external document management systeem is used.	D2.5
Suitability information	Information is at handover sufficient for operation phase.	Voor ons als gebruiker van het pand als beheerder zeg maar was er echt absoluut voldoende informatie te beschikking.	Information sufficient for the operation phase.	FM.C2
	No missing information at handover.	Ja, dat is eigenlijk de perfecte manier van het overhevelen van informatie. Of alles gevuld is, is een tweede.	Not all documentation complete at handover.	FM.C2
	A standard documentation structure is used.	En de structuur van elke file een beetje zelfde. Dat begint met tekeningen, documentatie tot en met onderhoudsvoorschriften.	Yes, a standard structure has been used.	FM.C2
		Codering samen vastleggen (elementen en ruimten). Codering en detailniveau gelijk aan BIM.	Communication on coding an detail level at beginning of construction phase.	D2.3
		Niet altijd is vooraf eenduidig vastgesteld waar een document aan moet voldoen en waarop geverifieerd moet worden.	It w snot always clear to what a document has to comply with.	D2.6
Definition of aspects for operation phase	Definition of aspects is at beginning of the project.	Die zijn gedefinieerd al bij de uitvraag van de tender voor het Build-Maintain.	Early definition of specific operation and maintenance aspects.	FM.C2
		Gedurende de fase Dienstverlening moet de Aannemer – ten behoeve van de continuïteit van het bedrijfsproces van de Gebruiker, alsmede ten behoeve van het behoud van de Nieuwbouw en de deugdelijke werking van de alle Elementen – de Opdrachtgever en Gebruiker proactief ontzorgen.	Early definition of general operation and maintenance aspects.	D2.1
		Nog niet scherp wat assets van Eurojust zijn.	Specific operation and maintenance aspects unclear at beginning of construction phase.	D2.3

		Dat wij strakker als 'facility manager' in de wedstrijd hadden moeten zitten in het begin toen zeg maar het Design gemaakt werd. Ik kom nu te veel dingen tegen waarvan ik denk oke daar had ik scherper op moeten zijn.	FM was involved but not all aspects are included in the design.	FM.C2
Involvement facility manager	The FM has been involved form the start of the project.	Wederom, net zoals we in het hele project gedaan hebben, is dat alle partijen continu om tafel zaten.	FM is from the beginning of the project involved.	FM.C2
		De gebruiker is integraal onderdeel geweest van de totstandkoming en ontwerp van dit plan en heeft specifieke eisen gesteld aan het ontwerp en de voorwaarden van het werk en de invulling van de dienstverlening.	FM is from the beginning of the project involved.	D2.7
		Het is wenselijk om rekening te houden met de toepassing van BIM-technologie in combinatie met een BMS (Building Management System).	The BIM model takes operation phase into account.	D2.7
Roles and responsibilities	Agreements have been made on the organisation of the transition between the project and operation phase	Ze hebben ook geëist van partijen in het contract dat er een transitiefase moest komen.	The contract contained the requirements for the transition.	FM.C2
		Gedurende de fase Transitie moet Aannemer zorg dragen voor een probleemloze faseovergang van de fase Nieuwbouw naar fase Dienstverlening.	The contract contained the requirements for the transition.	D2.1
		Fase Transitie; deze fase vangt aan 9 (negen) maanden voorafgaand aan de datum van oplevering Nieuwbouw en eindigt op datum van oplevering.	Transition phase started 9 months before handover.	D2.1
		Alle bestanden die die huisvesting beschrijving zijn extracten van een BIM en voldoen aan de Rgd BIM norm.	Information should be provided as BIM model extracts.	D2.2
	Agreements have been complied with.	Het proces wat we gekozen hebben is denk ik heel belangrijk geweest dat we aangegeven hebben dat 9 maanden voor de oplevering van het pand dat er een transitiefase moest beginnen	Agreements on the transition have been complied with.	FM.C2
		En er zijn tig problemen en issues geweest, maar het is altijd wel vanuit die optiek opgelost. Altijd oog hebben voor het standpunt van een ander.	Problems and issues did arise, but were solved by sitting around the table and discussing each other's viewpoints.	FM.C2

Results case III

Topic	Indicator	Description (Dutch)	Summary	Source
Type of information	Information is delivered in one source.	Nouja, we hadden wel tekeningen en constructieberekeningen.	2D tekeningen en constructie-berekeningen	FM.C3
		Doel: Het, doormiddel van een integraal virtueel 3D model, efficiënt later verlopen van het project door deze als basis te gebruiken bij de werkzaamheden gedurende realisatie- beheer-, onderhoud- en exploitatiefase.	BIM during the whole life cycle.	D3.3
Suitability information	Information is at handover sufficient for operation phase.	Nee. Dat hebben wij hier zelf moeten regelen.	Information insufficient for operation phase.	FM.C3
		En bij de eerste HCCP meting die we in de keuken kregen werd hij afgekeurd op de vloer. Als je daar aan de voorkant al betere afspraken over had gemaakt had dat misschien niet gebeurt.	Design mistakes were made.	FM.C3
	No missing information at handover.	Er zijn onvoldoende werk- en keuringsplannen geschreven. Aanbevolen wordt om vooraf (risicogestuurd) te bepalen voor welke specifieke onderdelen werk- en keuringplannen te schrijven.	Not all documentation was available after handover.	D3.7
	A standard documentation structure is used.	Daar hadden we Relatics voor en daar zaten we met z'n alle in te werken.	Yes, a standard structure has been used.	FM.C3
		Documenten (tekeningen en documenten) kunnen worden voorzien van een WBS-, SBS-codering, een Infra codering, een NL SfB-codering en een museale codering. Het betreft hier een dermate grote actie dat er een aanzienlijke kans bestaat dat deze actie niet voltooid is op het moment dat de documentatie wordt overgedragen naar M&O.	Structure of documentation was sufficient, but structure in documentation names/codes was missing.	D3.5
		Alle relevante documenten (o.a. vergunningen, planningen, tekeningen e.d.) moeten op eenvoudige wijze terug vindbaar zijn.	All documents had to be easily retrievable.	D3.2
		Opdrachtnemer is verplicht een overzicht bij te houden waarin alle wijzigingen met betrekking tot huisvesting en dienstverlening worden opgenomen met documenten en vindplaat.	The contractor was obliged to keep an overview of documentation location.	D3.2

Definition of aspects for operation phase	Definition of aspects is at beginning of the project.	In 2012. Ja ik kan je een boekje laten zien. Wij noemen dat dp6. Daar staat tot achter de komma staan dingen genoemd hoe wij het bedacht hebben.	Early definition of specific operation and maintenance aspects.	FM.C3
		Algemene aspecten voor de beheer fase zijn in de aanbieding van Heijmans verwerkt.	Definition of aspects for operation and maintenance identified in project tender.	D3.4
		Specifieke activiteiten voor het beheer en onderhoud zijn één jaar voor oplevering gedefinieerd. Daarbij is aangegeven wie voor welke verificatie verantwoordelijk is.	Specific actions for the operation phase are defined one year before handover.	D3.6
Involvement facility manager	The FM has been involved form the start of the project.	Toen wij in 2012 begonnen was er vanuit Heijmans nog geen klantmanager bij betrokken vanuit het beheer van denk eens met ons mee.	FM not involved from the start of the project.	FM.C3
		En tussen juni en december zijn wij als service organisatie heel veel aan de verifiëren geweest en of dat ook werkelijk klopte.	FM is six months before handover involved in the project.	FM.C3
		De M&O-organisatie was bij de ontwerp- en uitvoeringsfase betrokken, maar er werd onvoldoende gefocust op het gezamenlijk bepalen van de uitgangspunten en kiezen/genereren van ontwerpoplossingen.	FM was involved in the design phase, but there was insufficient focus on jointly selecting/ generating design solutions.	D3.7
		Eisen die ontstaan voor wat betreft de Beheer en Onderhoudsfase bij een van de werkmaatschappijen worden door de projectleider Beheer en Onderhoud gecommuniceerd met o.a. de Ontwerpmanager.	The BIM plan contained a description for the involvement of the FM in the design phase.	D3.3
Roles and responsibilities	Agreements have been made on the organisation of the transition between the project and operation phase	Nee, dat is helemaal gekomen vanuit Heijmans.	The Contractor has made its own agreements about the transition.	FM.C3
		In contract geen afspraken over transitie.	No agreements on the transition in the contract.	D3.1
		In contract geen afspraken over het gebruik van BIM.	No agreements about the use of BIM in the contract.	D3.1
	Agreements have been complied with.	Wat we zijn met BIM begonnen en gezien de tijdsdruk is BIM een half jaar voor oplevering gestrand.	Agreements on transition have not been complied with.	FM.C3

Results case IV

Topic	Indicator	Description (Dutch)	Summary	Source
Type of information	Information is delivered in one source.	En heel praktisch wat je dan ziet is, 'project naam' is een groot gebouw met heel veel tekeningen die worden als 1 brok over de muur gegooid.	Information is handed over in scattered documents.	FM.C4
		Voor de schriftelijke informatie-uitwisseling tussen aannemer, directie, architect en adviseurs wordt gebruik gemaakt van Ibis4Projects.	An external document management system is used.	D4.3
Suitability information	Information is at handover sufficient for operation phase.	2000 tekeningen op het laatste moment. Zonder enige structuur, zonder een naamgeving met allemaal een andere formats. Dat is echt ondoenlijk voor de beheerorganisatie.	Information insufficient for operation phase	FM.C4
	No missing information at handover.	Many documents (maintenance documentation, manuals and permits) are missing at handover.	Information incomplete at handover.	D4.6
	A standard documentation structure is used.	Zonder enige structuur, zonder een naamgeving met allemaal een andere formats. Die zijn gewoon letterlijk een half jaar bezig om die structuur te brengen in de tekeningen.	There was no standard structure in documentation at handover.	FM.C4
		Bij de naam moet het referentienummer of het kenmerk worden opgenomen. Wanneer er geen referentienummer of kenmerk op het document staat, kan worden volstaan met een beknopte naam vanuit de omschrijving.	A standard structure of documentation was required.	D4.7
Definition of aspects for operation phase	Definition of aspects is at beginning of the project.	Een paar maanden voor oplevering het liefst. Dan kunnen we er daar nog op sturen.	Late handover of asset list.	FM.C4
		Ontwerpuitgangspunten: - Bewoners en bezoekers kunnen het gebouw zonder belemmeringen betreden. - Logistieke routes en verkeersstromen moeten zoveel mogelijk worden gescheiden. - Voor de catering facilities en de sport facilities dient een separate logistieke entree te worden voorzien.	Early definition of general operation and maintenance aspects.	D4.2
Involvement facility manager	The FM has been involved form the start of the project.	Ja, we hebben het bij het project wat we net beschreven precies vastgelegd met elkaar van wanneer willen we wat en hoe willen we het aangeleverd hebben.	FM is from the beginning of the project involved.	FM.C4
		Gedurende het ontwerptraject hebben reguliere ontwerp afstemmings-overleggen met de huurders plaatsgevonden en zijn daarnaast op specifieke momenten projectteam overleggen met vertegenwoordigers van de huurders georganiseerd.	FM was involved from the design phase of the project.	D4.5

Roles and responsibilities	Agreements have been made on the organisation of the transition between the project and operation phase	Ja, we hebben het bij het project wat we net beschreven precies vastgelegd met elkaar van wanneer willen we wat en hoe willen we het aangeleverd hebben.	The contract contained the requirements for the transition.	FM.C4
		De aannemer levert de concept revisiestukken aan de directie, uiterlijk drie werkdagen voor de oplevering.	Agreements about the handover of documentation in the transition phase were made.	D4.4
		Het werk komt in aanmerking voor de overdracht naar de beheerorganisatie wanneer alle revisiestukken voldoen aan de vooraf gestelde eisen, zodat ze door zowel de projectorganisatie als de beheerorganisatie goedgekeurd kunnen worden en daarnaast is voldaan aan de overige vereisten opgenomen in de checklist 'overdracht beheerorganisatie'.	It was agreed that documentation only was accepted once it met the transfer requirements.	D4.4
		BAM verstrekt bij oplevering een ‘as-built’ BIM-model. BAM verwerkt de productinformatie in het ‘as built’ model.	At handover an ‘as-built’ BIM-model should be provided.	D4.1
	Agreements have been complied with.	En dan snappen wij natuurlijk wel dat je nog niet helemaal het protocol kan naleven qua timing et cetera, maar je weet zelf ook wel dat je dit en dit document echt moet aanleveren.	Agreements on transition have not been complied with.	FM.C4

Appendix VI – Generative session

In this appendix an overview is given of the participants with which the generative session is conducted. In addition, the program for the session is presented.

Participants

Who	Function	Company
Toine Bullens	Senior consultant	Brink Groep
Maarten Zwemmer	Senior consultant	Brink Groep
Rob van den Berg	Senior consultant	Brink Groep

Program

Time	What	Who	Tool	Extra
11:30	Walk in			
11:35	Introduction research/ explanation goal of session	Lauren	PowerPoint	
11:40	Explanation rounds	Lauren	PowerPoint	There are 3 questions for each desired situation. Each round will answer one question.
11:45	Round 1: question 1 will be answered.	Participants	For each participant an A4 form is needed with the list with desired situations.	!! If BIM is not of added value for a topic, it is removed from the session.
11:55	Round 2: question 2 will be answered	Participants	For each participant an A4 form is needed with the list with benefits of BIM	
12:05	Round 3: question 3 will be answered	Participants	A0 forms , tape and markers	Depending on the number of remaining issues, it is determined how long a brainstorm will be for each issue.
12:50	Wrap-up	Participants & Lauren		Short summary per issue

Appendix VII – Guideline and summary validation interviews

This appendix describes the validation session which is held concerning the development of the strategy. Four expert consultations have been held with professionals form practice. Based upon these consultations the model is optimized.

In the table below an overview is given of the four experts which have been questioned for the validation of the model. Thereafter the guideline for the validation session is presented followed by a summary of the interviews. Because the expert consultation was only done with Dutch experts, both the guideline and the summaries are in Dutch.

Who	Function	Company	Date/ time
Menno Meulebeek	Senior consultant	Brink Groep	16-08-2018 10:00u
Albert Versluis	Director	Versluisgroep	21-08-2018 16:00u
Albert van der Beek	BIM director	Rijnstate	22-08-2018 13:00u
Willem Jan Hanegraaf	Program director	Rijnstate	28-08-2018 15:30u

Dutch version

Introductie

Gedurende mijn onderzoek ben ik aan het kijken naar de overgang tussen de project en beheerfase in bouwprojecten. Daarbij ben ik aan het onderzoeken hoe BIM een ondersteuning zou kunnen en moeten bieden in deze overgang. Het onderzoek is bijna afgerond en ik als resultaat heb ik een tool ontwikkeld dat als een handvat gebruikt kan worden gedurende het gehele bouwproject. Dit om de implementatie van BIM en daarmee de overgang tussen het project en beheer beter te laten verlopen. Graag zou ik u deze tool aan u willen laten zien en met u bespreken.

Vragen

1. Wat s u eerste indruk van het model?
2. Zijn er onderdelen die u niet snapt of niet logisch vindt?
3. Wat zou dit schema betekenen voor u werkpraktijk? Biedt het ondersteuning?
4. Zijn er proces stappen of aandachtspunten die u op dit moment mist?
5. Zijn er nog tips die het schema kunnen verbeteren?

Summary interview Menno Meuleek (Dutch)

1. **Wat s u eerste indruk van het model?**
   Het is een helder overzicht. Duidelijk wat in- en output is. Het is wel een globaal overzicht.
2. **Zijn er onderdelen die u niet snapt of niet logisch vindt?**
   Ik vind het niet duidelijk wat er onder de initiatie fase valt en wat niet? Wordt er in die fase ook het ontwerp gemaakt en wordt er met ‘project’ alleen de uitvoering bedoeld? Dit moet je denk ik beter opschrijven.
3. **Wat zou dit schema betekenen voor u werkpraktijk? Biedt het ondersteuning?**
   Ik denk dat het schema voornamelijk gebruikt kan worden voor bewustwording van het grotere plaatje. Het is een handvat voor de opdrachtgever van zo zou het proces moeten verlopen en hier moet je op letten.

4. **Zijn er proces stappen of aandachtspunten die u op dit moment mist?**
   In de projectfase heb je nu bij de check-cycle alleen de contractor gekoppeld. Ik denk dat het handig is om de check waarin het BIM model wordt gekoppeld aan het BIM protocol aan de opdrachtgever toe te wijzen. Die kan op deze manier dan ook kijken of naast dat de opdrachtnemer zijn eigen werk goed bijhoudt en documenteert ook aan de eisen voor de operatie fase wordt voldaan. Zo is het voor de projectfase niet heel belangrijk wat de levensduur is van een lamp, maar in het BIM protocol staat waarschijnlijk wel dat dat moet ingevuld worden in het BIM model. De opdrachtgever is verantwoordelijk voor die check.
5. **Zijn er nog tips die het schema kunnen verbeteren?**
   Ik denk dus het duidelijker maken van de projectfasen en het toevoegen van de opdrachtgever in de projectfase. Misschien zou je ook nog ergens kunnen verwerken hoe de verantwoordelijkheden lopen in de verschillende fasen. En dan vooral de verandering naar de operatiefase toe. Verder vind ik het een goed model en overzichtelijk gemaakt.

Summary interview Albert Versluis (Dutch)

1. **Wat s u eerste indruk van het model?**
   Dat hij helemaal in het Engels is. Klinkt flauw, maar als je wil dat hij ook gebruikt wordt in de Nederlandse bouwprojecten, dan zal ik ook een Nederlandse versie maken. Verder snap ik de verschillende fasen en hoe je het hebt opgedeeld in input/output, het proces en de aandachtspunten.
2. **Zijn er onderdelen die u niet snapt of niet logisch vindt?**
   Welk contract bedoel je precies in jouw figuur? Over de bouw? Dat is misschien handig nog ergens te definiëren.
3. **Wat zou dit schema betekenen voor u werkpraktijk? Biedt het ondersteuning?**
   Ik zie dit schema vooral bij project managers. Zij kunnen het als een soort handleiding gebruiken of om mensen het proces en de aandachtspunten in de verschillende fasen uit te leggen. Ik denk niet dat dit door een uitvoerder op een prikbord gehangen gaat worden.
4. **Zijn er proces stappen of aandachtspunten die u op dit moment mist?**
   Ik heb een boek gelezen over leiderschap waarin beschreven werd dat het belangrijk is om aan het begin van het project precies te definiëren wat je aan het einde van het project wil hebben. Misschien is het handig om dit nog ergens te vermelden. Waar gaat die opdrachtgever zeggen wij hij precies wil?
5. **Zijn er nog tips die het schema kunnen verbeteren?**
   Niet perse op het schema gericht. Ik denk vooral dat voor de succes van zo'n schema als dit het van belang ik dat de partijen zich bekwamen met BIM. Persoonlijke vaardigheden ontwikkelen. Ik zelf zie nog niet op alle vlakken in waar BIM een toegevoegde waarde speelt. Ik denk dat dat besef enorm belangrijk is voordat de implementatie echt kan slagen.

Summary interview Albert van der Beek (Dutch)

1. **Wat s u eerste indruk van het model?**
   Ik zie herkenbare onderdelen. De onderdelen in de processtappen zijn duidelijk. Dat de ontwikkeling van het BIM protocol voor het contract is zodat het onderdeel uitmaakt van het contract is erg goed. Ik begrijp ook dat de kleurtjes worden gerefereerd aan de mensen die er verantwoordelijk voor zijn.
2. **Zijn er onderdelen die u niet snapt of niet logisch vindt?**
   Ik snap dat de cirkels achter de bolletjes te maken hebben met dat de onderdelen aan elkaar verbonden zijn. Echter kan ik me voorstellen dat mensen dat niet logisch vinden.

3. **Wat zou dit schema betekenen voor u werkpraktijk? Biedt het ondersteuning?**
   Ik denk dat het erg belangrijk is dat het gehele proces onder de aandacht gebracht wordt. Organisaties weten van het bestaan van BIM in ook de operatie fase, maar hebben geen overzicht over de bovenliggende structuur van deze implementatie ervan. Dit figuur kan je gebruiken voor ondersteuning bij uitleg en het overtuigen van het belang van bepaalde aandachtspunten.
4. **Zijn er proces stappen of aandachtspunten die u op dit moment mist?**
   Bedoel je met het eerste aandachtspunt alleen de facility manager zelf? Of ook de gehele beheer organisatie. Ik denk namelijk dat het gaat om de gehele beheer organisatie toevoegen. Die moet in zijn geheel in de organisatie structuur. Daarnaast denk ik dat het van belang is dat in de project fase, de opdrachtgever steekproefsgewijs controles uit voert. Ik zou hier nog een aandachtspunt voor de opdrachtgever aan toevoegen zodat deze die niet pas voor het eerst doet vlak voor de overdracht.
5. **Zijn er nog tips die het schema kunnen verbeteren?**
   Je kan misschien ook nog iets doen met verantwoordelijkheden. Nu heb je de aandachtspunten per stakeholder aangegeven, maar is deze stakeholder ook echt verantwoordelijk voor de uitvoering hiervan? Ook denk ik dat het misschien handig is om bij de verificatie van het contract wederom twee losse bollen te maken. De verificatie bestaat namelijk uit twee losse onderdelen. De verificatie van het BIM model en van het contract zelf. Misschien maak je dat wat duidelijker door ze los van elkaar te halen.

Summary interview Willem Jan Hanegraaf (Dutch)

1. **Wat s u eerste indruk van het model?**
   Ik vind het een goed en overzichtelijk model. Het is duidelijk dat de aandachtspunten aan verschillende stakeholders zijn gekoppeld.
2. **Zijn er onderdelen die u niet snapt of niet logisch vindt?**
   Op dit moment lijkt het of het sowieso om een Design Built contract gaat. Omdat de pijl van het contract bij het design en de uitvoering naar binnen gaat. Terwijl ik denk dat deze inrichting ook zo is wanneer ook de beheerfase in het contract is meegenomen.
3. **Wat zou dit schema betekenen voor u werkpraktijk? Biedt het ondersteuning?**
   Ja ik denk zeker dat het schema ondersteuning kan bieden. Misschien wel in de vraagspecificatie. Dat je laat zien ‘zo wil ik het georganiseerd hebben’. Als we gaan BIM’en dan gaan we het op deze manier doen.
4. **Zijn er proces stappen of aandachtspunten die u op dit moment mist?**
   Ik mis eigenlijk de vergelijking met het conventionele proces. Op die manier kan men beter zien wat het verschil is tussen het conventionele proces en de nieuwe processen met BIM. Dan wordt het misschien iets duidelijker wat er nou nu precies verandert voor elke stakeholder. Daarnaast mag het voor mij iets duidelijker dat voordat dit schema gebruikt gaat worden de opdrachtgever moet kiezen dat BIM in de beheerfase gebruikt gaat worden en dat er een overeenstemming is met de beheerder dat ze ook echt daadwerkelijk gaan beheren met BIM.
5. **Zijn er nog tips die het schema kunnen verbeteren?**
   Ik zou vanaf het contract, nog een stippellijn trekken naar de beheerfase. Op deze manier laat je zien dat het ook mogelijk is dat je in het contract de beheerfase koppelt. Dat vind ik nu nog te onduidelijk.