Exploring the perspectives of project managers towards BIM application in the building industry

Master thesis by Valery Lambermon

Exploring the perspectives of project managers towards BIM application in the building industry

by

Valery Lambermon

in partial fulfillment of the requirements for the degree of

Master of Science
Construction Management and Engineering
at the Delft University of Technology

to be defended publicly on Tuesday, June 30th, 2020 at 15:30

Student number 4345746

Graduation committee

Prof. dr. ir. J.W.F. Wamelink	Chairman	TU Delft
Dr. ir. M.G.C. Bosch-Rekveldt	First supervisor	TU Delft
Dr. ir. L.H.M.J. Lousberg	Second supervisor	TU Delft
ir. Toine Bullens	External supervisor	Brink Management / Advies
ir. Carolien van Hout-van Delft	External supervisor	Brink Management / Advies

Preface

After several months of hard work, I would like to present my graduation thesis which will conclude my master's degree in Construction Management and Engineering at the Delft University of Technology. This thesis was performed in collaboration with Brink Management / Advies.

The topic of this research, BIM (Building information modeling / management), has sparked my interest since the first year of my Civil Engineering bachelor's degree. However, it was only during my internships that I realized how challenging it is to implement BIM within the building industry. Throughout my research, I was fortunate enough to be supported by various professionals. They have provided me with an awareness of the benefits and challenges of BIM, shared their positive and negative experiences, and allowed me to obtain a better understanding of the various perspectives on BIM. I would like to express my gratitude to everyone who has helped me throughout this process, including the participants of this study and those who have contributed to my research in any other way.

I want to thank the members of my graduation committee from the Delft University of Technology for their guidance throughout this process. I would like to express my deepest appreciation to Marian for the incredible amount of support, time and feedback you have provided. Your fast replies, numerous meetings and meaningful insights were extremely helpful. Louis, thank you for your useful comments during our meetings, your advice, and for your appreciation for my work. I would also like to thank the chairman of the committee, Hans Wamelink. Thank you for believing in my research, your helpful advice, and insights: I really appreciate it!

I would also like to thank my two supervisors from Brink Management / Advies, Toine and Carolien. Toine, thank you for the time and effort that you have dedicated to my research, your quick responses, feedback and guidance throughout this process. I really appreciate that you regularly checked in with me to ask how I was doing and if I needed help with anything. Lastly, Carolien, thank you for all your feedback on my research. You always provided a different viewpoint to my research which helped me to reevaluate certain aspects in order to improve them.

Finally, I want to thank my boyfriend, family and friends for all their personal support throughout my thesis and the last few years. It has been a challenging journey, and I would not have been able to do this without you.

Valery Lambermon
Warmond, June 2020

Executive summary

The implementation of BIM is one of many developments in the building industry that is hindered by resistance to change. Enthusiastic key players can boost the use of developments, such as BIM, and increase readiness to change and acceptance. Therefore, it is crucial that important stakeholders in the industry are committed to new developments. This research was initiated because project managers, an important stakeholder in the industry, still portray resistance to BIM applications. Studies show that project managers are among the key players in BIM implementation as the project manager is the center of communication and is highly influential to decision-making in projects. Especially when there is no clear vision on BIM, implementation is highly dependent on the project manager of a specific project.

However, there is still little research on how project managers experience BIM. Therefore, this research explores the perspectives of project managers towards BIM implementation. The aim of the research is to visualize the perspectives of project managers and to develop a strategy to deal with contemporary barriers that project managers perceive. The research question is as follows: Which strategy can be developed to overcome barriers perceived by project managers towards BIM application in the building industry?

This research applies Q-methodology to visualize the perspectives of project managers. The perspectives are subsequently used to distinguish specific barriers that are perceived by project managers. In Q-methodology participants are asked to sort multiple statements on a sorting table from 'Least important' to 'Most important'. The following sorting question was asked during this session: "Which factors are important to you when considering whether you will apply BIM in your next project?" The participants were confronted with statements that are developed based on literature research and semi-structured interviews. The statements can be placed in two themes, namely perceived benefits and barriers of BIM application. The study consisted of 24 participants who each sorted 32 statements and answered questions in a Q-interview.

The results of this research indicate that three perspectives can be distinguished. The first perspective [N=17 participants], also called (BIM) supporters, consists of a group of enthusiastic BIM drivers who only experience the benefits of BIM. On average, this group of project managers has the most BIM experience of all perspectives. Given the aim of this study, this perspective has not been investigated further in the rest of the study.

Perspective two [N=4 participants], also known as the moderately hesitant group of project managers, experiences resistance towards implementing BIM because of multiple barriers. Not only do they lack knowledge about the possibilities, rules, and standards of BIM. They also experience a lack of comfort to manage a project in which BIM plays a role. Clearly, this plays a major role in their consideration of applying BIM in their projects and often leads to a reluctance to initiate BIM use. The project managers in this perspective have the most work experience and the least amount of BIM experience.

Perspective three [N=3 participants] is a critical group of project managers who are unsure whether BIM's benefits outweigh the investment costs. Furthermore, this group has doubts about whether the client is ready to apply BIM for facility management, in which, according to these project managers, the most benefits of BIM can be achieved. This perspective consists of the youngest group of project managers and thus belongs to the youngest generation. They have relatively much BIM experience, especially given their limited work experience.

After the interpretation phase of Q-methodology, in which the three perspectives were identified, an overview was created of the most critical barriers of perspective 2 and 3. Subsequently, a literature study was performed on change and transition management. Complementary to the literature on this topic, information was gathered by asking the participants of the Q study to provide suggestions on how to enthuse project managers to apply BIM. The results of the literature study and the propositions of the participants formed the starting

point for the development of the strategy to deal with the barriers from the research. To outline the strategy, it is recommended to (1) identify the perspectives of the project managers within the organization, (2) implement a customized approach to deal with barriers of the perspectives and (3) to monitor the implementation of BIM through recurring sessions with a project- and people-related goal.

To ensure that the barriers can be dealt with, a strong coalition must first be formed within the organization involving upper management, BIM experts, and early adopters. As a group, they are responsible for creating a sense of urgency within the organization. A clear BIM vision must be developed and communicated by this coalition. The inclusion of upper management is highly recommended as it expresses their commitment to the implementation of BIM within the organization.

When the required preparations are complete, an organization-wide "BIM Insights" session should be organized. This session will have a project- and people-related goal. On the one hand, this session will discuss why and how BIM will be used in projects. It is recommended to suggest PMs to implement a meeting at the start of each project in which the objectives and ambitions for the application of BIM are determined in consultation with a BIM expert. On the other hand, during this session an overview will be created through a (short) survey, where the project managers can identify which perspectives they relate to and indicate potential barriers that they perceive.

As a follow-up to the "BIM Insights" session, the barriers of perspective 2 and 3 can be dealt with based on the customized perspective approach. It is proposed for perspective 2 to emphasize on providing guidance and education to the project manager. In perspective 3, the emphasis should mainly be on education as there is less need for guidance. Through recurring "BIM Sharing" sessions, feedback can be obtained about the change process, both project- and people-related. Topics that will be discussed during these sessions include the use of BIM, the satisfaction of the project managers, lessons learned, and quick wins.

The theoretical implication of this study is the contribution to the field of BIM perspectives. The results of this research can be used as a starting point for future studies and to broaden the knowledge of BIM perspectives. The practical implication of this study includes the application of the perspectives found in this research and the implementation of the proposed strategy. The results of this study increase the understanding of resistance of project managers towards the implementation of BIM. Subsequently, organizations can apply the proposed strategy to find out whether project managers relate to one of the perspectives, to reach those who are resistant, and to deal with their corresponding barriers in a customized manner.

Despite the limited statistical generalizability, the results of this research are analytically generalizable. Q-methodology aims to identify shared viewpoints and provide insights into a topic, rather than generalizing to a wider population. To enhance this research, it is recommended for future studies to further investigate this topic with research methods more suitable for statistical generalizability. Furthermore, it is proposed to conduct similar research about other stakeholders in the building industry to further contribute to the limited literature on BIM perspectives.

Samenvatting

De implementatie van BIM is een van de vele ontwikkelingen in de bouwindustrie die geremd wordt door weerstand tegen verandering. Het is van groot belang dat belangrijke actoren in de industrie zich hard maken voor nieuwe ontwikkelingen, willen deze geaccepteerd en gedragen worden door anderen. Enthousiaste sleutelfiguren kunnen het gebruik van ontwikkelingen, zoals BIM, namelijk een boost geven. Dit onderzoek is geïnitieerd omdat projectmanagers, belangrijke actoren in de industrie, nog weerstand tonen tegenover BIM-applicaties. De literatuur wijst uit dat projectmanagers behoren tot de sleutelfiguren van BIM-implementatie. De projectmanager is namelijk de spin in het web en heeft invloed op de besluitvorming in projecten. Met name wanneer er nog geen duidelijke visie is op BIM, is implementatie sterk afhankelijk van de projectmanager van een specifiek project.

Er is echter nog weinig onderzoek over hoe projectmanagers BIM ervaren. Dit onderzoek gaat daarom verder in op de perspectieven van projectmanager tegenover BIM. Het doel van het onderzoek is om een strategie te ontwikkelen die gevonden barrières om BIM toe te passen vermindert. De onderzoeksvraag luidt als volgt: Welke strategie kan worden ontwikkeld om barrières te overkomen die door projectmanagers worden ervaren omtrent het toepassen van BIM in de bouwindustrie?

Dit onderzoek maakt gebruik van Q-methodologie om de perspectieven van projectmanagers in kaart te brengen. De gevonden perspectieven kunnen vervolgens gebruikt worden om te achterhalen welke specifieke barrières nog ervaren worden door projectmanagers. Q-methodologie is een methode waarbij deelnemers gevraagd worden om verschillende stellingen te sorteren in een sorteertabel van 'Minst belangrijk' tot 'Meest belangrijk'. De volgende sorteervraag is gesteld tijdens deze sessie: "Welke factoren zijn voor u belangrijk in uw overweging om BIM toe te passen in uw volgende project?" De stellingen waarmee de deelnemers geconfronteerd werden zijn opgesteld aan de hand van literatuuronderzoek en semigestructureerd interviews. De stellingen zijn te plaatsen in twee thema's, namelijk voordelen van het toepassen van BIM en barrières om BIM toe te passen. Het onderzoek bestond uit 24 deelnemers die elk 32 stellingen hebben gesorteerd en vragen hebben beantwoord in een Q-interview.

Uit het onderzoek is gebleken dat er drie perspectieven zijn te onderscheiden. Het eerste perspectief [N=17 deelnemers], ook wel (BIM) supporters genoemd, bestaat uit een groep enthousiaste BIM-aanjagers die alleen voordelen van BIM ervaren. Deze groep projectmanagers heeft gemiddeld de meeste BIM-ervaring van alle perspectieven. Gezien het doel van dit onderzoek, is dit perspectief in de rest van het onderzoek niet verder onderzocht.

Perspectief twee [N=4 deelnemers], ook wel de terughoudende groep projectmanagers, ervaart weerstand om BIM te implementeren vanwege meerdere barrières die zij ervaren. Niet alleen hebben ze een gebrek aan kennis over de mogelijkheden, regels, en standaarden van BIM, ze ervaren ook een gebrek aan comfort om leiding te geven op een project waarin BIM een rol speelt. Dit speelt uiteraard een grote rol in hun overweging om BIM toe te passen in hun projecten, en leidt vaak tot een terughoudendheid om BIM-gebruik te initiëren. De projectmanagers in dit perspectief beschikken over de meeste werkervaring en behoren dus tot de oudste generatie. Daarnaast hebben zij de minste BIM-ervaring.

Perspectief drie [N=3 deelnemers] is een kritische groep projectmanagers die twijfelt of de voordelen van BIM opwegen tegen de investering. Daarnaast twijfelt deze groep of de klant klaar is om BIM toe te passen tijdens de beheer en onderhoudsfase, waarin volgens deze projectmanagers de meeste voordelen van BIM te behalen zijn. Dit perspectief bestaat uit de jongste groep projectmanagers en behoren dus tot de jongste generatie. Zij hebben relatief veel BIM-ervaring, zeker gezien hun beperkte hoeveelheid werkervaring.

Aansluitend op de interpretatiefase van Q-methodologie, waarin de drie perspectieven geïdentificeerd zijn, is een overzicht gemaakt van de meest kritieke barrières van perspectief 2 en 3. Vervolgens is literatuuronderzoek uitgevoerd op het gebied van verander- en transitiemanagement. Als toevoeging op de literatuur over dit onderwerp zijn de deelnemers van het Q-onderzoek gevraagd om advies te geven over op welke manieren projectmanagers kunnen worden geënthousiasmeerd om BIM toe te passen. De resultaten van het literatuuronderzoek en de antwoorden van de deelnemers vormen de basis voor de ontwikkeling van de strategie om de barrières uit het onderzoek te mitigeren. In grote lijnen is het advies om (1) in kaart te brengen in welke perspectieven de projectmanagers binnen de organisatie vallen, (2) een op maat gemaakt plan van aanpak uit te voeren aan de hand van de barrières van de perspectieven en (3) om door middel van terugkerende sessies te monitoren hoe de implementatie van BIM loopt op project- en mensniveau.

Om te zorgen dat de barrières aangepakt kunnen worden moet er eerst een sterke coalitie gevormd worden binnen de organisatie waarbij hoger management, BIM-experts en early adopters betrokken zijn. Gezamenlijk zijn zij verantwoordelijk voor het inzichtelijk maken van de noodzaak om BIM toe te passen in projecten binnen de organisatie. Daarnaast zal er een duidelijke BIM-visie ontwikkeld en gecommuniceerd moeten worden. Door middel van een coalitie wordt aangegeven dat hoger management de ontwikkeling van BIM wil uitdragen binnen de organisatie.

Wanneer de benodigde voorbereidingen getroffen zijn, kan er een organisatie-brede "BIM Insights" sessie georganiseerd worden met een project- en mens-gerelateerd doel. Enerzijds zal tijdens deze sessie behandeld worden waarom en hoe er met BIM gewerkt gaat worden. Zo wordt er voorgesteld dat er aan het begin van elk project een BIM-vergadering plaats zal vinden waarin (met behulp van een BIM-expert) de ambities en doelstelling bepaald worden voor de toepassing van BIM in het project. Anderzijds zal er tijdens deze sessie in kaart worden gebracht onder welke perspectieven de projectmanagers vallen aan de hand van een (korte) survey. Daarnaast kunnen projectmanagers aangeven welke eventuele andere barrières zij ervaren.

Als vervolg op de "BIM Insights" sessie kan er, aan de hand van de op maat gemaakte aanpakstrategie, worden omgegaan met de barrières van perspectief 2 en 3. Er wordt voorgesteld om de nadruk bij perspectief 2 te leggen op het ondersteunen en opleiden van de projectmanager. Bij perspectief 3 moet de nadruk vooral liggen op het opleiden, en is er minder noodzaak voor ondersteuning. Door middel van terugkerende "BIM Sharing" sessies kan er feedback verkregen worden over het implementatietraject, wederom op project- en mensniveau. Onderwerpen die tijdens deze sessies aan bod komen betreffen: het gebruik van BIM, de tevredenheid van de projectmanagers, lessons learned en quick-wins.

De theoretische implicatie van deze studie is de bijdrage die de resultaten leveren op het gebied van BIM-perspectieven. Deze resultaten kunnen worden gebruikt als startpunt voor vervolgstudies en om de kennis van BIM-perspectieven te verbreden. De praktische implicatie van deze studie bestaat uit de toepassing van de perspectieven gevonden in dit onderzoek en de implementatie van de voorgestelde strategie. De resultaten van dit onderzoek vergroten het inzicht in de potentiële weerstand van projectmanagers tegen de implementatie van BIM. Vervolgens kunnen organisaties de strategie toepassen om met de gevonden barrières om te gaan.

Ondanks de beperkte statistische generaliseerbaarheid, is er sprake van theoretische generaliseerbaarheid. Het doel van Q-methodologie is om verschillende standpunten te identificeren en inzichten te verschaffen in een onderwerp, in plaats van te generaliseren naar een bredere populatie. Als toevoeging op dit onderzoek wordt voor vervolgonderzoek aangeraden om dit onderwerp verder te onderzoeken met onderzoekmethoden die geschikt zijn voor statistische generaliseerbaarheid. Daarnaast wordt voorgesteld om soortgelijk onderzoek uit te voeren op andere stakeholders in de bouwindustrie om verder bij te dragen aan de beperkte literatuur over BIM-perspectieven.

Table of contents

List of figures

List of tables

List of abbreviations

AEC: Architecture, engineering and construction
BIM: Building information modeling / management
BMA: Brink Management / Advies
PM: Project manager

1 Introduction

Building information modeling / management (BIM) technology is frequently used to assist professionals in the building industry for planning, designing, building, managing and operation purposes (Azhar, 2011). BIM entails much more than information modeling only, and currently includes many additional areas of innovation (Hardin & McCool, 2015). Among other benefits, BIM claims to decrease failure costs, and increase collaboration, productivity, and efficiency (Siebelink, Voordijk & Adriaanse, 2018). Even though BIM technology has been around for decades, its implementation in the building industry has been relatively slow in comparison to other industries such as manufacturing (Chan et al., 2019; Enshassi et al., 2019; Smith, 2014).

1.1 Research context

According to Hardin & McCool (2015), tools, processes, and behaviors are the three components that are required for successful BIM integration. Research by Siebelink, Voordijk & Adriaanse (2018) emphasizes the importance of 'people and culture' for the success of BIM implementation. Factors related to people and culture include personal motivation and willingness to change. Lahdou and Zetterman's (2011) research shows that all project team members must believe in the significance of BIM to have a satisfactory outcome.

Recent studies show that there are still numerous obstacles that hinder the implementation of BIM. For example, research by Enshassi et al. (2019) and Sun et al. (2017) shows that one of the complications often encountered in the building industry is the lack of managers' awareness and support. Gu & London (2010) argue that resistance to change is evident in the industry and Liao & Ai Lin Teo (2018) state that resistance to change is one of the main obstacles that delay the adoption of BIM in the building industry. Recent research by Jamal et al. (2019) also indicates additional barriers such as a resistance towards change within organizations, a lack of active participation from employees and a reluctance to change by members of project teams.

1.2 Problem statement

This research was initiated by a practical problem in the Dutch architecture, engineering and construction (AEC) industry. It has been observed that a group of project managers is still present who prefer not to initiate BIM in their projects. Referring to literature, it is evident that resistance to change is still a contemporary barrier leading to slow implementation of BIM in the AEC industry (Bosch-Sijtsema et al., 2019; Chan et al., 2019; Enshassi et al., 2019; Jamal et al., 2019; Liu et al., 2019; Sun et al., 2017).

It is often unclear which actors are implied when resistance to change is referred to as a barrier in previous studies. For example, Jamal et al. (2019) mention a reluctance of change by *members of project teams*, Chan et al. (2019) mention a resistance to change by *construction stakeholders*, Enshassi et al. (2019) mention a resistance to change by *staff*, Liu et al. (2019) mention a resistance to change at *management levels*, and Sun et al. (2017) mention *habitual* resistance to change.

To conclude, when referring to the literature on this subject, it is indistinct whether project managers are part of the issue with regards to resistance to change. However, if project managers are resistant towards BIM implementation, this can have a negative effect on the implementation of BIM in the industry. Management support is proven to be important for BIM adoption (Chen et al., 2019; Liu et al., 2010). Project managers are influential to decision-making in projects (Gu & London, 2010), so when there is no clear vision on BIM present, BIM implementation is dependent on the project manager of a specific project (Maki & Kerosou, 2019).

A relationship was found between efforts made by management to promote BIM adoption and actual BIM implementation (Yuan et al., 2019). Furthermore, respondents of research by Miedema (2019) unanimously agreed that both senior and project managers are among the key figures for BIM implementation. Lastly, research by Lindblad & Guerrero (2020) argues that managers play an integral role in how innovations such as BIM are promoted.

1.3 Research objectives

This research will further explore the relationship between PMs and BIM implementation by exploring the perspectives of PMs concerning BIM. This research aims to identify the perspectives of PMs towards BIM implementation in the building industry and to develop a customized strategy to incentivize PMs to consider BIM for their projects. The goal is not to apply BIM to every project but to ensure that PMs consider BIM and can make a well-informed decision about it.

The main **research objectives** are:

(1) to discover which perspectives of PMs are present concerning BIM application by interviewing PMs who are active in the building industry;

(2) to develop a customized strategy to incentivize PMs to consider BIM by targeting critical barriers and considering the benefits of applying BIM specifically for PMs. The strategy will aim to incentivize PMs to consider BIM when their project can benefit from the implementation of BIM if (1) all facilities to work with BIM are already present or (2) investments still need to be made. In both cases, the strategy aims to direct the PMs to embrace the implementation of BIM in their projects;

(3) to extend past research by distinguishing perspectives of PMs towards BIM, by creating an inventory of factors that influence resistance to change and reluctance among PMs and creating a customized strategy for PMs in the building industry.

1.4 Research question

To summarize, there are two main drivers of this research: an observed reluctance of PMs to implement BIM into projects and an overall slow implementation of BIM in the building industry. The following **research question** and **sub-questions** are addressed in this research, see Figure 1.

RQ	Which strategy can be developed to overcome barriers perceived by project managers towards BIM application in the building industry?	
SQ1	Which perceived benefits and barriers do project managers experience towards BIM application?	Literature study Semi-structured interviews
SQ2	Which perspectives can be distinguished of project managers towards BIM application?	Q-sort Q-discussion } Q-study
SQ3	Which factors can be identified as barriers leading to reluctance of PMs to apply BIM to their projects?	Q-study
SQ4	How can factors that lead to reluctance to change be influenced?	Q- and Literature study Expert interviews

Figure 1 Research question and sub-questions

1.5 Relevance of the research

Plentiful research has been performed on the barriers and benefits of BIM implementation. However, the impact of individual perceptions on BIM is disregarded in literature, even though research has shown that there is a correlation between individual perceptions and BIM implementation (Howard et al., 2017). Research by Zhou et al. (2017) suggests that there is a knowledge gap in BIM studies on the perceptions of individual participants for each project phase. Zhao, Pienaar & Gao (2018) and Enegbuma, Aliagha & Ali (2015) suggest that future research on the perspectives of project participants towards BIM is worth paying attention to. Specifically, there is little research on the PMs' perspective on BIM (Bryde, Broquetas & Volm, 2012; Sawhney, Khanzode & Tiwari, 2017; Xiao & Noble, 2014). To conclude, exploring the PMs' perspective towards BIM implementation and studying which factors influence their opinions on BIM is of added value to literature and practice.

1.6 Scope of the research

Brink Management / Advies (BMA) is the starting point of this research. To expand the scope and increase the value of this research, participants from other organizations are also involved. In total, participants from four companies are included in the research: two consultancy firms, and two governmental organizations.

The scope of this research is aimed at PMs who are active in the building industry. Since BMA's projects take place in this field, the participants from BMA who will participate in this research will mainly provide a perspective from this industry. To maintain the scope of this research, participants included from other organizations will be selected on their experience in the same field. The pre-construction phase is often the starting point of the discussion surrounding BIM and whether the client wishes to apply BIM to their project. However, applying BIM in the construction phase also offers various benefits. Hence, this research will predominantly focus on the pre-construction and construction phases of projects in the building industry.

1.7 Structure of the research

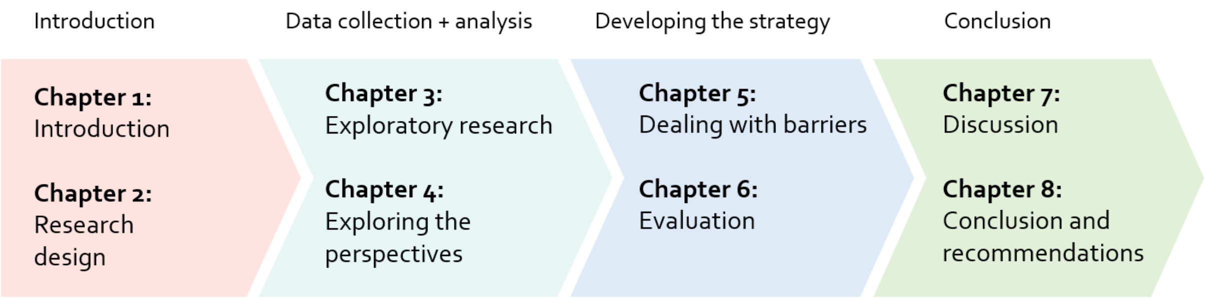


Figure 2 Overview of the structure of the research

An overview of the structure of the research can be found in Figure 2. This report can be divided into four parts: (1) Introduction, (2) Data collection + analysis, (3) Developing the strategy, and (4) Conclusion. The introduction phase consists of two chapters. Chapter 1 presents the introduction to the research, and Chapter 2 describes the research design. Chapter 3 and 4 consist of exploratory research and explores the perspectives of PMs on BIM. Subsequently, the data will be further analyzed in Chapter 5, where various methods are proposed to deal with the barriers found in the research. Chapter 6 will evaluate the proposed strategy. Finally, the conclusion phase will consist of Chapter 7 and Chapter 8. Chapter 7 will present a discussion of the research. The research will finish with the conclusion and recommendations in Chapter 8.

2 Research design

In this chapter, the research design will be presented. First, the main research strategy will be introduced. Subsequently, the research approach will be discussed. In the research approach, the applied research method per sub-question will be discussed.

2.1 Main research strategy

The starting point of the research methodology is choosing the main research strategy. This research can be identified as exploratory research that tries to find correlations between various factors and aims to develop relevant hypotheses and recommendations for further research (Yin, 2014). Exploratory research starts with suspicions and aims to be able to formulate statements about reality (Van der Voordt, 1998). According to Yin (2014), an exploratory study can choose any of five research strategies: experiment, survey, archival analysis, history, or case study. The case study strategy is applicable when the researcher is interested in an in-depth study of a complex case (Verschuren & Doorewaard, 2015). As a strategy it aims to investigate:

(a) 'a contemporary phenomenon in its real-life context, especially when
(b) The boundaries between phenomenon and context are not clearly evident' (Yin, 2014)

This research can be seen as a case study on PMs and their perspectives on BIM at BMA and a small number of additional organizations. Considering the aims and objectives of this research, a case study research strategy is best suitable.

A case study research approach allows for multiple data gathering methods (Saunders et al., 2011). In this research, a multi-method approach will be used to gather data. Multi-method approaches provide a more complete picture of the subject and allow for an overall better understanding (Teddlie & Tashakkori, 2003). The following research methods are applied in this study: literature studies, semi-structured interviews, Q-methodology, and expert interviews.

2.1.1 Literature studies

A literature study is an extensive summary of previous research on a topic. Three literature studies will be performed to develop a theoretical background and provide context to the research. The first literature study aims to show the relevance of the research and explore the knowledge gap to prevent duplication. It creates a broader perspective on the subject and places the research in context. The second literature study aims to develop the universe of statements concerning BIM from the perspective of PMs, which is the first step of Q-methodology (see 2.1.3 for more information on Q-methodology). Lastly, to develop a theoretical background for the creation of the proposed strategy to deal with barriers perceived by PMs, a literature study is performed on change and transition management.

2.1.2 Semi-structured interviews

Semi-structured interviews are a research method often used in qualitative research. Semi-structured interviews are characterized by a combination of closed- and open-ended questions which are often followed by 'why' and 'how' questions. They are especially valuable in multi-method research and provide an added dimension to research (Newcomer, Hatry & Wholey, 2015). Semi-structured interviews will function as a supplementary data-gathering method for the universe of statements. The universe of statements required for Q-methodology can be created through primary and secondary sources such as literature study, interviews, and media output (Cross, 2005).

2.1.3 Q-methodology

Q-methodology is the main data gathering method of this research. Q-methodology is selected to allow for in-depth semi-quantitative analyses on the perspectives of PMs from various organizations. Currently, Q-methodology is a popular research method to study attitudes towards various subjects, such as the adoption of information technology, patients' needs and concerns (in medical research), environmental issues and education (Ten Klooster et al., 2008). Q-methodology leads to a clearer understanding of complexities and viewpoints (Zabala, Sandbrook & Mukherjee, 2018). Even when opinions are heterogeneous, Q-methodology can identify potential patterns between the participants (Lee, 2017). The following steps are required to perform the Q-study (Zabala, Sandbrook & Mukherjee, 2018), see Figure 3.

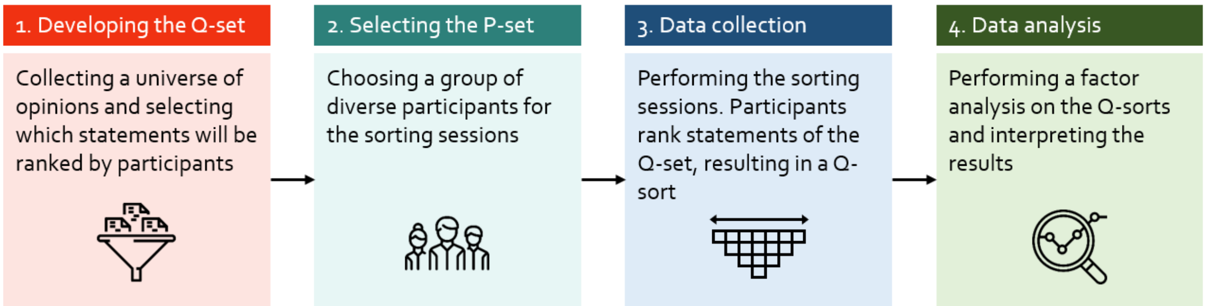


Figure 3 Q-methodology procedure

2.1.4 Expert interviews

The goal of expert interviews is to bring together the knowledge of various experts to gather feedback. Four expert interviews will be performed to evaluate the proposed strategy to deal with the barriers found in the Q-study. Questions will be asked regarding the feasibility and applicability of the proposed strategy.

2.2 Research approach

The research approach can be divided into two phases and is based on the required steps of Q-methodology. Phase 1 will provide an answer to SQ1 - SQ2 and studies the perspectives of PMs towards BIM implementation. In this phase, the Q-study is prepared, performed, and the required theoretical background is presented. Phase 2 of the research addresses SQ3 and SQ4. This phase aims to develop a strategy to deal with the critical factors found in the first phase through an analysis of the results of the Q-study, supplementary literature study and expert interviews. An overview of the research approach can be found in Figure 4.

1	SQ1	Literature study Semi-structured interviews	Developing a universe of statements for Q-study
1	SQ2	Q-study	Distinguishing the perspectives concerning BIM application
2	SQ3	Q-study	Interpretation of the results of the Q-study
2	SQ4	Q- and Literature study Expert interviews	Analyze solution directions and develop a strategy to mitigate critical factors
	RQ	Combining the results	Concluding the research by presenting the results

Figure 4 Research approach per sub-question

The starting point of this research is to create a comprehensive inventory of opinions on BIM from the perspectives of the target group, PMs. The goal of **SQ1** is to obtain a 'universe of opinions' from the perspective of PMs concerning BIM. This SQ is essential to this research as it forms the base of statements that will be used to distinguish different perspectives of PMs (SQ2). A multi-method, exploratory approach will be applied when answering SQ1, namely a literature study and semi-structured interviews.

The literature study and semi-structured interviews will be used to gather a range of opinions (perceived benefits and barriers) of PMs concerning BIM. The interviews aim to gather opinions on how BIM is perceived in practice. Therefore, the interviews are performed with experienced BIM professionals, who can provide more background information on how BIM is perceived in practice. This will add to the literature study, and check whether significant factors are missed in the literature study.

Due to the large amount of data gathered in this phase of the research, it is necessary to structurally analyze the data from the literature study and interviews. A common method to analyze qualitative data is coding, and the selected method for data analysis is thematic coding. The result of this part of the research is the Q-set, which will be the starting point of the Q-study. The results of the Q-study will provide an answer to **SQ2** and distinguishes the perspectives of PMs on BIM application.

Phase 2 of the research will answer **SQ3 - SQ4** and consists of developing a strategy to deal with the barriers found in the Q-study. The start of this phase will consist of an analysis of the Q-study results and a literature study on change and transition management theories. Subsequently, a strategy will be proposed which is evaluated in the following chapter through expert interviews. At the end of this phase, the final strategy is presented.

3 Exploratory research

The goal of the exploratory research is to provide a theoretical background on the research topic. To explore relevant literature for this research, academic literature was consulted through Google Scholar. The following topics are researched individually:

(1) BIM in the architecture, engineering and construction (AEC) industry
(2) BIM application by PMs
(3) Resistance to change

The literature study starts with topic (1) on BIM in the AEC industry. This study is required for this research because it provides an essential and contemporary theoretical background that is necessary to understand the research topic. To properly address this topic, various keywords are investigated such as 'BIM', 'building information management' and 'building information modeling' in combination with 'building industry' and 'AEC industry'. To provide a broad view on how BIM is applied and perceived in the industry, keywords such as 'application', 'usage', 'implementation' are investigated individually and in combination with keywords such as 'benefits', and 'barriers.

Subsequently, the literature study narrows down towards the following topic (2), namely BIM application by PMs explicitly. This study aims to provide context on the applications, benefits and barriers of BIM usage for PMs. Keywords such as 'manager', 'management', 'project management', and 'project manager' are combined with 'BIM' and 'building information modeling'.

Lastly, the exploratory research will focus on the contemporary issue present in the AEC industry (3) resistance to change. Resistance to change is studied comprehensively to develop a theoretical background on the topic. This will help create a broad understanding of why resistance to change occurs, before the connection is made towards resistance to change in the AEC industry.

3.1 BIM in the architecture, engineering and construction (AEC) industry

This section will provide a general overview of BIM in the AEC industry. The goal of this section is to introduce BIM and present the benefits and challenges that working with BIM entails.

3.1.1 Defining BIM

Various articles and studies have attempted to define BIM, which has led to uncertainties and a lack of clarity surrounding the term 'BIM'. Therefore, the first step of this literature study is to clarify how BIM is defined in this research.

Siebelink, Voordijk & Adriaanse (2018) studied multiple articles to define BIM. They describe BIM as "an object-based and multidisciplinary approach aimed at facilitating collaboration between parties and the integration of object-related information over the entire life cycle of an asset. This function is supported by IT, through which building objects are often captured in 3D representations". This definition is in line with Succar's definition who also emphasizes that BIM is more than just software for modeling. Succar defines BIM as a 'set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle' (Succar, 2010).

The following categories are reoccurring when analyzing the definitions found in literature: the management of data, the collaborative aspect, the digital aspect and efficiency that can be achieved throughout an assets' entire lifecycle.

BIM is sometimes referred to as 'nD' modeling, which implies that the building information model can be extended with 'infinite' dimensions, such as 4D, 5D, 6D … nD (Eastman et al., 2008). The definition of 4D and 5D BIM is generally agreed upon. 4D BIM represents the planning or scheduling linked to the three-dimensional information model and 5D BIM represents the dimensions where cost information is linked to the model. There is a lack of clarity and agreement on the definitions above the 5^{th} dimension. Recent research by Charef, Alaka & Emmitt (2018) has studied the dimensions and concluded the following: 6D BIM is mostly related to sustainability (86%) and the 7D BIM dimension is generally used to describe facility management activities (85%). These dimensions will also be used for the rest of this research and are visualized in Figure 5.

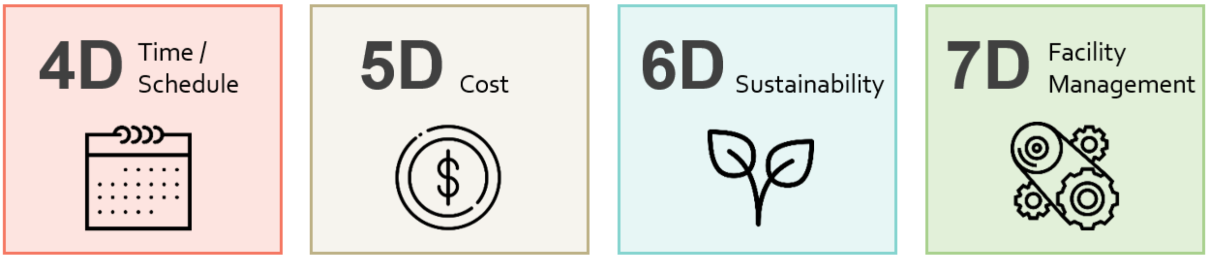


Figure 5 BIM dimensions

3.1.2 Applications of BIM

The applications of BIM in the AEC industry will be presented based on the following phases of an AEC project: pre-construction, construction, and post-construction. The scope of this research is restricted to the design (part of the pre-construction phase) and the construction phase.

Pre-construction phase

According to Azhar et al. (2012), there are three applications of BIM in the pre-construction phase: estimating, site coordination and constructability analysis. Latiffi et al. (2013) also mention BIM applications in the modeling, planning, design and scheduling activities of the pre-construction phase. BIM enables relevant insight into the project schedule, by utilizing 4D planning, which leads to earlier detection of sequencing issues. Project stakeholders such as project managers (PMs) are enabled to track progress and optimize logistics.

Perhaps one of the most significant strengths of BIM in the pre-construction phase is the visual aspect of the model. Building virtually before real-life construction leads to better insights to all actors involved in the project. Benefits such as improved communication and clash detections are the result of virtual building. Subsequently, this will lead to quicker decision-making and detection of issues early in the design process (Chan et al., 2019).

An additional application of BIM could benefit the following aspect of the pre-construction phase: optimizing the permit granting process. Currently this is still very much in the developing stages in the Netherlands. However, various sources argue that application of BIM can lead to a more efficient permit granting process (Duivenvoorden & Alwicher, 2018; Greefhorst, Knibbe & Huisman, 2018, Olsson et al., 2018).

Construction phase

Azhar et al. (2012) distinguish the following three applications of BIM in the construction phase: progress monitoring, coordination meetings and integration of request for information (RFI), change orders and punch lists. Latiffi et al. (2013) also mention other applications of BIM during the construction phase, such as the ability to demonstrate the construction process through 4D visualizations. As an effect of the previously mentioned applications during the construction phase, correct application of BIM can improve the construction safety (Chan, 2015; Chan et al., 2019).

Post-construction phase
The main post-construction application of BIM establishes from the BIM model of the asset, which ideally consists of the full data set. This information can subsequently be used for facility management and helps make the operations and management phase of a project more efficient (Azhar et al., 2012). Scheduled maintenance is one application of BIM, as well as the possibility to retrieve maintenance history (Latiffi et al., 2013). However, compared to the pre-construction and construction phase, the use of BIM in the post-construction phase is more limited.

3.1.3 Advantages of using BIM

When considering all applications of BIM, it is evident that there are various benefits of applying BIM in an AEC project. A couple of advantages will be addressed in this section, this is not an exhaustive list.

Multiple factors of BIM contribute to communication efficiency. An example is the possibility to arrange collaborative viewing sessions. During the viewing sessions, stakeholders can come together to discuss the models (e.g. in 3D) which additionally leads to better visualization of the situation. This collaboration increases efficiency as it leads to a fast decision-making process early in the project (Chan et al., 2019). It also increases trust between the stakeholders (Azhar, 2011), leads to a better understanding of the processes and ensures early identification of issues (Latiffi et al., 2013). Furthermore, fewer change orders and RFI's (request for information) are the results of visualization through BIM (Ghaffarianhoseini et al., 2017). Not only does BIM allow for clash detection earlier in the design process, leading to better design quality, BIM also has the potential to increase the quality of information exchange throughout the project life cycle, leading to better documentation quality (Juan et al., 2017; Latiffi et al., 2013).

Ideally, when applied correctly, BIM is said to reduce frequently occurring problems in AEC projects such as delays and cost overruns (Latiffi et al., 2013). The potential benefits of BIM application in the AEC industry are generally agreed upon. However, an important problem lies in the actual benefits of BIM, which are often unclear.

3.1.4 Complications and challenges of using BIM

Multiple challenges are slowing down the implementation of BIM in the AEC industry. This is not an exhaustive list but aims to show a range of challenging factors that have arisen when implementing BIM.

Resistance to change
An important challenge of BIM implementation is the resistance to change existing ways of working and to learn new technologies (Gu & London, 2010). A study by Ahmed (2018) proved that social and habitual resistance to change was the number one factor contributing to the slow implementation of BIM in the AEC industry. Furthermore, Liao & Ai Lin Teo (2018) mention that resistance to change is one of the main hindrances that delay the application of BIM. Employees are often resistant to change their comfortable routines (Liao & Ai Lin Teo, 2018). Barlish & Sullivan (2012) state that employees might feel intimidated by the new system and some fear that their jobs will be affected negatively.

A recent study by Jamal et al. (2019) indicates resistance towards change within organizations, an absence of active participation of employees, and a reluctance to change by members of project teams. Not only employees show resistance to change, research by Migilinskas et al. (2013) states that one of the main barriers is the lack of support from senior leadership. A sectoral analysis by Siebelink, Voordijk & Adriaanse (2018) showed that willingness to change is a complicated process. Lahdou and Zetterman's (2011) research shows that project team members must believe in the significance of BIM to have a satisfactory outcome.

Investment costs
Costs are an important factor in BIM implementation. Not only does BIM require expensive software, but it also requires training of employees (Ahmed, 2018). In addition to the expenses, the learning curve is also notable. The learning curve implies that the results of BIM application are not immediately visible. Therefore, the investment costs and learning curve make it difficult to convince stakeholders to apply BIM to their projects as they are not always able to look past the initial costs (Liao & Ai Lin Teo, 2018; Migilinskas et al., 2013). It is often feared that the success will be too low to compensate for the high investment costs and that implementing BIM can lead to big failure (Migilinskas et al., 2013). One of the reasons for this is the high investment costs related to the implementation process (Liu et al., 2015).

Lack of clarity and awareness
There is a lack of clarity on how BIM is best integrated within an organization. In addition, there is a lack of understanding surrounding the changing roles and responsibilities when applying BIM (Liao & Ai Lin Teo, 2018). The amount of misconception surrounding the term 'BIM' also makes BIM adoption more challenging (Gu & London, 2010). Many people believe that BIM only consists of the one 3D model, when, BIM entails much more than that (Fazli et al., 2014).

Another important lack of awareness that is present throughout literature is the lack of awareness of BIM application in facility management. There is a lack of awareness on the benefits that BIM can have during the operation and management phase, leading to a lack of complete usage of the building information throughout the entire life cycle. A crucial consequence of this issue is that the facility management experts are not included during the early project phases, which is when the requirements for the information model are determined (Dixit et al., 2019).

The challenge of implementing BIM throughout the entire chain
Specifically, when addressing permit granting in the Netherlands, and throughout Europe (Noardo et al., 2019), there is a lack of BIM implementation possibilities. In most cases, permit granting is a manual process that consists of submissions by PDF documents. Municipalities are often not able to accept IFC (Industry Foundation Class) models. And perhaps even more challenging: The Ministerial Regulation on the Environment Act or MOR (Nederlands: Ministriele Regeling Omgevingswet, MOR) blocks the use of BIM in the permit application for the environmental permit. Partly because of these limitations with regards to legislation, the municipalities in the Netherlands are not incentivized to prepare for receiving BIM documents (Duivenvoorden & Alwicher, 2018), leading to a lack of demand from the client's perspective. A lack of client demand is clearly visible throughout literature. For example, Chan et al. (2019) found a lack of demand of innovative technologies, such as BIM, by clients.

3.1.5 Conclusion of BIM in the architecture, engineering and construction (AEC) industry

Various studies are available on the applications, benefits, and challenges of BIM. Overall, it is accepted that applying BIM has the potential to benefit all phases of construction projects. However, many studies present challenges that have risen in the past years concerning BIM implementation, such as the high investment costs and amount of required (organizational, cultural, personal, technical, legislative) change. Studies show that it is complicated to convince stakeholders to work with BIM and that there is still a lot of misconception surrounding the term. Currently, the fundamental reason for people management related challenges is often neglected in the literature. Yet, there are no studies that explore the factors that influence the resistance to change for BIM. This is a very complex challenge for BIM implementation. The opinions of various stakeholders have been researched thoroughly, such as designers. However, very little research has been performed on PMs and BIM. Considering the significant impact that PMs have on decision-making in projects, the following section will focus on BIM application by PMs.

3.2 BIM application by PMs

One of the challenges of implementing BIM is the resistance to change from employees. The scope of this research will specifically focus on the perspectives of BIM from a PMs point of view. PMs have a significant influence on the use of BIM in a project. The client, PMs and/or the facility manager are the key players who are required to make important decisions on BIM implementation (Gu & London, 2010).

The PM oversees multiple areas of a project such as cost, time, quality, safety, risk management. Moreover, the PM is in regular contact with the stakeholders. Rokooei (2015) emphasizes the necessity of knowledge of modern management when managing construction projects. Changes in technology are crucial, as well as new procedures and methods to manage organizations and projects. The PM is at the center of the projects' communication and decision-making. Therefore, Rokooei suggests that the PM should consider applying BIM as a managerial tool.

Surprisingly, PMs are one of the least researched stakeholders concerning BIM (Sawhney, Khanzode & Tiwari, 2017). Specifically, there is little research on the project managers' perspective on BIM (Bryde, Broquetas & Volm, 2012; Xiao & Noble, 2014). Due to their important role in projects, the PM must be willing to work with BIM for successful implementation. Therefore, one of the aims of this research is to distinguish which perspectives are present from PMs about BIM.

3.2.1 Opportunities of BIM for PMs

Latiffi et al. (2013) explain the opportunity for PMs to utilize BIM (specifically Autodesk Navisworks) to create a model for schedule optimization and to detect clashes. Subsequently, this model can be used as a tool to stimulate collaboration and enhance control among the different actors, such as contractors, architects, engineers. This collaboration can lead to a better insight into possible problems, increase communication and decrease risks.

Table 1 Potential benefits for PMs when using BIM (Bryde et al., 2013; Allison, 2010)

Potential benefits for PMs	Why?
Organize the project schedule and budget	An integrated 5D BIM model immediately updates both the schedule and budget when any design change occur
Work well with the Design Team	By using the integrated 5D BIM model to visualize and explore the impact of changes, PMs can keep project scope in check and become a trustworthy liaison between the designers and Owner
Hiring and controlling the Subcontractors	Having a handle on clash detection and coordination plays a key role in keeping Sub-contractors' work predictable
Requests For Information (RFIs) and Change Orders	Utilizing Coordination Resolution in preconstruction, these numbers can be brought to near zero
Optimize the Owner's experience and satisfaction	Owner received a big injection of confidence in the GC when the PM showed him/her how design decisions impacted cost and schedule
Project closeout	PM to present a 7D BIM–a facilities resource with information on warranties, specifications, maintenance schedules, and other valuable information
Profit margin	By thoroughly understanding the project in 5D, the PM has more tools at his disposal to keep tight reins, and more reports to monitor progress
Progressive Owners are mandating BIM on their projects:	Becoming the BIM expert, in both preconstruction and out in the field, makes the PM invaluable and a key player.
PM Firm Growth	Project's success with 5D BIM means the opportunity to grow the firm's reputation and helps the corporate team win new business.

Rokooei (2015) presented knowledge areas of PMs (based on PMBOK: Project Management Body of Knowledge definition) in combination with the corresponding BIM aspects that can provide opportunities for PMs. To mention a few, the PM is responsible for planning, time management, cost estimation, and monitoring progress. As Rokooei (2015) suggests, there are many aspects of BIM that help contribute and guide a PM with their responsibilities. For example, BIM aspects such as 4D and 5D modeling enable visualization of the project throughout time and costs. These tools can assist during decision-making processes when alternative designs are compared based on time and cost estimations, and they can assist in progress monitoring. As documentation is centralized, the risk of poor communication is mitigated for PMs.

Allison (2010) presented the benefits of BIM for the role of PM, which was then expanded by Bryde et al. in 2013. The results of this research are presented in Table 1. To conclude, BIM tools and aspects can be applied by PMs to help improve communication, collaboration, and coordination throughout their projects.

3.2.2 Challenges of BIM for PMs

Theoretically, BIM potentially provides PMs with numerous valuable applications to support their work and provide guidance. However, several challenges are presented in the literature when researching the role of PM with BIM.

Rokooei (2015) emphasizes the relationship between BIM success and the experience level of a PM. Research by Tauriainen et al. (2016) found that PMs are often unfamiliar with BIM. Unfamiliarity often makes PMs uncomfortable with BIM implementation in their own projects because of the various unknowns. PM's inexperience with BIM often makes them unable to properly evaluate the design and modeling contract and struggle to determine the magnitude of the modeling processes.

A study by Fazli et al. (2014) shows that PMs understand the potential advantages that working with BIM has, especially the 4D aspect of BIM (building information model linked with time). Nevertheless, the main challenge of convincing PMs to work with BIM was their personal opinions. Vass & Gustavsson (2017) specifically emphasize that PMs are hard to convince when it comes to applying BIM for their projects. Eastman et al. (2008) also mention that convincing staff, like PMs, to transition into working with new technologies such as BIM is one of the greatest challenges of implementation. Collaboration is such a significant feature of BIM, therefore a crucial factor in the effectiveness of BIM is the attitude of team members. Especially the attitude of the PM is crucial because they are the center of communication in a project (Rokooei, 2015).

3.2.3 Conclusion of BIM application by PMs

Previous studies show how BIM applications can provide guidance and support to PMs to improve communication, collaboration, and coordination throughout their project. Studies show a resistance from PMs to work with BIM, and it is emphasized that PMs are hard to convince when it comes to applying BIM to their projects. A lack of research into the perspectives of PMs on BIM exists, and there is a lack of research on the influence mechanisms that lead to resistance from PMs concerning BIM. Therefore, the following section will further explore the general reasoning behind resistance to change and resistance to innovation.

3.3 Exploring resistance to change

This part of the literature review explores why certain groups of people feel resistance when they are expected to change. This study is valuable to this research because it leads to a broader understanding of the topic. Subsequently, the results of this research can be compared to the broader literature available on this topic.

3.3.1 Defining resistance to change

Resistance to change can be defined as 'a (negative) attitude towards change, which includes affective, behavioral, and cognitive components' (Oreg, 2006), see Table 2.

Table 2 Definition of resistance to change by Oreg (2006)

Affective	'The negative emotions that individuals feel about change'
Behavioral	'The negative actions, or intentions to act, in response to change'
Cognitive	'The negative beliefs about the change such as 'change is unnecessary' and 'change will not be beneficial''

Erwin & Garman (2010) state that 'resistance to change is the number one reason for failures of organizational change initiatives. Their research explains affective reactions that one might feel to be stress, anxiety, anger. Or positively: enthusiasm and apprehension. Individuals might choose to embrace the change or complain about it.

Boonstra (2004) provides several understandings found in literature on the perceived definitions of resistance to change. On one hand, it is described as a behavior explained by psychology through factors such as fear, a lack of motivation or a preference for stability. On the other hand, resistance is explained as a misunderstanding of the change, or doubts from employees regarding the objectives or feasibility. When considering resistance to change from this perspective, it can be argued that it should be an expression of concern that should be taken seriously.

According to Huy (2002) and Kiefer (2005), one of the reasons why negative emotions arise is because change is often inseparable from disruption. Rafferty & Jimmieson (2017) suggest that changes to fundamental aspects of employees' work environment (e.g. structure, strategy or values) lead to much uneasiness because of the degree of required adaptation. Subsequently, this can lead to affective, behavioral, and cognitive resistance to change. Rafferty & Jimmieson (2017) argue that frequent change also increases the resistance to change.

Davis & Songer (2002) divided resistance to change into three factors: (1) Cause of resistance – Why is change resisted? Eight common reasons are presented in Table 3, (2) Level of resistance – How much resistance is present?, (3) Manifestation of resistance – What behaviors are exhibited to show resistance? Lines et al. (2016) separated change-rejecting behaviors into indifferent, passive and active actions.

Table 3 Eight common reasons for resistance to change (Adapted from Hultman, 1998; Davis & Songer, 2002)

1.	**A lack of incentive** to change. The person is content with the status quo
2.	The change is viewed as a **threat** to the status quo
3.	The **risks** associated with change are seen as **greater than the benefits**
4.	There is **no awareness** of the crisis that is driving change
5.	There is **dissatisfaction** with the implementation method
6.	There is a **lack of confidence** that the change will be successful
7.	The change is **not consistent** with values and beliefs
8.	There are **doubts about honesty and openness** of the leadership responsible for change

3.3.2 Passive and active innovation resistance

When studying resistance in relation to innovation, two types of resistance can be distinguished: passive and active innovation resistance. Innovation resistance is defined by Salawu et al. (2019) as 'resistance linked to changes imposed by innovation, either before or after the evaluation of a new offering and as such highlights innovation resistance as a key inhibitor to the process of adoption'. Resistance might have to do with the readiness of a person to change, the level of satisfaction with the status quo or with potential conflicts of a persons' belief.

Research suggests that innovation often leads to a level of uncertainty. Some individuals will reject or postpone innovation because of those uncertainties. Some individuals will analyze the innovation, while others pay little attention to innovation. The adoption process is an ongoing process where positive and negative outcomes can happen at any time. According to Talke & Heidenreich (2014), the following stages can be identified in the resistance process:

(1) 'Knowledge stage: The passive innovation resistance'
(2) 'Persuasion stage: The active innovation resistance'
(3) 'Decision stage: The intention to reject or adopt an innovation'
(4) 'Implementation stage: Active rejection or adoption'
(5) 'Confirmation stage: Discontinuous or continuous rejection or adoption'

Passive innovation resistance is the result of two factors, the inclination to resist changes and status quo satisfaction. Active innovation resistance is the result of innovation specific factors, functional barriers and psychological barriers. It is suggested to differentiate these two types of resistance to properly manage the adoption process.

3.3.3 Conclusion of exploring resistance to change

Resistance can be expressed in numerous manners and can originate because of different reasons. It is argued that to properly manage resistance to change, it should be investigated which type of resistance is present throughout an organization or in a group of people. The cause of resistance, level of resistance and manifestation of resistance are three factors that should be considered. Indifferent, passive and active actions are examples of change-rejecting behaviors.

3.4 Conclusion of the exploratory research

The exploratory research focused on BIM in the AEC industry, BIM application by PMs, and resistance to change. Applications of BIM are discussed for the pre-construction, construction, and post-construction phase. The advantages of BIM are mostly acknowledged throughout the industry (Latiffi et al., 2013). However, the complications and challenges of BIM applications are still present. Resistance to change, investment costs, a lack of clarity and a lack of awareness are examples of challenges hindering BIM implementation (i.e. Jamal et al., 2019; Liao & Ai Lin Teo, 2018; Migilinskas et al., 2013; Noardo et al., 2019).

PMs are found to have a significant impact on the level of BIM adoption (Chen et al., 2019; Gu & London, 2010; Liu et al., 2010). Especially when a BIM vision is not clearly defined, BIM implementation is depended on the PM (Maki & Kerosou, 2019). Research shows that BIM application provides multiple opportunities for PMs in the building industry. BIM tools can assist PMs during processes such as decision-making, progress monitoring, and schedule optimization. Subsequently, BIM applications can help PMs improve communication, collaboration, and coordination throughout projects (Bryde et al., 2013). However, research argues that PMs are challenging to convince to work with BIM.

A research gap is found on the perspectives of PMs towards BIM application. Based on the literature study, it is expected that there is a group of PMs who perceive barriers towards implementing BIM to their own projects. The following chapters will focus on exploring the perspectives and aims to identify whether PMs perceive barriers.

4 Exploring the perspectives

In this chapter, an exploratory study will be performed on the perspectives of PMs towards BIM application in the building industry. First, a universe of statements is developed through a literature study and semi-structured interviews. The universe of statements will function as the starting point for the Q-study. Subsequently, the data analysis and results of the study will be presented.

4.1 Exploring the universe of statements

A universe of statements, also called the concourse, is the starting point of this research. A universe of statements consists of a comprehensive overview of existing opinions on BIM from the perspective of PMs. Besides functioning as the starting point of the Q-study, this part of the research will provide an answer to the first sub-question of this research: *'Which perceived benefits and barriers do project managers experience towards BIM application?'* The concourse can be collected from primary (e.g. interviews or group discussions) and/or secondary (e.g. literature or media) sources (Cross, 2005). This research has selected a primary and secondary source to gather the universe of statements, namely a literature study and semi-structured interviews.

4.1.1 Literature study

A literature study was the first step in the development of the concourse. To find appropriate literature on this subject, academic literature was initially consulted. Various topics are explored by combining keywords such as 'viewpoints', 'opinions', 'perspectives', 'perception' with 'BIM', 'Building Information Management', 'Building Information Modeling'. Furthermore, topics such as BIM implementation and BIM adoption are analyzed in combination with 'enablers, 'benefits', 'successes' and 'limitations', 'barriers', 'obstacles'.

To acquire a universe of statements that is up to date, four scientific articles are chosen from this past year (2019). The rest of the literature included in the study has been published in the past 10 years, except for one paper. The paper by Han and Damian (2008) is particularly applicable to this research and cited by 200+ researchers. Their research consisted of a questionnaire of 70+ AEC professionals, including project managers, to obtain their professional opinions about BIM. Since this article is highly cited and relevant to this research topic, this paper was also included in the literature study.

To obtain a broad view of opinions, articles are chosen that included both positive and negative perspectives on BIM. Some articles are more focused on the barriers of BIM implementation and the corresponding negative perspectives, while other articles focus more on the perceived benefits to project stakeholders, including project managers. Besides the positive and negative sides of the opinions, various countries are also included in the literature study (e.g. The Netherlands, Turkey, China). Moreover, the scope of the literature study was restricted to the AEC industry. Also, various research methods are applied in the studies, namely: 3 case studies, 3 surveys, 2 questionnaires, 1 literature review.

Most of the sources included in the literature study are considered academic research, except for one source. The 'Virtual Building Guide' by Straatman, Pel and Hendrinks (2012) is also included because it consists of multiple relevant perspectives on BIM from project managers within the Netherlands, obtained from practice. Therefore, considering the significance that this report has for this research, it has been added to the literature study for the concourse. Table 4 provides a summary of the content and research methodology of each source used for the literature study.

Table 4 Secondary sources used for literature study

Source	Summary of content and methodology
1. Kiaulakis et al., 2019	Construction project stakeholders' perceptions and expectations of their roles in BIM-based collaboration – This research consists of a survey on project stakeholders to analyze their attitudes and perceptions on the use of BIM. The project stakeholders were divided into two groups: public administrations and professionals.
2. Keskin, Ozorhon and Koseoglu, 2019	BIM Implementation in Mega Projects: Challenges and Enablers in the Istanbul Grand Airport (IGA) Project – This research consists of a case study on the IGA project in Turkey to gather an understanding of BIM application in large infrastructure projects. The case study was performed through semi-structured interviews.
3. Enshassi et al., 2019	Limitation Factors of Building Information Modeling (BIM) Implementation – This research consists of a questionnaire on 65 engineers to investigate the limiting factors of BIM implementation in the construction industry.
4. Chan et al., 2019	Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction – This research includes the perception of key stakeholders in the construction industry, varying from clients to consultants in Hong Kong, using a structured empirical questionnaire survey.
5. Bui et al., 2016	A review of Building Information Modelling for construction in developing countries – This research consists of a review of BIM implementation through a systematic literature review. An overview is given on BIM implementation in developing countries based on three categories: technical, perspective and construction business function.
6. Chan, 2015	BIM from Design Stage–Are Hong Kong Designers Ready? – This research consists of a questionnaire survey at 52 design firms in Hong Kong. Usage patterns are analyzed and barriers to BIM implementations are distinguished.
7. Migilinskas et al., 2013	The benefits, obstacles and problems of practical BIM implementation – In this research, trends of BIM were addressed as well as case studies on four building projects in Lithuania. Project participants were interviewed to gain insight on the benefits, obstacles and problems experienced. Among others, project managers were part of the participant group.
8. Straatman, Pel and Hendriks, 2012	Getting started with BIM; A Virtual Building Guide – This guide presents experiences from the practical implementation of BIM after one and a half years from nine building companies in the Netherlands
9. Zhou et al., 2012	Readiness of BIM: a case study of a quantity surveying organization – This research consists of a case study on the building industry in the UK. Relevant to this research is the project level interviews that consists of 41 questions. Project managers are included in the research, among other stakeholders such as architect and client.
10. Yan & Demian, 2008	Benefits and barriers of building information modelling – This research consists of a questionnaire on 70+ AEC professionals in the UK and US on their professional opinions about BIM. Among others, project managers were part of the participant group.

4.1.2 Semi-structured interviews

In this research, semi-structured interviews function as an additional data-gathering method for the universe of statements. Semi-structured interviews are a combination of closed- and open-ended questions and provide supplementary insights to research (Newcomer, Hatry & Wholey, 2015). Interviews are selected to obtain information from practice and find out how BIM is perceived by experienced PMs at BMA. The participants who took part in the semi-structured interviews will not take part in the Q-sorting sessions.

The interviews are performed face-to-face with two senior managers at BMA. The selection criteria of the participants for the interviews were based on (1) Level of management experience and (2) Level of BIM experience. Both participants have a high level of management experience (senior manager function) and a high level of BIM experience (10+ years). The participants were only selected if they were able to provide relevant information on how BIM is perceived in practice. The interview guide can be found in Appendix A.

To gather a comprehensive view of the perspectives on BIM from practice, the following themes are addressed during the semi-structured interviews:

(1) BIM use in the AEC industry
(2) Personal experiences with BIM
(3) Viewpoints on BIM

The goal of the interviews is to (1) **gather information on the extent to which BIM is applied** in the industry. How often do they apply BIM in their projects, and to what extent? If BIM is not used in a project, why? And if BIM is indeed used in projects, how is BIM received by all involved parties? Second, the interview aims to (2) **explore the personal experiences with BIM** of the participants. What are their experiences with BIM? And, which barriers and benefits do they encounter when working with BIM? Third, the interview will (3) **explore the viewpoints** on BIM. Which viewpoints do these managers often encounter in practice? Do these experienced managers often encounter people with strong (positive or negative) opinions on BIM?

4.1.3 Thematic coding

The outcome of the literature study and performed interviews consist of large amounts of raw qualitative data. Therefore, it is necessary to select a method to structurally analyze this data. A common method to analyze qualitative data is coding. One type of coding is thematic coding, which is often used to reduce the capacity of the data and explores underlying perceptions (Seale, 2012). The coding process is performed in Atlas.ti, which is a software developed to analyze qualitative data.

All qualitative data has been read thoroughly before starting the coding process. The first step of the coding process is to search for repeating ideas. Subsequently, groups of repeating ideas are organized in themes (Auerbach & Silverstein, 2003). The zigzag approach is applied, which is an iterative approach where additional data is sought until no new information or unexpected themes were observed (Guest, Bunce & Johnson, 2006; Seale, 2012). The results of the coding process can be found in Appendix B.

Howard et al. (2017) developed an application model based on the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003). This research proves that the following variables influence the behavioral intention and usage behavior for working with BIM: attitude, performance expectancy, effort expectancy, social influence, and facilitating conditions. The model is visualized in Figure 6.

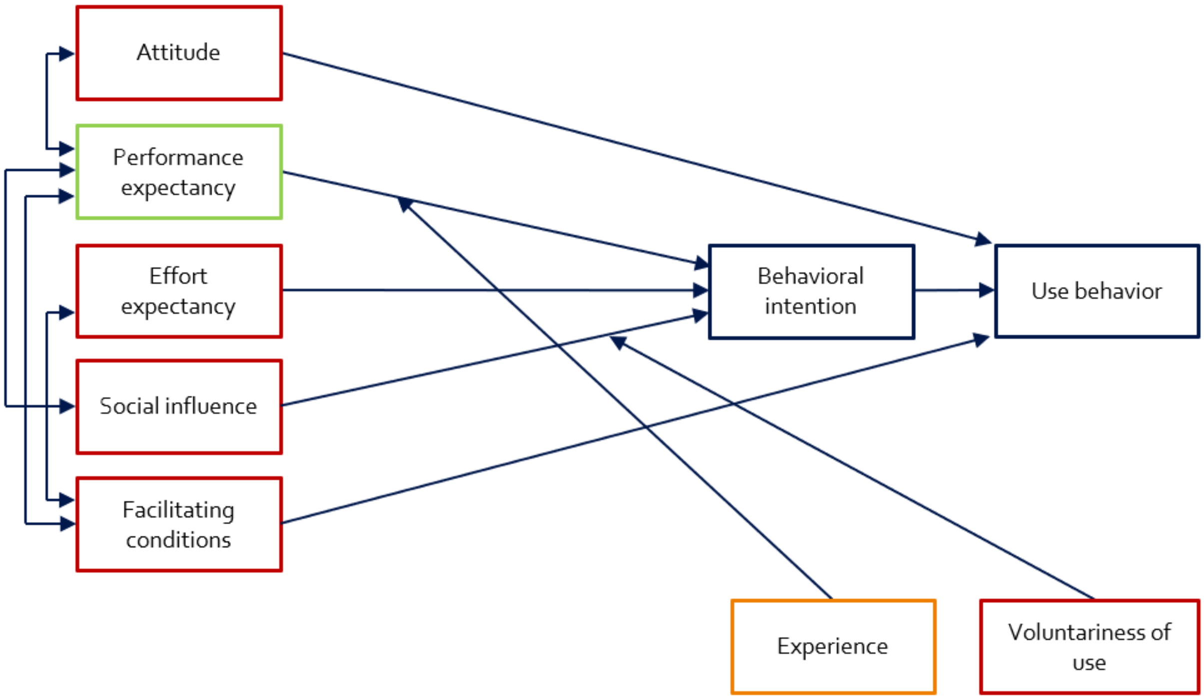


Figure 6 UTAUT model BIM specific (Howard et al., 2017)

This model was the starting point when developing the themes found in the data. The following definitions are provided for the variables attitude, performance expectancy, effort expectancy, social influence and facilitation conditions, see Table 5.

Table 5 Definitions of variables in UTAUT model (Howard et al., 2017)

Variables	Definition
Performance expectancy	'The extent to which users of the system believe it will help them achieve gains in job performance' Venkatesh et al. (2003) divided performance expectancy into the following sub-categories: perceived usefulness, extrinsic motivation, job-fit, relative advantage and outcome expectations. Considering the volume and type of codes in this theme, the researcher has decided to divide this theme into the following two categories: **Perceived usefulness as a supporting management tool** (based on job-fit: 'The extent to which an individual believes that using [the technology] can enhance the performance of their job' (Tan, 2013)); and **Perceived benefits of BIM implementation for project performance** (based on the outcome expectations: 'The performance related consequence of the behavior. Specifically, performance expectations on job-related outcomes' (Tan, 2013).
Effort expectancy	'The extent to which the use of the system is easy for the individual'
Social influence	'The extent to which individuals perceive that important people believe they should use the system'
Facilitating conditions	'The extent to which an individual believes the organization is there to support the use of the system'
Attitude	'An individual's positive or negative feelings about performing the target behavior'

When trying to distribute the codes found in literature amongst the pre-described themes, it was challenging to place the codes in the best suitable corresponding theme. When reevaluating the codes found in the data it was evident that there was a distribution of positively and negatively formulated codes. All positive codes could be placed in the performance expectancy theme, and all negative codes could be placed in the themes: effort expectancy, social influence, facilitating conditions and attitude. Subsequently, it was decided to create two main themes: Perceived benefits of BIM implementation and perceived barriers of BIM implementation. These themes are considered when narrowing down the universe of opinions to the Q-set. The themes and codes identified from the data can be found in Table 6. This table also presents an answer to the first sub-question of this research: *'Which perceived benefits and barriers do PMs experience towards BIM application?'*

Table 6 Themes / codes / grounded results from Atlas.ti

Themes	Codes	Grounded
Perceived benefits of BIM implementation Including codes on the influence of BIM on project performance and codes on how BIM can function as a supporting management tool. These codes are part of the enablers of BIM implementation.	Efficiency	9
	Costs	8
	Coordination	5
	Reduce project duration	5
	Collaboration	5
	Reduction of errors	4
	Visualization	4
	Better quality	3
	Early detection of issues	3
	Better understanding	3
	Decision making	3
	Life cycle data	2
	Construction safety	2
	Feedback	2
	Monitoring	2
	Better estimations	1*
	Productivity	1*
	Competitive advantage	1*
	Communication	1*
Perceived barriers of BIM implementation Internal and external factors that influence how individuals perceive barriers of BIM implementation. These include factors from: - 'Social influence', such as lack of demand; - 'Effort expectancy', such as complexity; - 'Facilitating conditions', such as organizational change required; - 'Attitude', such as willingness to change.	Lack of expertise	9
	Cost of investment	9
	Certainty of success	8
	Willingness to change	6
	Lack of rules and standards	6
	Lack of demand	6
	Familiarity with BIM	5
	Attached to comfortable routine	5
	Lack of awareness	5
	Additional work	5
	Learning curve	4
	Organizational change required	4
	Legal issues	4
	Afraid of personal consequences	3
	Satisfied with status quo	3**
	Lack of support	3
	Complexity	2
	Unclear roles and responsibilities	2
	Fragmented construction process	1*
	Lack of software	1*
	Lack of information sharing	1*
	Cultural change required	1*

* A red colored number implies that the corresponding codes are not included in the Q-set based on the criteria discussed in Section 4.2.2.
** Satisfied with status quo has not been included in the Q-set because of its resemblance with the other codes in this theme such as attached to comfortable routine and willingness to change

4.2 Q-methodology set-up

Through Q-methodology, the perspectives of PMs are investigated. The concourse of the Q-methodology was developed through interviews and a literature review. The following steps of Q-methodology consist of the set-up, data collection, data analysis, and data interpretation. In this section, the Q-methodology set-up is presented.

4.2.1 Formulating the sorting question

The first step of the Q-methodology set-up consists of formulating a sorting question which is presented during the Q-sorting session. The main goal of applying Q-methodology is to determine whether different perspectives can be distinguished from PMs towards BIM application. An important aspect of someone's perspective of an 'application' is whether they would be willing to apply it to their own projects. BIM is a relatively new technology for certain individuals. Individuals intent to accept or reject technology based on various factors, as mentioned before, such as perceived ease of use and perceived usefulness (Howard et al., 2017).

In order to develop a better understanding on why PMs chose to accept or reject BIM for their own projects, the sorting question has been formulated as follows: **"Which factors are important to you when considering whether you will apply BIM in your next project?"**

4.2.2 Composing the Q-set

In Q-methodology, the Q-set refers to the list of statements that the participants are asked to rank on a sorting grid. The aim of this research is to create a structured Q-set, rather than an unstructured Q-set. In Q-methodology this implies that the researcher has developed a set of themes before developing the Q-set. The Q-set will then consist of several items per theme to cover all relevant subjects of the topic (Watts & Stenner, 2012). To keep the number of statements manageable, the Q-set generally consists of 20 to 60 statements (Webler et al., 2009). When the statements are about the opinions on a product or brand, there should be an equal amount of positively and negatively formulated statements (Ten Klooster et al., 2008). An equal distribution will guarantee a balanced range of statements and prevent bias in the research (Angelopulo, 2009). Brown (1996) also provides a practical reason to structure positive and negative statements, namely, to prevent statements from piling up on the left or right side of the Q-sort diagram if a participant is particularly positive or negative on the topic.

Initially, the universe of statements consisted of 162 statements which were divided into 42 codes (sub-themes), which were part of 2 code groups (themes). To narrow down the concourse even further, the following criteria were applied:

(1) The codes should be listed in at least 2 (primary or secondary) sources;
(2) There should be an equal distribution of positively and negatively formulated statements.

Subsequently, the Q-set was formulated. The starting point of each statement was the corresponding code (sub-theme), which is part of a code group (theme). While keeping the sorting question in mind, the statements could then be formulated. In order to test the Q-set, two pilot Q-sort sessions were performed with the same participants as the semi-structured interviews. Feedback was provided on the formulation of a few statements because they lacked clarity. No feedback was given on the substance of the statements. The final Q-set consists of 32 statements, see Table 7.

Table 7 Final Q-set (T: Themes, divided into PU: Perceived usefulness, PB: Perceived barriers)

#	Statements	Code	T
1	The positive effect on efficiency	Efficiency	PU
2	The cost reduction of the project	Costs	PU
3	The possibility to coordinate the work of different parties	Coordination	PU
4	The reduced project duration	Reduce project duration	PU
5	The positive effect on cooperation between the parties involved	Collaboration	PU
6	The reduction of errors during the execution phase	Reduction of errors	PU
7	The 3D visualization possibilities	Visualization	PU
8	The improved quality of the project	Better quality	PU
9	Discovering design issues at an early stage of the project	Early detection of issues	PU
10	The possibility to improve the understanding of the design	Better understanding	PU
11	The effect on the speed of decision-making	Decision making	PU
12	The possibility to reuse the data in the building information model	Life cycle data	PU
13	The effect on construction safety during implementation	Construction safety	PU
14	The feedback process that BIM stimulates during the design phase	Feedback	PU
15	The ability to track progress during construction	Monitoring	PU
16	The limited availability of staff with BIM expertise	Lack of expertise	PB
17	The investment costs of BIM implementation	Cost of investment	PB
18	The uncertainty whether the realized benefits outweigh the investments of BIM implementation	Certainty of success	PB
19	My limited willingness to change in order to work with BIM	Willingness to change	PB
20	The lack of clarity surrounding rules and standards of BIM	Lack of rules and standards	PB
21	The limited demand from chain partners to work with BIM	Lack of demand	PB
22	The level of experience that I have with BIM	Familiarity with BIM	PB
23	The lack of comfort that I have to manage a project in which BIM plays a role	Attached to comfortable routine	PB
24	The limited extent to which I am familiar with the possibilities of BIM	Lack of awareness	PB
25	The additional work of working with BIM	Additional work	PB
26	The learning curve required (the time it takes to become familiar with the material)	Learning curve	PB
27	The organizational change required	Organizational change required	PB
28	The legal issues surrounding BIM applications (i.e. ownership of the model)	Legal issues	PB
29	The possible negative consequences of BIM implementation for my career	Afraid of personal consequences	PB
30	The limited support from upper management to work with BIM	Lack of support	PB
31	The complexity of BIM software	Complexity	PB
32	The lack of clarity about the changing role as a project manager when BIM is applied	Unclear roles and responsibilities	PB

4.2.3 Determining the layout of the sorting grid

During the Q-sort, the participants are asked to sort the previously presented statements on a sorting table from 'Least important' to 'Most important'. The researcher designs the shape of the sorting table. Depending on the topic of the research, the researcher determines the best applicable shape of the graph. Generally, the shape of the sorting table represents a normal distribution. The steeper the graph, the fewer statements can be placed on the limits of the graph. Therefore, a steeper graph challenges the participants to prioritize the statements more. Van Exel & De Graaf (2005) explain that the shape of the graph should depend on the level of controversy around the topic. The goal of this research is to distinguish critical opinions of BIM application from the point of view of PMs. Therefore, a steep distribution has been chosen, with only 5 statements on both limits of the graph, to encourage participants to highly prioritize the statements. It is expected that this will provide more interesting results for this research. The layout of the diagram can be found in Figure 7.

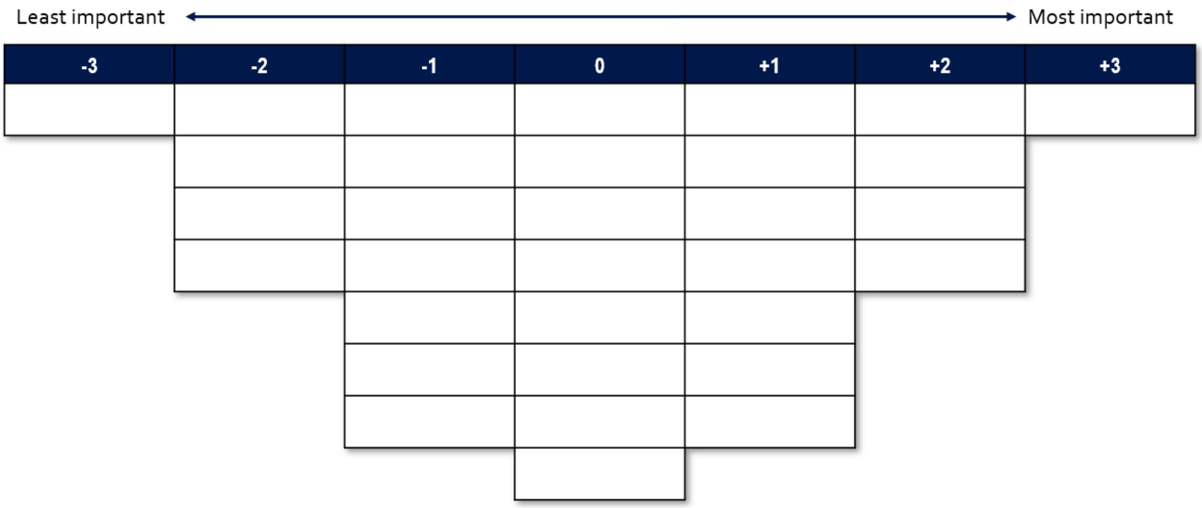


Figure 7 Layout of sorting grid

4.2.4 Composing discussion questions

Besides the Q-sort, Q-sessions are used to discuss the research topic with the participants to obtain additional qualitative data. It is especially useful to ask the participants whether they missed certain factors in the Q-set. This ensures that fundamental factors do not go unnoticed since it provides the participants to specify additional factors that are personally significant to them. Furthermore, similarly to semi-structured interviews, when the Q-sessions are performed face-to-face the researcher can ask open and follow-up questions to obtain more relevant data and start a discussion. The following questions have been formulated:

(1) Which **additional factors** do you find important in your consideration of whether to apply BIM?
(2) Do you **experience barriers** when working with BIM in projects?
    a. If so, do you try to **overcome** these barriers?
    b. If so, what did you experience as **effective methods** for dealing with these barriers?
(3) In which ways do you think that you can make yourself or other PMs **enthusiastic** about working with BIM in projects?

4.2.5 Selecting the P-set

The P-set is the group of participants who will perform a Q-sort and is carefully selected according to Q-methodology guidelines. The P-set consists of a structured selection of respondents 'who are theoretically

Figure 8 Distribution of characteristics in P-set

relevant to the problem under consideration' (Van Exel & De Graaf, 2005). Q-methodology requires a relatively small number of participants which is generally smaller than the Q-set, which is 32. Therefore, the number of participants would suffice if it is smaller than 32. According to Webler et al. (2009) and Cairns (2012), the P-set generally consists of 12 to 40 participants. Taking these guidelines into account, the P-set for this research consists of 24 participants.

This research aims to select participants from different organizations to guarantee a level of diversity in the Q-study. Multiple-case research will provide an in-depth understanding of the perspectives of PMs by comparing the results from the different organizations. This will guarantee more reliable research and ensure a comprehensive answer to the research questions (Gustafsson, 2017). To avoid unreliable research results by including predominantly BMA participants, the P-set consists of 10 participants from other companies.

The following criteria are applied to obtain a wide range of opinions on the subject from a PMs' perspective:

1. A distribution of management experience (junior positions – senior positions)
2. A distribution of the level of BIM experience (no experience – experienced)
3. A distribution of attitude towards BIM (predominantly 'critical' – predominantly 'positive')

The distributions of the P-set are visualized in Figure 8. The upper-left graph shows the distribution of working experience in the P-set. The graph shows that the largest group of participants is more mature and consists of

16+ years of working experience. This distribution was expected because most management functions (i.e. project managers) are performed by employees with many years of experience. The upper-right graph shows the distribution of BIM experience in the P-set. The largest group of participants has been involved with projects where BIM is applied (to a smaller and larger extent) over the past 2-5 years. The lower graphs show the company background and work field in which the participants are predominantly active. Since most of the participants are managers at consultancy firms (BMA + DVP consist of 67% of the total P-set), it was expected that the participants are often involved throughout the entire project duration from design to construction. This is also evident in the lower-right graph, which shows that 67% of the participants are active in the design and construction phases.

4.3 Data analysis of Q-study

The Q-sorts are imported into a data analysis program called PQMethod, specifically developed for Q-studies. The most recent version of this program is used, namely PQMethod 2.35 (released in November 2014). PQMethod aims to find correlations between the individual responses. In theory, if every participant has a unique opinion or perspective on a subject there should be no correlation between participants. By means of factor analysis, the program can find possible clusters of opinions from participants. Each factor will represent a group of individuals with similar perspectives concerning the subject (Jeleloo & Van Staa, 2009).

The first step of the data analysis is the creation of a correlation matrix, which shows the correlation between all Q-sorts, see Table 23. A level of disagreement and agreement is shown by providing a range from -1 to 1. Subsequently, a factor analysis is performed in which similarities between participants are revealed. PQMethod allows for two factor analyses: (1) Centroid factor analysis and (2) Principal component analysis. Centroid factor analysis is a method that is often used for Q-methodology. However, the principal component analysis is also used outside of Q-methodology for factor extraction in other programs such as SPSS (Schmolck, 2014). After the factor analysis is performed, a rotation method is selected. PQMethod provides two alternatives: (1) Manual rotation and (2) Varimax rotation. A manual factor rotation is appropriate when the researcher wishes to compare responses of groups of participants (Herrington & Coogan, 2011).

For this research, a principal component analysis is applied in combination with Varimax rotation. The principal component analysis requires a thorough analysis of the appropriate number of relevant factors. Through a comparison of the 2 to 8 factor solutions, the best suitable solution is determined based on multiple parameters and criteria:

(1) A minimum of **two Q-sorts** should define a factor for it to be accepted (Brown, 1993);
(2) A correlation is considered significant if it is larger than the standard error (SE = 1/√N, with N = 32 or the number of statements) times 2 to 2.5 (Brown, 1993). 2.0 * SE = 0.35, and 2.5 * SE = 0.44. Thus, there is a positive correlation if **SE > 0.44** and a negative correlation if **SE < -0.44**. The correlation is insignificant if it is less than ± 0.35;
(3) If the **eigenvalue** becomes smaller than 1, Kaiser states that the factor becomes uninterpretable (Kaiser, 1991). Therefore, this research will take the eigenvalue of the factors into account;
(4) **Simplicity**: Fewer factors are preferred to maintain comprehensibility (Webler et al., 2009);
(5) **Clarity**: It is preferred to select the factor solution where each Q-sort only loads significantly on one factor. Non-loaders (sorts that do not load on a factor) and confounders (sorts that load on more than one factor) should be minimized (Weblet et al., 2009);
(6) **Distinctness**: Low correlations are preferred over high correlations between factors. When factors are highly correlated it implies that they are similar. However, even if factors are highly correlated, the factors can be significant because of the statements that they disagree on (Webler et al., 2009);
(7) **Stability**: Groups of Q-sorts that are often clustered together should be preserved as much as possible (Webler et al., 2009).

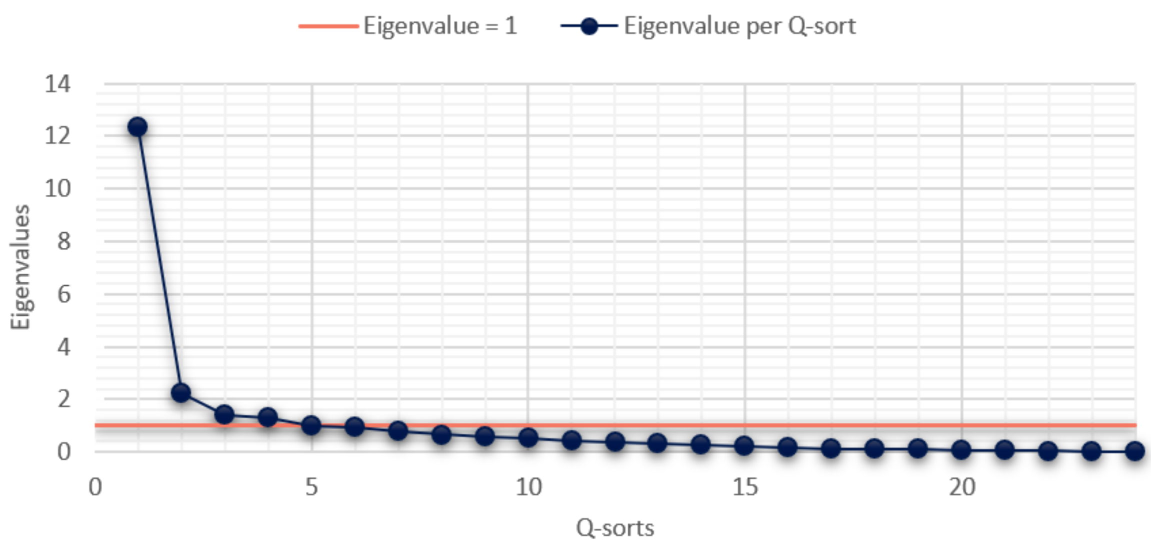


Figure 9 Eigenvalues of unrotated factors per Q-sort

Table 8 Characteristics of 2-4 factor solutions (Principal analysis with Varimax rotation)

	2-factor	3-factor	4-factor
Eigenvalue	2,2428	1,3773	1,3153
Expl. Variance [%]	61	67	72
Distinguishing statements	22	6 to 12	2 to 7
Sorts per factor	18-6	16-3-3	16-3-1-1
Automatically flagged sorts	24	22	21
Acceptable factors (>1 sorts)	2	3	2
Confounders	0	2	1

Regarding eigenvalues, Figure 9 shows that no more than 4 factors should be considered for this research as the eigenvalue then drops below 1. Analyzing Table 8, it shows that not all factors are acceptable from 4 factors and upwards, because some factors are distinguished by only one Q-sort. Therefore, with this data set, it is not beneficial to choose a 4-factor solution (or higher). Thus, it seems realistic to accept either the 2-factor or 3-factor solution. Both solutions consist of one large group and one or two smaller groups. Even though the 3-factor solution consists of two relatively small groups of 3 sorts, the researcher has decided to choose the 3-factor solution for the following reasons.

The large group of 18 (2-factor) and 16 (3-factor) Q-sorts describe a predominantly positive perspective of managers towards BIM application. The 2-factor solution provides one additional group, which describes a group of a predominately critical perspective of managers towards BIM application. Considering the goal of this research, which is to distinguish various perspectives of PMs (and specifically provide perspectives of reluctant PMs), the 3-factor solution provides a more in-depth presentation of two 'critical' perspectives. Moreover, the 3-factor solution consists of a significant amount of distinguishing statements per factor (6 to 12) and is therefore noteworthy to further investigate.

4.3.1 3-factor solution analysis

Table 9 shows the factor loadings of the 3-factor solution that has been chosen for this research. The table shows the distribution of the Q-sorts among the 3 factors. The largest group loads on factor 1, which consists of 16 Q-sorts. Factor 2 and factor 3 both consist of 3 Q-sorts. Furthermore, there are 2 confounders, Q-sort 13 and 15 both load on factor 1 and 2. It has been decided to include both Q-sorts and assign them to their highest factor loading. This means that Q-sort 13 joins factor 2 and Q-sort 15 joins factor 1. The final distribution of sorts per factor then becomes: Factor 1 consists of 17 sorts, Factor 2 consists of 4 sorts, and Factor 3 consists of 3 sorts.

Table 9 Factor loadings of 3-factor solution (Principal analysis with Varimax rotation)

Q-sort	Factor 1	Factor 2	Factor 3
1	0.5286	0.0379	0.7404 X
2	0.1556	0.2399	0.5280 X
3	0.7766 X	0.1326	0.3466
4	0.5887 X	0.0959	0.4013
5	0.7971 X	0.0013	0.3086
6	0.7988 X	0.0170	-0.0176
7	0.7597 X	0.2309	-0.1005
8	0.7615 X	0.4381	-0.0193
9	-0.2253	0.3212	0.7065 X
10	0.2475	0.6765 X	0.1188
11	0.8303 X	0.0791	0.4119
12	0.5905 X	0.2822	0.4292
13*	0.5116**	**0.5559****	0.3406
14	0.7582 X	0.3907	-0.0386
15*	**0.5945****	0.5195**	0.3016
16	0.8083 X	0.2386	0.1013
17	0.4950 X	0.2504	0.3934
18	0.5425 X	0.3688	0.1491
19	0.6658 X	0.5173	0.2613
20	0.0635	0.7808 X	0.1235
21	0.8011 X	0.1515	0.1243
22	0.0458	0.7448 X	0.2288
23	0.8721 X	0.0586	0.2295
24	0.7928 X	0.3344	0.2428

X This indicates the significant factor loading for the corresponding Q-sort. This means that (1) the factor loading is significant (larger than 0.44) and (2);

* This Q-sort is confounding on two factors (see **). This means that the sort is significant for more than one loading, for example, see sort 13.

4.4 From factors to perspectives

The data analysis has concluded in a 3-factor solution created by a principal component analysis with Varimax rotation. The next phase of the Q-study consists of visualizing the factors by interpreting the factors as separate perspectives. The Q-sorts corresponding to a factor have been merged together to create an average score per statement. This score is called the Z-score and visualizes the placement on the grid based on the average results of all Q-sorts in this factor.

In addition to the Z-score of each statement per factor, the perspectives can be analyzed based on distinguishing and consensus statements. Distinguishing statements are statements that characterize a factor. These statements were significantly placed in a different place on the grid, compared to the other statements. Therefore, these statements are unique to one factor and help to separate the factors from each other. On the other hand, consensus statements are statements that were ranked similarly by all factors. Therefore, these statements are less relevant when describing the different perspectives as they do not differentiate between the factors. Distinguishing statements will be indicated for significance by (**) for $P < 0.05$ and (*) for $P < 0.01$.

4.4.1 Perspective 1: '(BIM) Supporter' [N=17]

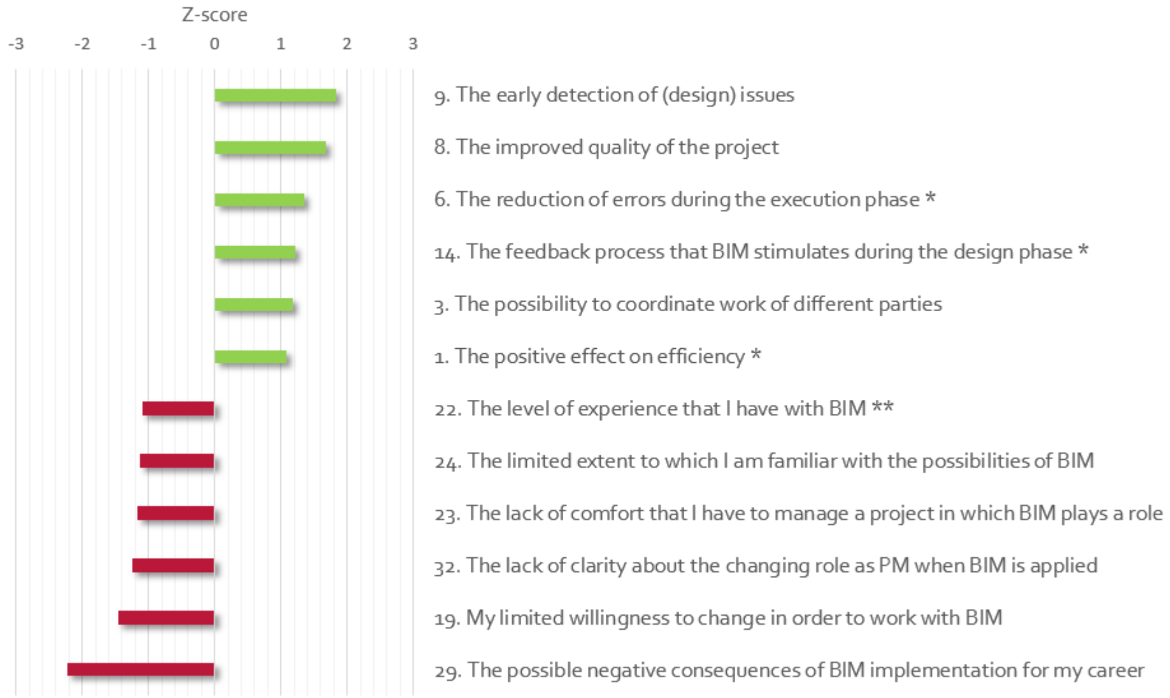


Figure 10 Z-scores of the most important and least important statements for factor 1

Perspective 1 shows the perspective of a PM who is a true BIM supporter. Not only does this PM support BIM, but they also support other innovations if they believe that they could be beneficial to the project. As portrayed in Figure 10 and Figure 24 (see page 91), the PMs in this perspective clearly rank the perceived benefits of BIM (green bars) as the most important factors when deciding whether BIM should be applied to their projects. On the other hand, these PMs clearly view the perceived barriers (red bars) as the least important factors. These PMs specifically state that their own level of experience with BIM (statement 22), or other personal factors, should not influence whether BIM is applied in a project. Even if they are inexperienced with BIM, or do not feel comfortable enough to work with BIM, they would still advise BIM application to their client if they believe that BIM could benefit the project.

"I view my role as subordinate to tools and methods that can improve a project. If BIM can improve a project and I feel like I do not have enough knowledge or experience, then I would let someone else manage the project. The quality of the project is the most important." (#12)

Besides their ranking of personal factors, the PMs in this perspective are also highly convinced of the benefits of BIM application. This is evident when looking at the distinguishing statements that have been ranked as the most significant. These PMs have experienced the positive effect that BIM has on efficiency and find the feedback process that BIM stimulates during the design phase valuable. Furthermore, they notice a reduction of errors during the execution phase due to the early detection of design issues.

"I believe the feedback process is extremely important because it forces parties to take action and to come together. I think of BIM as a means to bring people in contact with each other." (#3)

"To me, it is very important that BIM reduces errors during the execution phase. As someone who is actively present in the execution phase, I see how many errors are now already detected during the design phase. This includes errors that I am sure would have caused much delay and additional costs if we would have found out during the execution." (#7)

Table 10 Distinguishing statements for factor 1 (Asterisk (*) Indicates Significance at P < .01))

		Factor 1		Factor 2		Factor 3	
		Q-SV	**Z-score**	Q-SV	Z-score	Q-SV	Z-score
6	The reduction of errors during the execution phase	**2**	**1.35***	1	0.64	0	0.23
14	The feedback process that BIM stimulates during the design phase	**2**	**1.22***	-1	-0.26	0	0.18
1	The positive effect on efficiency	**1**	**1.08***	0	0.25	0	-0.29
2	The cost reduction of the project	**1**	**0.57***	-2	-0.96	-1	-0.52
4	The reduced project duration	**0**	**0.30***	-1	-0.75	-2	-1.61
13	The effect on construction safety during implementation	**0**	**0.24***	-1	-0.58	-1	-0.69
27	The organizational change required	**-1**	**-0.49***	1	0.95	1	0.40
26	The learning curve required	**-1**	**-0.51***	1	0.95	1	0.75
16	The limited availability of staff with BIM expertise	**-1**	**-0.63***	1	0.59	1	0.50
20	The lack of clarity surrounding rules and standards of BIM	**-1**	**-0.64***	2	1.41	1	0.84
22	The level of experience that I have with BIM	**-1**	**-1.09**	-1	-0.33	0	-0.45

Even though this perspective consists of BIM supporters, multiple PMs in this group also mentioned barriers that they experience. For example, mistakes are still made during the execution phase, even when BIM is applied (#6). Clash detections are not always performed, and at times issues still slip through clash detection. Besides, #3 and #16 state that as a result of clash sessions, issues arise early in the design process. This means that multiple decisions must be made at an earlier stage, compared to a traditional process. At times, this implies that issues arise that can only be solved with information that is not yet available.

Lastly, most participants in this perspective mentioned that the following additional factors are important to them when deciding whether they would apply BIM to their project: (1) The complexity of the project, (2) Will the client use the model for facility management?

(1) The complexity of a project: When a project is particularly complex, the PMs in this perspective are convinced of all the benefits of BIM. For smaller projects (less budget, less complexity, fewer parties to coordinate), not all PMs are convinced that the benefits outweigh the investments;
(2) Will the client use the model for facility management? For a client who maintains multiple buildings, some PMs in this perspective are convinced that even smaller, less complex projects would benefit from BIM. #24 also argued that the desired LOD and LOI are significant.

A complete overview of the distribution of statements corresponding to this perspective can be found in Figure 24 (see page 91) and Table 24 (see page 90).

4.4.2 Perspective 2: 'Moderately hesitant' [N=4]

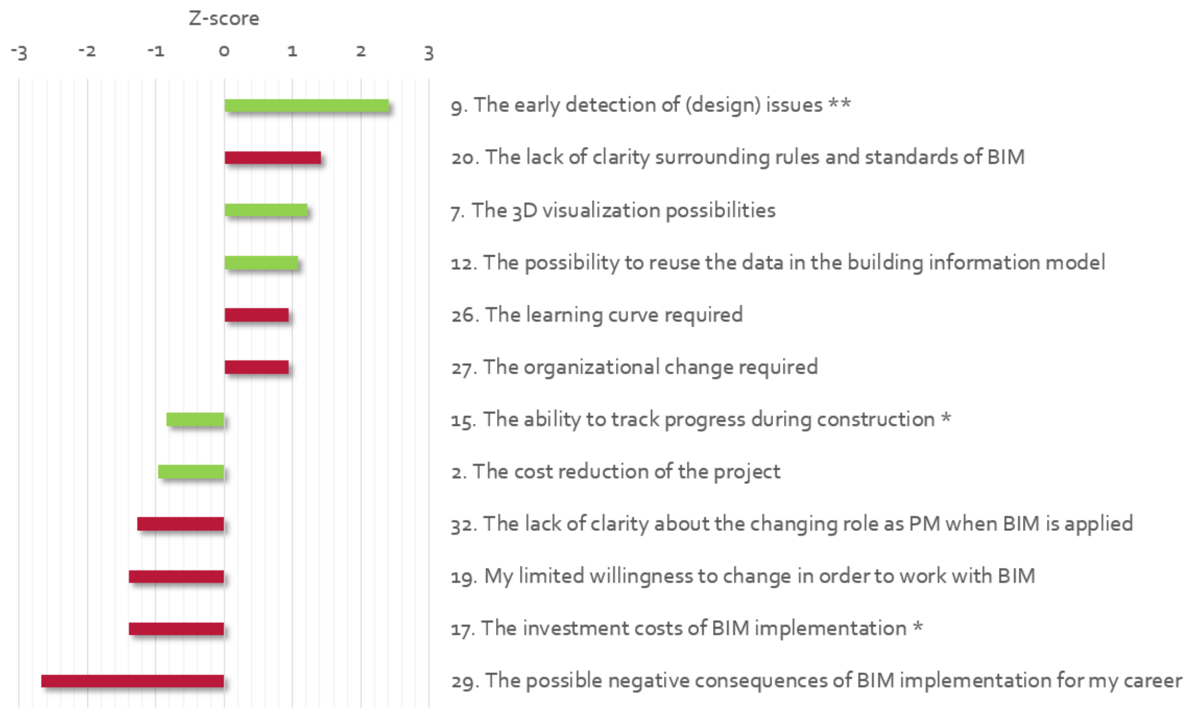


Figure 11 Z-scores of the most important and least important statements for factor 2

Perspective 2 consists of experienced managers (15+ years of experience) who are aware of, and believe in, specific benefits of BIM that they have personally experienced in their projects. They average in approximately 4 years of experience with BIM. Besides their awareness of benefits of BIM, they are moderately hesitant to implement BIM because of negative experiences with regards to a lack of clarity surrounding rules and standards, and the required learning curve and organizational change. As Figure 11 and Figure 25 (see page 93) portray, this perspective shows a mix of perceived barriers and benefits throughout the sorting graph.

Perspective 2 scores exceptionally high on statement 9: The early detection of (design) issues. In practice, this is the main benefit of BIM that they have experienced as well as the other possibilities of 3D visualization, such as clearer communication with the client. Besides visible benefits, this perspective is also aware of the potential advantage of reusing the data in the building information model during the operation and maintenance phase. However, this aspect of BIM is often not used in practice because of a lack of demand and awareness from the client.

"The benefit of BIM is not yet recognized for facility management by clients. Many clients are unaware of the advantages and disadvantages of BIM. I observe the least demand from facility management departments or organizations to work with BIM." (#10)

The distinguishing factors of perspective 2 clearly show factors that lead to moderate hesitance, see Table 11. For example, statement 23: The lack of comfort that I feel to manage a project in which BIM plays a role is scored relatively high by this perspective at a Z-score of 0.78. This is confirmed by the following statements:

"I am not yet comfortable with BIM. I would not dare to ask for BIM during a tender because I would not be prepared to answer the questions I could get from the industry." (#20)

"I certainly do not yet feel comfortable to work with BIM, so I would not initiate it in a project." (#22)

Table 11 Distinguishing statements for factor 2 (Asterisk (*) Indicates Significance at P < .01))

		Factor 1		**Factor 2**		Factor 2	
		Q-SV	Z-score	**Q-SV**	**Z-score**	Q-SV	Z-score
9	Discovering design issues at an early stage of the project	3	1.84	**3**	**2.41**	2	1.25
23	The lack of comfort that I have to manage a project in which BIM plays a role	-2	-1.17	**1**	**0.78***	-2	-0.97
24	The limited extent to which I am familiar with the possibilities of BIM	-2	-1.14	**1**	**0.26***	-2	-0.79
8	The improved quality of the project	2	1.67	**0**	**0.14***	2	1.17
4	The reduced project duration	0	0.30	**-1**	**-0.75**	-2	-1.61
15	The ability to track progress during construction	0	0.21	**-1**	**-0.84***	1	0.40
17	The investment costs of BIM implementation	0	-0.05	**-2**	**-1.40***	0	0.12

This lack of comfort is also evident in the perceived barriers (red bars) that are ranked as most important, see Figure 11. The lack of clarity surrounding rules and standards of BIM is one of the reasons PMs in this perspective do not feel comfortable to apply BIM. They feel unprepared for questions on 'technical' aspects such as rules and standards that are related to BIM, such as a BIM protocol and requirements with regards to LOD and LOI.

PMs in this perspective also perceive barriers such as the learning curve and organizational change as important to their decision to apply BIM. Often, they have experienced projects in which BIM was applied with parties who were less familiar with BIM than they promised at the start. Therefore, the learning curve that is required by those parties is ranked as important because it delayed the building process. Managers in this perspective mention that they run into the same issues every week because certain disciplines are not as far advanced with BIM as other disciplines, which can really slow down the process. They are also critical towards the level of detail in the BIM models:

"I am not yet convinced that a BIM model is sufficient with regards to the level of detail and completeness. I find the technical drawings nowadays are below standard." (#10)

"The model is not detailed enough to act as a contractual document." (#13).

Interestingly, PMs in this perspective find the investment costs of BIM implementation (statement 17) unimportant with a Z-score of -1.40. However, at the same time, they are unsure if BIM leads to a cost reduction of the project (statement 2) which is scored with a Z-score of -0.96. This can be seen in relation to the relatively low Z-score for the reduction of the project duration (-0.75) and the less positive experiences that these PMs have had with BIM in projects.

"The design process takes longer. It also takes longer to process changes in the BIM model compared to drawings" (#10)

A complete overview of the distribution of statements corresponding to this perspective can be found in Figure 25 (see page 93) and Table 25 (see page 92).

4.4.3 Perspective 3: 'Critical realists' [N=3]

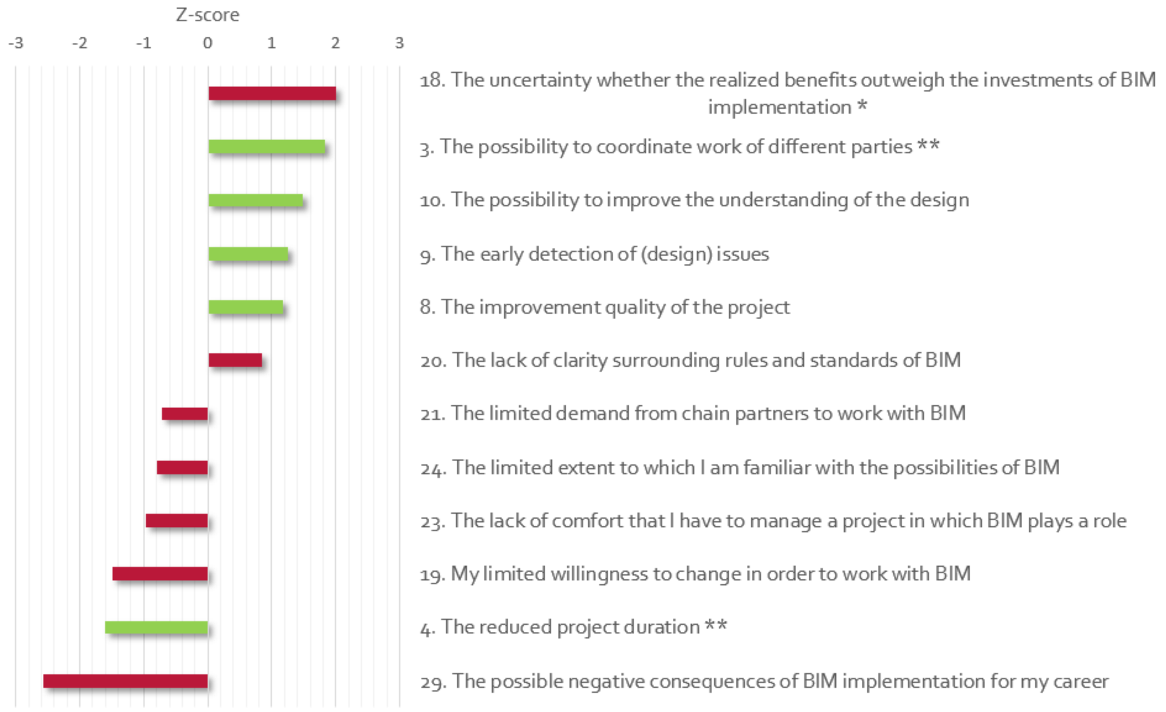


Figure 12 Z-scores of the most important and least important statements for factor 3

Perspective 3 shows a mixture of perceived barriers and benefits throughout the graph, see Figure 12 and Figure 26 (page 95). The bottom line of perspective 3 is whether it is realistic to apply BIM to a project. This focus is evident in the results of this perspective. When viewing the Z-scores of the statements, see Figure 12, statement 18 is ranked most important. Will the realized benefits outweigh the investments of BIM implementation? This is the most important question PMs in this perspective ask themselves at the start of a project.

"Will it be useful to work with BIM in this project? Is this the best tool to use to achieve the desired result? Are there other techniques or tools that are better for this project?" (#2)

"I am convinced of the benefits of BIM, but especially when BIM is used as a 'life-cycle' tool. Often, this is not the case and the BIM is not used for facility management, and as a result, fewer benefits are achieved." (#1)

Another distinguishing statement that the PMs in this perspective ranked as highly important is the possibility to coordinate the work of different parties (statement 3). This perspective emphasizes the importance of coordination between parties. #2 argues that because of the possibility to coordinate different parties, issues are detected faster. #1 emphasizes that BIM coordinates more than different disciplines only. A BIM approach also focusses on coordinating information needs of different parties during multiple phases of a project. Statement 10, 9 and 8 also portray this perspectives' perceived usefulness of BIM applications (improved understanding, early detection of issues, and improved quality). Besides perceived usefulness, the PMs are skeptical about the reduced project duration of BIM:

"I do not believe that working with BIM is much faster. Adjusting the BIM model takes longer than a quick change in a drawing. I am not sure if you will make up for the extra time at the start of the project during the execution phase. The design time does not always remove all issues from the model before execution." (#9)

Some PMs even believe that working with BIM can increase project duration:

"I do not think that BIM will decrease the project duration. I think that sometimes it will even lead to a longer duration, depending on the parties you work with." (#2)

Table 12 Distinguishing statements for factor 3 (Asterisk (*) Indicates Significance at P < .01))

		Factor 1		Factor 2		**Factor 3**	
		Q-SV	Z-score	Q-SV	Z-score	**Q-SV**	**Z-score**
18	The uncertainty whether the realized benefits outweigh the investments of BIM implementation	0	-0.31	-1	-0.77	**3**	**2.00***
3	The possibility to coordinate work of different parties	2	1.19	1	0.77	**2**	**1.82**
32	The lack of clarity about the changing role as project manager when BIM is applied	-2	-1.24	-2	-1.27	**1**	**0.56***
12	The possibility to reuse the data in the building information model	1	0.56	2	1.08	**-1**	**-0.50***
7	The 3D visualization possibilities	1	0.90	2	1.21	**-1**	**-0.56***
4	The reduced project duration	0	0.30	-1	-0.75	**-2**	**-1.61**

The PMs in this perspective scored the possibilities of 3D visualization at a relatively low importance, at -0.56, because they believe that 3D visualizations are possible without a BIM model. Furthermore, they scored the possibility to reuse data in the building information model at a low importance, at -0.50, because the client often does not demand it. Maintenance is still a broad concept at the beginning of a project. Therefore, it is difficult to include the wishes of a facility management team at the start of the project in the model.

The participants in this perspective find the wishes and type of client extremely important in their decision to apply BIM. #2 explains that the expectations of the client are crucial. Even if the project is relatively small, if the client wishes to be actively involved in a project and wants to follow the process, it can be beneficial to work with BIM. On the other hand, if you are working with a highly experienced developer who has several projects a year, there is a possibility that he is less interested in working three-dimensionally.

"It has many opportunities, but I do not believe that is it always the best means for all projects or all clients because (1) it requires a lot of effort and (2) it is not always the best communication method with your client or in your project team." (#2)

A complete overview of the distribution of statements corresponding to this perspective can be found in Figure 26 (see page 95) and Table 26 (see page 93).

4.4.4 Consensus between the perspectives

Table 13 shows seven consensus statements between the perspectives. Consensus statements are statements that have a low difference in Z-score between the factors and portray opinions that all perspectives share. First, statement 10 was ranked as relatively important by all perspectives, ranging from 0.55 to 1.48. The possibility to improve the understanding of the design is a shared opinion that is considered important. Through 3D visualizations, the clarity of the design increased for all parties involved. Especially in the communication with inexperienced clients, who are unfamiliar with understanding technical 2D drawings, the usefulness of BIM to improve the understanding of the design is perceived by all perspectives.

Two statements are scored neutrally by all perspectives: The legal issues surrounding BIM application (statement 28) and the limited support from upper management to work with BIM (30). These statements range in Z-score from -0.50 to 0.11. First, PMs in this P-set weigh the legal issues as neutrally important when considering BIM. Most PMs mentioned that the legal issues are a factor that they consider, but when properly laid down in a contract they are no longer an issue. Furthermore, PMs state that legal issues of BIM are no different from a traditional process with 2D technical drawings. Second, the limited support from upper management. Overall, most PMs did not experience limited support. Some PMs mentioned that there was a lack of support and that they wished to be supported more by upper management, for example by workshops to understand the working of BIM viewers.

All perspectives ranked four statements as least important in their consideration to apply BIM to their projects. Two of these statements are related to personal willingness to change and possible negative consequences of BIM implementation to their career. Both statements are ranked very low, with Z-scores ranging from -2.67 to -1.39. All PMs stated that they were very willing to change, and some PMs argued that they did not believe they had to change in order to work with BIM. Furthermore, there was only one PM who openly agreed that BIM can have possible negative consequences to their career and even discussed the possible consequences with their supervisor.

The complexity of BIM software was relatively unimportant across the perspectives, ranging from -0.75 to -0.12. Most PMs argued that it was not expected from them to be able to work with BIM software, therefore the complexity was irrelevant to them. Lastly, the limited demand from chain partners (i.e. the contractors) to work with BIM was ranked as less important. PMs frequently stated that there was significant demand from chain partners.

Table 13 Consensus statements between factors ((*) Statements are non-significant at P>0.01 and (**) statements are also non-significant at P>0.05)

		Factor 1		Factor 2		Factor 3	
		Q-SV	Z-score	Q-SV	Z-score	Q-SV	Z-score
10.	The possibility to improve the understanding of the design *	1	0.96	1	0.55	2	1.48
19.	My limited willingness to change in order to work with BIM **	-2	-1.45	-2	-1.39	-2	-1.48
21.	The limited demand from chain partners to work with BIM **	-1	-0.48	0	-0.20	-1	-0.72
28.	The legal issues surrounding BIM application *	0	-0.42	0	0.11	0	-0.06
29.	The possible negative consequences of BIM implementation for my career **	-3	-2.22	-3	-2.67	-3	-2.56
30.	The limited support from upper management to work with BIM **	0	-0.46	-1	-0.50	0	-0.40
31.	The complexity of BIM software *	-1	-0.75	0	-0.12	-1	-0.57

4.5 Conclusion of the Q-study results

The Q-study has resulted in a 3-factor solution through a principal component analysis with a Varimax rotation. The P-set has been divided into three groups of participants with similar views on BIM application in the building industry. The largest group of PMs are found in perspective 1, which can be referred to as the (BIM) supporters. On average, this group is enthusiastic about BIM and would initiate BIM to achieve perceived benefits. Furthermore, there are two other groups, perspectives 2 and 3, who are more critical about BIM applications in their projects. An overview of the Q-study results, which provides an answer to the second sub-question: *'Which perspectives can be distinguished of project managers towards BIM application?'*, can be found in Figure 13.

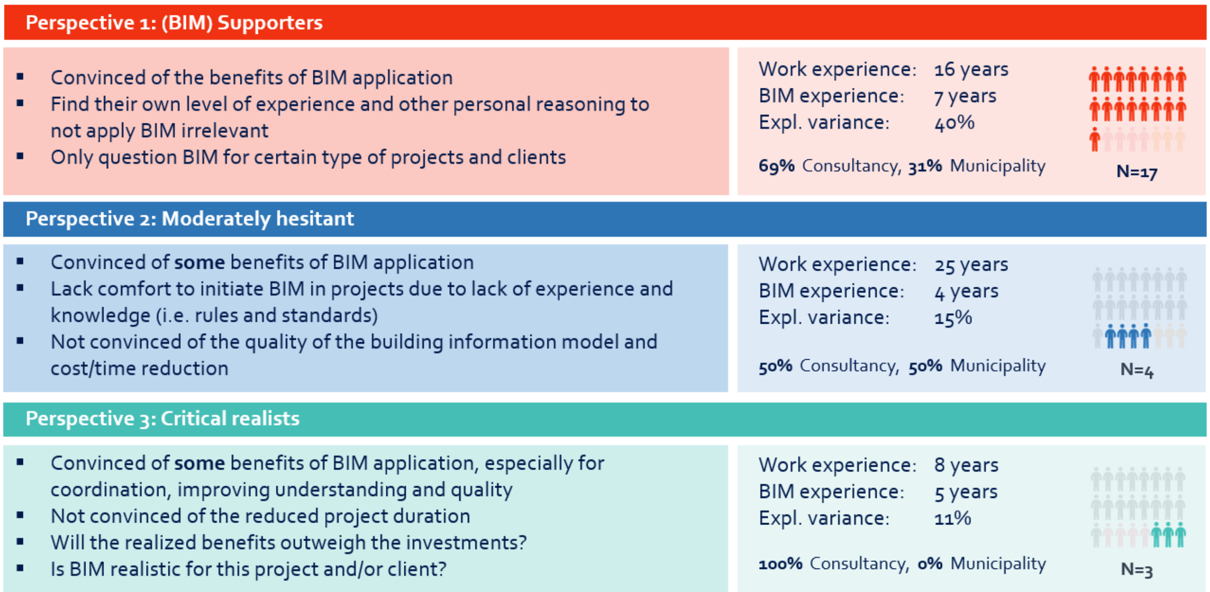


Figure 13 Overview of three BIM perspectives

Figure 13 also shows the overall characteristics of the participants placed in the corresponding perspective. Note: The limited number of loaders of the two perspectives (N=4 and N=3) should be considered when discussing the characteristics of the groups. Due to the small number of loaders, each participant has a high influence on the characteristics of the perspective, such as age and work experience. Conclusions drawn about the characteristics of the perspectives must, therefore, be deliberated carefully.

The characteristics show that perspective two consists of participants with a high level of work experience (an average of 25 years) and the least amount of BIM experience (an average of 4 years). At the same time, this perspective accounts for the most hesitant group towards BIM application and consists of 50% PMs active at consultancy firms and 50% PMs active at municipalities. Perspective 1 consists of the highest amount of BIM experience, and at the same time consists of the most positive view on BIM. Lastly, the youngest average group of PMs are found in perspective 3.

5 Dealing with barriers

In this chapter, methods to deal with barriers found in the Q-study are discussed. First, the barriers perceived by PMs of perspective 2 and 3 are analyzed and presented. Second, theoretical methods are discussed based on change and transition management theories. Third, practical methods to deal with barriers are introduced. Finally, a strategy aimed to reduce the barriers found in the Q-study is developed.

5.1 Analysis of barriers

Based on the results found in the Q-study, it can be concluded that two groups of PMs are present who perceive barriers towards BIM application in their own projects: Perspective 2 and 3. Perspective 1 did not show any signs of resistance according to the Q-study results and will therefore not be considered for the remainder of this analysis. The results of this section will provide an answer to the third sub-question: *'Which factors can be identified as barriers leading to reluctance of PMs to apply BIM to their projects?'*

The following criteria are used to distinguish barriers:

(1) If the perspective scores a previously determined 'Perceived barrier' as highly important in their consideration to apply BIM (three highest Z-scores, or distinguishing statements with a Q-sort value ≥ 1) this statement is perceived as a barrier;
(2) If the perspective scores a previously determined 'Perceived benefit' as less important in their consideration to apply BIM (three lowest Z-scores, or distinguishing statements with a Q-sort value ≤ -1), this statement is perceived as a barrier;
(3) If more than one participant from the same perspective mentioned a barrier during the discussion of the Q-sessions, this will be perceived as a barrier specific to this perspective.

5.1.1 Barriers perceived by PMs in perspective 2

Perspective 2 is interpreted as a group of PMs who are hesitant to implement BIM to their projects. Relatively, this perspective consists of the largest number of perceived barriers. Generally, they are convinced of various benefits of BIM application such as the early detection of (design) issues and the possibilities to reuse the data in the building information model. However, the reoccurring theme of barriers in this perspective can be categorized under a lack of awareness and knowledge, which is leading to a lack of comfort.

Participants have experienced that BIM can lead to an increase in cost and time due to the learning curve and organizational change required. Consequently, these PMs are not incentivized to initiate BIM in their projects. The quality of the building information models that they have seen in practice is also perceived as 'not good enough'. Therefore, these PMs are not yet convinced that the chain is ready to make the step from traditional building methods to BIM.

PMs in this perspective expect other parties, such as the contractors, to work with BIM for complex projects. However, they will not demand BIM because of their lack of comfort to manage a project where BIM is involved. Especially the rules and standards required for BIM, which they are not well acquainted with, are perceived as a barrier to initiate BIM. They are not comfortable enough to answer questions that they might receive from the chain partners if they were to demand BIM from them.

On average, the participants in this perspective are the oldest generation and their work experience averages 25 years. This group consists of the least amount of BIM experience, which averages in 4 years. With a side note that this research consists of a relatively small participant size, it can be hypothesized that the older generation, with little BIM experience, can have similar views as perspective 2.

The following barriers should be dealt with to decrease reluctance to apply BIM for PMs in perspective 2:

(1) The lack of comfort that I have to manage a project in which BIM plays a role (distinguishing statement);
(2) The limited extent to which I am familiar with the possibilities of BIM (distinguishing statement);
(3) The lack of clarity surrounding rules and standards of BIM (Z-scores);
(4) Skeptical about the change:
    a. Not convinced of the quality of the building information model (gathered from the discussion);
    b. Not convinced that BIM decreases project duration or the benefits of BIM for tracking progress during construction (distinguishing statements).

5.1.2 Barriers perceived by PMs in perspective 3

PMs in perspective 3 are unsure whether the realized benefits of BIM outweigh the investments. On average, the participants of perspective 3 are the youngest generation, averaging in 8 years of work experience. This group has a relatively high level of experience with BIM (5 years) considering that they have 8 years of working experience in total. It can be concluded that BIM has been involved from an early point in their working career. Therefore, it is hypothesized that this group does not portray resistance because of a lack of technology acceptance. However, they are characterized as a critical group that considers multiple methods for each project to ensure that the best suitable method is applied.

It is hypothesized that the PMs in this perspective are a step further with regards to technology acceptance compared to perspective 2. Perspective 2 PMs are uncomfortable to apply BIM on any project because of a fear of the unknown, are skeptical about the quality of the BIM, and lack familiarity in the possibilities of BIM. Perspective 3 PMs are characterized as 'critical realists'. They are convinced of many benefits of BIM. However, they have experienced that working with BIM does not always perform as effortlessly as hoped. Therefore, they are not convinced that BIM applies to each project as it requires a significant investment that should be compensated with enough realized benefits.

PMs in perspective 3 are convinced of BIM application for complex projects and clients who wish to use the BIM for facility management. However, they are not convinced that their clients are always ready for this tool. Therefore, the benefits of BIM must be achieved during the design and construct phase only. According to PMs in perspective 3, small, less complex projects that do not require to coordinate the work of multiple parties are not expected to be worth the investment.

The following barriers should be dealt with to decrease reluctance to apply BIM for PMs in perspective 3:

(1) The uncertainty whether the realized benefits outweigh the investments of BIM implementation (distinguishing statement);
    a. They believe that BIM investments are not worth it for smaller, less complex projects (gathered from the discussion);
    b. Is BIM worth it for clients who do not wish to be actively engaged and who do not wish to use BIM for facility management? (gathered from the discussion);
(2) The lack of clarity about the changing role as PM when BIM is applied (distinguishing statement);
(3) Skeptical about the change:
    a. Not convinced of the reduced project duration;
    b. Are unsure if clients are ready and/or willing to reuse the data in the BIM (distinguishing statements).

5.2 Discussing theoretical methods to deal with barriers

To propose methods to deal with the barriers that have been found in the Q-study, literature was performed. Resistance to change, lack of comfort, lack of awareness, lack of knowledge and skepticism towards change are themes present throughout the barriers. Considering the nature of these barriers, it can be argued that there is a need to investigate change management theories. Most change management theories provide strategies to guide an organization through a change process. For the scope of this research, methods are desired that provide directions to minimize resistance of the target group (PMs in the building industry), rather than an entire organization. However, change management theories are often centered around motivating personnel to accept changes.

A literature review is performed to show a variety of methods to overcome change-related barriers. Overcoming resistance to change, increasing change-readiness, minimizing skepticism, dealing with resistance to change, change and transition management theories are examples of keywords and phrases that were searched for. Recent studies are often partially based on well-known theories. Therefore, it is necessary to further discuss those methods. The literature review will start by presenting recent studies and is followed by the discussion of well-known theories from the early founders of change-related research.

5.2.1 Contemporary methods to deal with barriers

The desire to implement new technologies into an organization will inevitably provoke a mixture of emotions from employees (Knight, 2015). It is expected that roughly three types of employees will present themselves: a group of advocates, a group that is not well acquainted with technology, and a group of 'naysayers' who are commonly opposed to change. There will always be a group of employees who are too attached to their comfortable routine and simply do not want to change. It is crucial to understand in which stage of transitioning employees find themselves. Knight (2015) proposes the following ideas to encourage technology adoption of skeptical employees.

(1) State your case: To effectively persuade a team to adapt to new technologies, it should be identified and expressed what the vision for the new technology is and what the technology entails. Provide demonstrations to show what the technology can offer the individual ('What's in it for me?'), while also presenting the larger goal of implementing the technology;

(2) Customize training: Each employee is different, and each has a different level of familiarity and interest in technology. Therefore, it is crucial to customize training to ensure that various needs are met. For example, some employees would prefer to take an online training session, while others might desire more one-on-one guidance. The crux is to communicate with the members of your organization to gather information on which method of learning they would prefer;

(3) Get influencers on board: As soon as possible, a team of enthusiasts should join to function as a network of champions. Subsequently, this group can spread awareness, promote use, share success stories and try to encourage the middle adopters and laggards to adapt to the technology. According to the technology acceptance curve, people's behaviors are highly influenced by how widespread they believe a specific technology is. This highlights the importance of vocal enthusiasts within an organization;

(4) Highlight quick wins: Emphasize the positive impact and quick wins that the new technology is having on the organization to encourage adoption;

(5) Make it fun and engaging: Consider the possibility to reward employees who are adopting the technology. For example, rewards can be provided through recognition, perks, or other compensations. Try to encourage employees by making it fun and engaging employees as much as possible.

Research by Lines et al. (2015) studied which factors minimize the level of resistance to change in AEC organizations. First, their research presented a relation between the speed of implementation and the level of resistance. Organizations with realistic expectations and long-term plans experienced the least amount of resistance. Second, a relation was found between resistance and the scope, size and duration of projects. Therefore, it is suggested that organizations start implementing new processes in smaller projects. Smaller projects (<$1 million) portrayed a higher change readiness from project members compared to larger projects Third, an acknowledged group of change agents with considerable daily involvement in projects significantly decreases the level of resistance. It is suggested that change agents are present to actively drive implementation.

A more recent study by Lines et al. (2016) researched change readiness in AEC project teams and presented factors that influence the change readiness of personnel. First, change message delivery was found to have the highest correlation with change readiness. Therefore, it is suggested to provide step-by-step information, how-to information and to describe long-term objectives of the change (i.e. why do we want to implement this change?). Second, a relationship was found between the level of involvement of change agents and change readiness. This is in line with previous research that shows that there is a correlation between the level of uncertainty and the level of resistance that is present (Hultman, 2006). Lines et al. (2016) suggest employing change agents who are willing, and available, to participate actively in day-to-day deliverables. The change agents will provide support, leading to an increase in change readiness and showing personnel that the organization is committed. It is argued that this will decrease skepticism and increase enthusiasm. Increasing enthusiasm is especially crucial for PMs. The third factor of their research revolves around the influence of change readiness by personnel characteristics. It is suggested to encourage feedback and participation of frontline personnel since they are critical drivers of the success of implementation.

In Lines et al.'s (2017) most recent research a table is presented with recommended actions to successfully implement change for change practitioners, see Table 14.

Table 14 Recommended actions for change practitioners (Lines et al., 2017)

Change management practice	Recommended actions for change practitioners
Change agent effectiveness	Identify change agents who are influential yet distinct from senior executives/
	Designate time & resources for change agent job responsibilities (i.e., not overburdening for the change).
	Ensure change agents are active, visible, and available to help employees throughout the change.
Communicated benefits	Answer the question, "What's in it for me?" for all stakeholders within the company.
	Create urgency by illustrating the disadvantages of the status quo.
	Celebrate intermediate wins with employees to showcase relatable results.
Measured benchmarks	Clearly identify (and track) the quantifiable performance outputs expected.
	Define any new abilities, capabilities, processes, and functions that the company will acquire.
	Ensure accuracy of the performance data and use the data to enforce positive accountability.
Realistic timescale	Develop an implementation plan that accounts for all major change-related transition activities.
	Avoid the temptation to push aggressively for a quick fix; rather, maintain focus on long-term adoption.
	Set leadership expectations for patience and forgiveness of minor setbacks, which will encourage the change.
Senior leadership commitment	Provide visible demonstrations of commitment for the duration of the change.
	Be sure to walk the talk wherever possible by participating in the company's new practices.
	Illustrate that the change is not a fad by showing that leaders are focused on long-term adoption.
Training resources	Provide up-front training and guides to minimize uncertainty before initiating change processes.
	Establish avenues to encourage employee questions (thereby reducing uncertainty).
	Provide on-the-job training for each employee's job function.

Research by authors such as Babic & Rebolj (2016), Deutsch (2011) and Xue et al. (2012) even argue that a cultural change is required for BIM to successfully be implemented in the AEC industry.

5.2.2 Well-known change and transition management models and theories

Due to the large amount of available change and transition management models and theories that have been developed over the years, it can be challenging to obtain a clear overview. Two recent books ((1) The theory and practice of change management by Hayes (2018), and (2) Making sense of change management by Cameron and Green (2019)), have tried to make sense of the available change management theories to help make sense of change management. It was concluded that the well-known change management models and theories to be discussed for this research would be related to understanding how people respond to change, how to implement change in a manner that minimizes the chance of resistance, and the importance of triggering double-loop learning. Both books discuss the chosen well-known theories to address these topics: Bridges transition model, Kotter's eight-step model to lead change, Kotter & Schlesinger's strategies to minimize resistance, and Argyris & Schön's concept of single-loop and double-loop learning.

Bridges' transition model

One of the unique strengths of Bridges' model is that it does not focus on change, but on transitioning. Bridges (1991) argues that the terms 'change' and 'transition' are often used interchangeably. However, he argues that transitioning consists of three stages and is a psychological process that often leads to resistance. The three stages are presented in Figure 14. The key to this transition model is to understand the transitional phases that individuals go through when change is desired to provide proper guidance to employees.

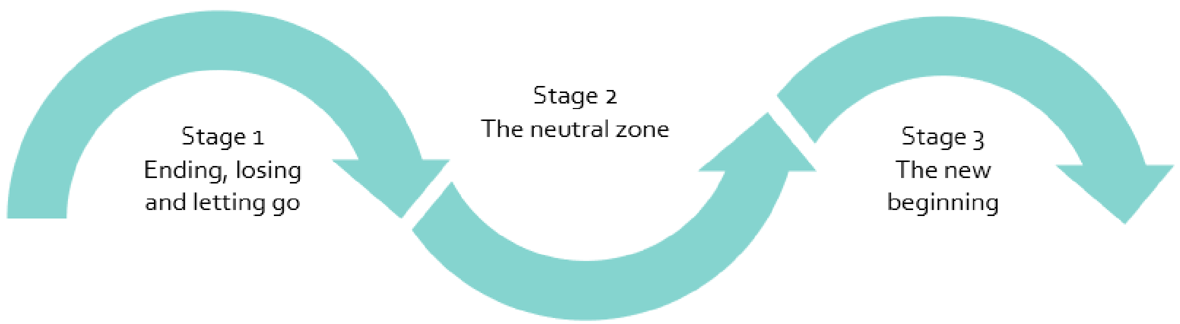


Figure 14 Bridges' transition model (Bridges, 1991)

The transition process starts with Stage 1, which resembles the ending of a previous phase. Significant levels of resistance to change are present in this stage. People will learn that their comfortable routines might have to be adjusted. They may feel frustrated or experience uncertainty. The purpose of the change must be communicated, the benefits should be clarified, and it should be clarified what will change and what will remain the same. Communication is key during this stage.

The center of the transition process is Stage 2, which is considered the neutral zone. During this stage, individuals are learning to deal with the changes. However, often they are not yet fully comfortable with the change and require encouragement. They might look back at how things used to be and prefer the old way of working. They are in the process of adapting to the new way of working and might feel skeptical about the change. It is especially important during this stage to offer training and handle issues that emerge.

The final stage resembles a new beginning, where the changes have been accepted completely. Employees are developing the required skills necessary for the new working method. The results of the hard work will finally show, and individuals will fully realize why the new way of working was needed. This stage should be sustained through celebrations of the results and milestones, consistent communication and behavior, and explicitly showing the successes resulting from the change.

Bridges (1991) argues that successful transition management involves the following steps. Communicate the reason for the change. Gather information from those who are affected by the change to comprehend what impact it is having on them. Educate leaders about the three stages of transition and monitor how individuals progress through the transition model. Lastly, engage individuals on how they can contribute to the change and express their importance in the process.

Kotter's eight-step model to lead change

Kotter (1996) developed an eight-step model to lead change and transform an organization, see Figure 15. The model is based on lessons learned from change efforts. Kotter argues that change is a process that goes through several phases. Skipping steps will create the illusion of progress and speed but will never lead to the desired result. The three main phases that should be followed include: (1) Creating a climate for change, (2) Engaging and enabling the whole organization, and (3) Implementing and sustaining change.

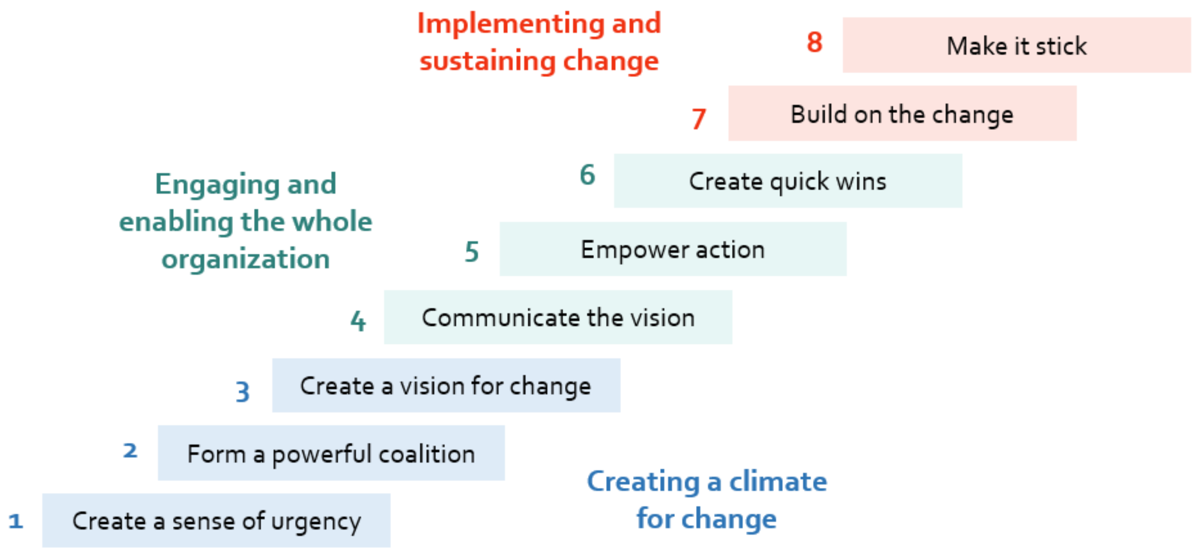


Figure 15 Visualization of Kotter's eight-step model to implement change

The first phase involves creating a sense of urgency, forming a powerful coalition and creating a vision for change. It is crucial to create an environment where employees are aware of the problems of the status-quo and how change can improve these problems. Through a powerful coalition, that ideally consists of a range of experience and employees throughout the organization, messages can be communicated throughout the organization. To ensure that everyone moves towards the same goal, it is crucial to create an understandable and compact vision for change that is inspirational to the employees.

The second phase involves communicating the vision, empowering action and generating quick wins. The vision must be communicated, and feedback must be processed. Step 5 is essential to improve your vision by removing obstacles. Through active dialogue with employees, especially those who are resistant and critical, obstacles can be overcome, and their input can be included in the change process. The last step of the second phase is to create quick wins. Generating quick wins will motivate employees to continue working on, or join, the change process.

The third phase of Kotter's eight-step implementation model consists of implementing and sustaining change. The goal of this phase is to build on the quick wins, as they are only the beginning of the desired long-term change. Therefore, an organization must continue to look for improvements. The continuation of success will slowly lead to the conclusion that the change is worth it. Lastly, the change should be anchored and become part of the corporate culture. It is suggested to regularly evaluate and perform progress talks to consolidate change.

Kotter and Schlesinger's strategies to minimize resistance to change

In Kotter and Schlesinger's (1979) research, they distinguish reasons for resistance to change and present strategies to decrease it. They argue that it is important to invest in the reasons why resistance occurs to properly select the best suitable implementation strategy. Misunderstandings, a lack of trust and a low tolerance for change are among the reasons behind resistance to change. Kotter and Schlesinger present the following strategies to decrease resistance:

(1) Education and communication: This approach is applicable when resistance is based on a lack of information or inaccurate information. Educating people can be done through lectures and discussions, both individually or in groups, and face-to-face or online. The desired changes and influence that the change will have on employees should be clearly communicated.
(2) Participation and involvement: Engaging employees is expected to decrease resistance to change as it increases a feeling of commitment. Initiators of change can implement advice by employees when designing the change strategy.
(3) Facilitation and support: When fear is the core reason for resistance, facilitation and support is the most efficient strategy to overcome resistance. Support can be provided through various methods such as training, listening and ensuring that they are not alone.
(4) Negotiation and agreement: Resistance can be also be decreased by offering incentives to those who are resistant. This method is especially useful when resistant employees have a lot of power within an organization.
(5) Manipulation and co-optation: This strategy involves sharing only a selective amount of information or providing (possible resistant) employees with an important 'key role' in the implementation process. This strategy can be a quick method to solve resistance, however, if people eventually feel manipulated problems might arise. It is suggested to only use this strategy if other strategies have not worked.
(6) Explicit and implicit coercion: Coercion might be the only option if the change must be implemented quickly combined with a predominantly unpopular opinion on the change. It is a risky strategy where managers 'force' employees to accept the change.

Kotter and Schlesinger (1979) argue that the chance of successful change can be increased if the following steps are followed:

(1) Conduct an organizational analysis to visualize the current state of the organization: What is the current situation? Which problems are occurring? What are the possible reasons for these problems?
(2) Conduct an analysis of expected consequences of implementing change: How much resistance is expected? Which parties will likely show resistance? Which factors are essential to change implementation?
(3) Select the proper change strategy based on the previous analyses;
(4) Monitor the implementation process.

Argyris and Schön concept of single- and double-loop learning

Argyris and Schön (1978) developed the concept of single- and double-loop learning, which is considered an influential change management and behavioral change tool to stimulate organizational learning. Through single- and double-loop learning, Argyris and Schön aim to improve employees' understanding of root causes behind problems to boost learning and minimize resistance to change. Their research is arguably necessary if organizations and employees want to manage problems successfully. The model is visualized in Figure 16.

"Single-loop learning occurs when errors are corrected without altering the underlying governing values. Double-loop learning occurs when errors are corrected by changing the governing values and then the actions" (Argyris and Schön, 1978)

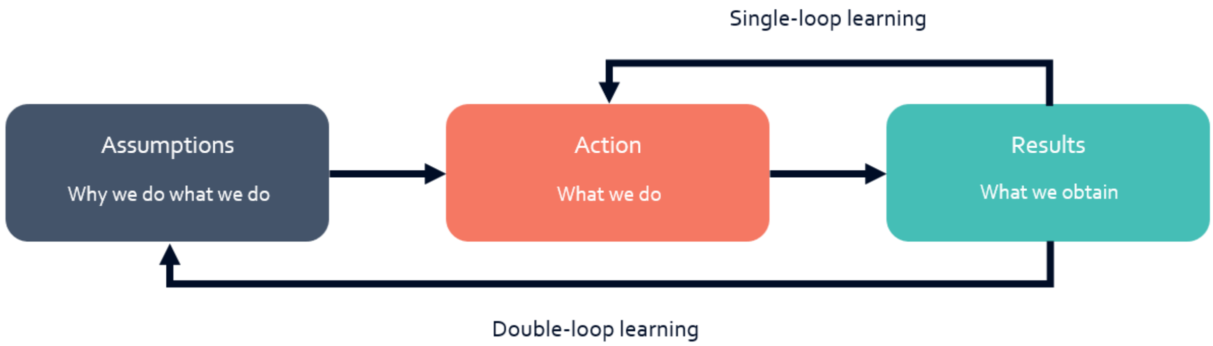


Figure 16 Single- and double-loop learning concept (Adapted from Argyris and Schön, 1978)

Double-loop learning highlights the importance of investigating underlying reasoning and assumptions about behaviors. Processes and procedures in organizations often become the norm and are frequently left unquestioned. 'We have always done it this way.' Unfortunately, it is often very challenging to implement double-loop learning into organizations because it demands a lot of self-reflection and can even make employees more resistant.

Single- and double-loop theory can be applied to raise awareness of employees towards the desired change. In this case, implementing BIM requires a new way of working in a traditional industry. Among others, one of the goals of working with BIM is to decrease the number of errors that occur in traditional building processes. With single-loop learning, one will only see the errors and does not challenge the underlying reasons of why we work according to the traditional standards. Double-loop learning demands critical reflection towards the process as we know it, and how (e.g. BIM or other innovations) can make this process better.

5.2.3 Conclusion of the theoretical methods to deal with barriers

The literature study emphasizes that resistance to change presents itself in various forms and is almost inevitable. It is stressed that to deal with resistance, the different ways in which people react to change and the transitional stages should be understood. Throughout the literature, from early founders of change management research to recent research, various methods are recurring.

First, it is emphasized that the reason for the desired change must be communicated. The following questions should be addressed: Why do we want to change, what are the benefits of this change and what's in it for me? This aims to create a climate for change, a sense of urgency and a level of understanding. Second, customized training and education. Customizing training and education once again accentuates that ideally, everyone requires different forms of training. Training is essential to reduce uncertainty and thereby can increase change-readiness. The results of the Q-study make it possible to target specific subjects to offer customized training. Third, providing support is evident throughout the literature to achieve a willingness to change and minimize resistance. Support can be offered by employing training, but also through change agents. Change agents are often mentioned as an important method to steer change in an organization. It should be ensured that change agents are available and willing to provide active guidance. Throughout the process, it is also suggested to monitor the progress, highlight quick wins, and to make it fun and engaging.

5.3 Methods to deal with barriers suggested by participants

Participants of the Q-study were also asked to propose methods to enthuse PMs to initiate BIM in their projects. The following methods were proposed by multiple participants.

First, it is suggested to **specify the benefits** for PMs explicitly. Currently, many PMs are unfamiliar with the benefits and advantages of BIM applications for their job. They view BIM as a design tool that is (mainly) relevant to designers and contractors. The benefits of BIM for management are often overlooked. Therefore, participants suggest communicating the benefits of BIM for PMs with a focus on the core values such as time, quality, costs, and risks. (Participant #7, #12, #18, #19, #20)

Besides specifying the benefits for PMs, it is suggested to **clarify what is expected** from PMs on a BIM project. What will change, and what will stay the same? Many PMs do not have a clear overview of the changes that will occur when BIM is applied to a project. Therefore, combined with an attachment to the comfortable routine, some PMs might never initiate BIM use because of the uncertainties that will arise. Clarifying the changes will decrease the level of uncertainty and can increase the level of comfort if PMs are reassured that their job will not change a lot. Most participants argued that their jobs overall remained the same. Problems do arise quicker when BIM is used, which means that often decisions will have to be made earlier in the process. Occasionally, this means that information is not yet available to solve the problems that arise. However, participants simply noted that this still means that you can inform your client better and more efficiently. The most significant change stated is that they now have more time to manage the process. (Participant #2, #4, #6, #13, #19)

Clarifying what is expected from PMs aims to increase comfort. Furthermore, other methods are suggested to **increase comfort** for PMs. First, the participants suggest ensuring PMs that they do not have to know everything BIM related. Hesitant PMs mentioned that they are not comfortable to manage a small BIM project on their own and feel hesitant to include a BIM specialist to accompany them on small projects. It is perceived that the budget is not available on smaller projects to include BIM specialists. However, if a PM can convince their client that the inclusion of a BIM specialist will decrease costs in the long run, this should not be an issue. This starts with knowledge on the benefits of BIM to create a level of comfort for PMs to be able to convince their client. Hesitant PMs should be referred to the experts within the organization and ensured that they do not have to solve every problem that comes their way on their own. Guidance and support should be provided by BIM experts in the organization. This should be customized per PM: some PMs will prefer to fully educate themselves, while others are comfortable enough to tackle a BIM project with an accompanying BIM specialist. (Participant #2, #5, #11, #12, #13)

Participants also highlighted the need to **raise knowledge and awareness** in the organization. Through workshops, such as virtual reality sessions or a fictive case study, PMs can be engaged with BIM technology in a fun way. Reference projects and success stories should be shared. Training should be made available to educate on the possibilities of BIM, the changes in the process and the required software. (Participant #1, #3, #7, #9, #10, #11, #15, #16, #23)

The proposed methods to enthuse PMs to apply BIM to their projects by participants of the Q-study overlap the methods gathered in the literature review. The following step is to merge these methods to create a customized strategy for the barriers found in the Q-study.

5.4 Presenting the proposed strategy to deal with barriers

The goal of the proposed strategy is to deal with the barriers that are perceived by PMs in perspective 2 and 3 by combining theoretical and practical solutions. The strategy is also aimed to further increase the enthusiasm of perspective 1 (BIM supporters) to stimulate the technology acceptance curve within an organization. The proposed strategy is developed based on the following criteria:

(1) The strategy should be based on well-known theories;
(2) Insights from practice should be included and related to theoretical solutions;
(3) An organization should be able to perform the proposed strategy.

As Figure 17 shows, there is much difference in the extent to which PMs in the different perspectives perceive the following barriers. The barriers shown in Figure 17 represent the highly ranked barriers by perspective 2 and 3, and places them in context by comparing the results to the other perspectives. Furthermore, cost reduction and reduced project duration, two perceived benefits, are also included in the graph to visualize that perspective 2 and 3 scored them significantly lower than perspective 1. The figure shows that there is a significant difference in how BIM is perceived by the various groups of PMs. To conclude, each perspective requires a unique approach to deal with barriers.

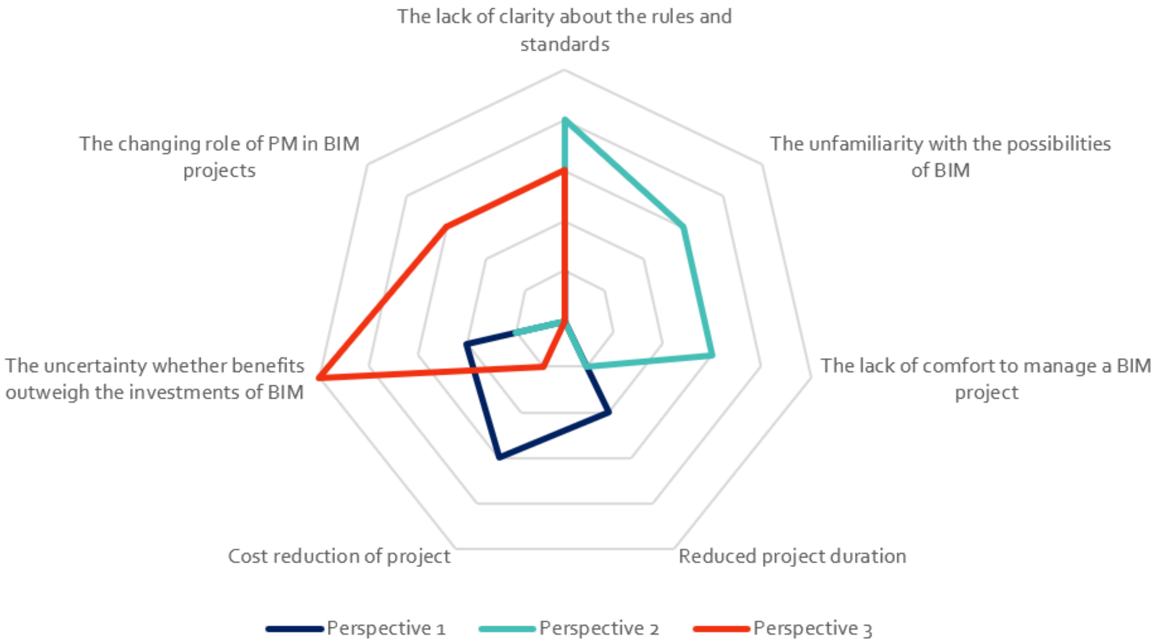


Figure 17 Visualizing the differences between the perspectives in a radar graph

5.4.1 Dealing with the barriers perceived by PMs in perspective 2

Participants in perspective 2 portray various characteristics of stage 1 and 2 from Bridges' transition model. Participants are uncomfortable with the change and require encouragement. They realize that change is inevitable and are convinced of the benefits of BIM. However, they are still more comfortable with the 'traditional' methods of working, which they often experience as 'better'. Perspective 2 is lacking knowledge of the change, which is evident through their lack of familiarity. They desire support and guidance, for example on BIM software (i.e. BIM viewers), rules and standards. Also, they are skeptical about certain aspects of the change such as the quality of the building information model.

Bridges (1991) advises providing support to those who are lacking comfort. When people stumble upon tough areas while change is being implemented, training and other forms of help should be offered to this group.

Knight (2015) also proposed multiple ideas to encourage technology adoption for skeptical employees such as: state your case (why do we want to work with BIM, what's in it for the PMs?), customized training and highlighting quick wins. Argyris and Schön's (1978) single- and double-loop concept can be applied to raise awareness of why we are changing to this new technology.

This is in line with Kotter & Schlesinger (1979) strategies to implement change. Participants from perspective 2 portray resistance because of 'fear' that they are not well acquainted with the change. According to Kotter & Schlesinger's methods for managing resistance, the following strategy is suggested: Facilitation and support. This implies that skill training and (emotional) support should be provided for individuals who are resistant because of a lack of comfort. Additionally, Kotter & Schlesinger's method: Education and communication should be applied to this perspective to increase familiarity, knowledge and comfort.

Lines et al. (2016, 2017) also suggest similar strategies to deal with the barriers perceived by PMs in perspective 2. Step-by-step information and how-to information should be provided to these PMs to increase change-readiness. Combined with sharing the long-term objectives (i.e. why do we want to change?) and communicated benefits (i.e. what's in it for me?), the chance of successful change adoption will increase. Support should be provided by actively involved change agents to show personnel that the organization is committed to decrease skepticism and increase enthusiasm. Finally, feedback and participation should be encouraged of PMs.

The participants indicate that a lack of clarity of the rules and standards, and the limited extent to which they are familiar with the possibilities, make them hesitant to initiate BIM. It is hypothesized that the lack of comfort partly originates from the lack of experience and knowledge. The suggested strategies, to provide guidance through training and other forms of help, are expected to increase the familiarity with BIM. It is expected that an increase in familiarity will lead to an increase in comfort to manage a project in which BIM plays a role. Besides an increase in familiarity, awareness should be raised about the available support within the organization.

5.4.2 Dealing with the barriers perceived by PMs in perspective 3

Participants in perspective 3 portray various characteristics of stage 2 from Bridges' transition model. They are convinced of the benefits that BIM can have on projects. However, they are still skeptical about whether BIM is applicable for each project- and client type. PMs also portray uncertainties about their changing role in BIM projects. This uncertainty is characteristics of stage 2 from Bridges' transition model. Bridges suggests providing a sense of direction to employees who are experiencing these feelings. This can be achieved through Kotter & Schlesinger's (1979) method for decreasing resistance: Education and communication.

Lines et al. (2015) suggest starting the implementation of new processes in smaller projects with a shorter duration. Interestingly, PMs in this perspective are hesitant to implement the technology on smaller projects. However, it is expected that the PMs will experience that BIM is indeed also beneficial for smaller projects. Therefore, either through success stories and reference projects or hands-on experience (managing a smaller project in which BIM is applied), PMs can be convinced that BIM is also beneficial for smaller projects.

Kotter's eight-step model to implement change would benefit PMs in this perspective by creating and communicating a BIM vision throughout the organization. This will generate a sense of direction. The benefits of BIM should be clarified, with the focus on benefits in smaller projects. The BIM vision and goals should be shared as it is unclear whether there even is a desire to implement BIM on each project. When is BIM applicable and worth the investment? The PMs should also receive education on how to persuade a client to apply BIM for facility management purposes. This automatically increases the chance of BIM initiation by PMs as they believe that this is the phase where much of the investment costs are returned.

5.4.3 The proposed strategy

The implementation of BIM entails change management, it requires support and willingness to change from all parties involved. The proposed strategy is designed for PMs in the building industry and aims to (1) increase comfort, (2) decrease skepticism, and (3) increase knowledge. The goal of the proposed strategy is to decrease resistance to change, increase BIM initiation by PMs, and eventually increase the BIM implementation rate of the Dutch building industry. The main framework of the strategy revolves around first identifying which PMs are present within a group, and subsequently applying a customized approach that is tailored to the barriers perceived by perspective 2 and 3. The barriers perceived by PMs in perspective 2 and 3 will be tackled as follows:

- Perspective 2: Focus on **guidance** and **education**
- Perspective 3: Focus on **education**

Guidance:

(1) Accompanying the PM throughout the project;
(2) Providing BIM roadmaps and guidelines (step-by-step, how-to information for each project phase);
(3) Provide guidance for software use, such as BIM viewers, through training or guidelines.

Education:

(1) (Customized) Training, (interactive) workshops and/or lunch lectures;
(2) Address barrier subjects based on a (fictional) case study;
(3) Share reference projects and success stories;
(4) Keep the sessions fun and engaging.

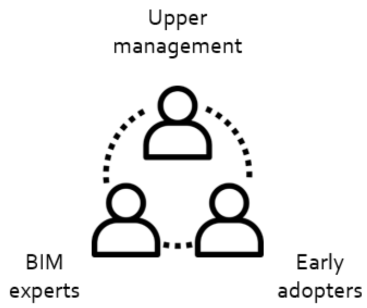
In Table 15, an overview is provided of suggested approaches to deal with the individual barriers identified per perspective. This table provides a more detailed explanation of which guidance and education methods can be applied for each barrier.

Table 15 Detailed approach to deal with individual barriers

	Perceived barriers:	How to deal with barriers?
Perspective 2	1. The lack of comfort that I have to manage a project in which BIM plays a role; 2. The limited extent to which I am familiar with the possibilities of BIM; 3. The lack of clarity surrounding rules and standards of BIM; 4. Skeptical about the change: a) Not convinced of the quality of the building information model; b) Not convinced that BIM decreases project duration, reduces costs or the benefits of BIM for tracking progress during construction.	**1. INCREASING THE LEVEL OF COMFORT BY:** Referring to experts within the organization and/or accompanying the PM throughout the project; Emphasizing that the PM does not have to know everything about BIM; Providing training (i.e. on BIM viewers, what changes in a BIM project and what remains the same); Providing roadmaps (step-by-step, how-to information for each project phase with an emphasis on the role of PM) **2. INCREASING KNOWLEDGE OF BIM POSSIBILITIES BY:** Providing training about the possibilities of BIM, with an emphasis on the role of PM; Sharing reference projects that show the possibilities. **3. INCREASING KNOWLEDGE OF BIM RULES AND STANDARDS BY:** Providing training about the (important for PMs to know) rules and standards of BIM. **4. DECREASING SKEPTICISM BY:** Sharing reference projects and success stories in which these benefits have been achieved; Providing guidelines (i.e. how to ensure that the quality of the BIM is up to standard).
Perspective 3	1. The uncertainty whether the realized benefits outweigh the investments of BIM implementation: a) They believe that BIM investments are not worth it for smaller, less complex projects; b) Is BIM worth it for clients who do not wish to be actively engaged and who do not wish to use BIM for facility management? 2. The lack of clarity about the changing role as PM when BIM is applied; 3. Skeptical about the change: a) Not convinced of the reduced project duration; b) Unsure if clients are ready and/or willing to reuse the data in the BIM.	**1. DECREASING THE LEVEL OF UNCERTAINTY BY:** Providing training in which the benefits of BIM is addressed, with an emphasis on smaller projects; Sharing reference projects and success stories in which benefits have been achieved; Providing guidelines on how to convince your client to apply BIM for facility management. **2. INCREASING KNOWLEDGE OF THE CHANGING ROLE AS PM BY:** Providing training about the changing role as PM (i.e. through a workshop or case study with a walk-through of a BIM project in the role of PM); Clarifying what changes, what remains the same, and what is expected from PMs. **3. DECREASING SKEPTICISM BY:** Sharing reference projects and success stories in which these benefits have been achieved; Providing guidelines on how to convince your client to apply BIM for facility management.

However, it is often the most difficult step in the implementation process to reach those who are resistant to implement BIM to their projects. Therefore, it is suggested to ensure that BIM awareness is carried throughout the organization, **top-down, and bottom-up.** Kotter's (1996) eight-step model is the foundation to reach those who are difficult to access. The first few steps of Kotter's are especially useful as they aim to spark the employees to accept the desired change on their own. Hence, it is proposed to **create a sense of urgency** within the organization to encourage PMs to realize that it is necessary to change and that the status quo no longer suffices. At this moment, it is still optional whether BIM is applied to projects. It goes without saying that it is crucial to remain critical as BIM may not always be the right choice for a project. However, it is necessary that BIM is always considered, for each project and each client, with the correct information in mind. Therefore, it is important that there is **strong support from upper management**. If the organization wants to ensure that every PM considers BIM for their projects, upper management must create a sense of urgency within the organization and confront the employees with the change.

The following step is to **create a powerful coalition**, which is possible by means of a centralized BIM expertise center within the organization, in collaboration with upper management and early adopters of BIM. This coalition will help communicate and spread messages throughout the organization and ensure that there is organization-wide support. **Create a vision for change** in collaboration with this powerful coalition and **communicate the vision** throughout the organization. The BIM vision should consist of an organization-wide strategy to ensure that all employees work towards achieving the same goal. Highlight why the organization wants to work with BIM and what is expected from different roles (i.e. PMs). An overview of the coalition and the corresponding goals of the groups involved can be found in Figure 18.



Upper management

Goals:
(1) Creating a sense of urgency;
(2) Creating a BIM vision (with BIM experts);
(3) Communicating the BIM vision;
(4) Making necessary changes in the process.

BIM experts

Goals:
(1) Performing and monitoring changes in the process;
(2) Organizing trainings, workshops and/or lunch lectures;
(3) Developing roadmaps;
(4) Providing guidance and support.

Early adopters

Goals:
(1) Promoting BIM application throughout the organization;
(2) Sharing success stories, lessons learned and reference projects;
(3) Creating awareness and enthusiasm;
(4) Supporting the BIM experts.

Figure 18 The proposed coalition

To create a BIM sense of urgency, awareness and knowledge, it is proposed to schedule a **"BIM Insights" session** with the PMs of the organization. Upper management, early adopters and BIM experts should also be present during this session. The BIM experts should include technical skills, knowledge of BIM and be able to guide teams and project members through BIM implementation. There are two goals for this event:

(1) **Project-related goal:** Determine why and how BIM should be implemented to benefit projects. Suggest implementing a BIM meeting at the start of each project in which the objectives and ambitions for the application of BIM are determined in consultation with a BIM expert.

(2) **People-related goal:** Find out which perspectives are present in the group to create a customized education / guidance plan. To generate a quick overview, tools such as Mentimeter can be applied to hold a quick survey (before or during the meeting). Based on the results, a customized strategy can be developed to guide and educate the team of PMs to increase the chance of successful BIM use and decrease resistance to implement BIM. A sample survey can be found in Appendix F, see page 100.

If necessary, it can be decided to make the "BIM Insights" session mandatory. Kotter and Schlesinger (1979) argue that imposing change is sometimes the only option to minimize resistance to change and to persuade the late majority. However, it is highly suggested to incorporate the session into the recognized knowledge-sharing methods within the organization, ideally, sessions where it is already customary for everyone to be present. It is suggested to repeat the "BIM Insights" session when there are important developments surrounding BIM that require modifications to the BIM vision of the organization, and when there are new employees.

The BIM experts who guide this process should monitor the (BIM) results, as well as the experiences of the PMs. According to the models of Kotter (1996) and Kotter & Schlesinger (1979), it is important to monitor in order to sustain change and adjust the change process when necessary. Monitoring will also enable BIM experts to highlight quick wins and actively promote BIM use throughout the organization. It is suggested to do so via **recurring "BIM Sharing" sessions**. The goal of the reviews is to:

(1) Repeat BIM awareness throughout the organization through recurring sessions;
(2) Monitor and control: Ensure that BIM use is monitored to check whether BIM is applied properly;
(3) Create an inventory of lessons learned, share quick wins;
(4) Provide (additional) guidance, advise, and/or assistance when needed.

Like the "BIM Insights" session, it is possible to make the "BIM Sharing" sessions mandatory. However, it is recommended to implement the recurring "BIM Sharing" sessions within previously established fixed moments within an organization. Periodically raising awareness of BIM among the PMs will ensure that there is a constant spotlight on BIM, and it demonstrates that the organization is serious about implementing BIM.

An overview of the proposed strategy can be found in Figure 19.

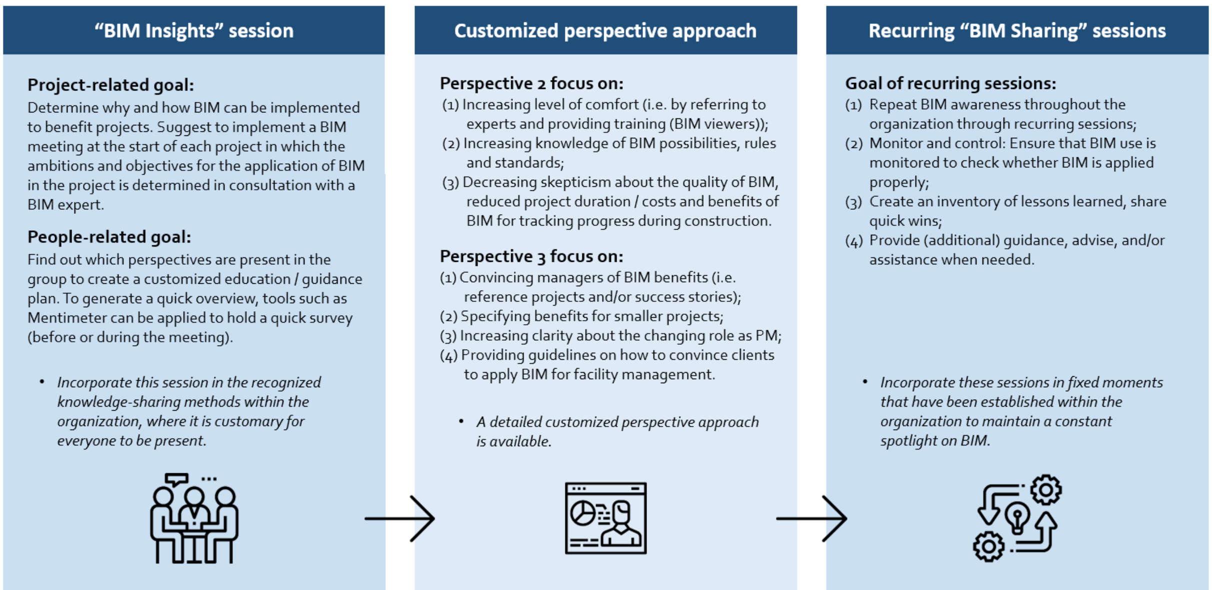


Figure 19 Overview of the proposed strategy to reach those who are resistant and to deal with barriers

6 Evaluation

In this chapter, the evaluation of the research is presented. The proposed strategy is evaluated through expert interviews. This chapter will discuss how the expert interviews were set-up, the results of the interviews and present a conclusion.

6.1 Expert interview set-up

The purpose of the evaluation phase is to gather feedback on the feasibility and applicability of the proposed strategy. The evaluation phase of this research has been structured as follows. To ensure that feedback is provided from a range of relevant viewpoints, four individual expert interviews have been performed with participants with different expertise, all of which are employees at BMA. Considering the different aspects of the proposed strategy, i.e. involving upper management, implementing BIM, implementing change, and trying to convince BIM critics to apply BIM, the following participants were selected for the expert interviews:

(1) A BIM critic (20+ years of experience);
(2) A member of upper management (20+ years of experience);
(3) A change management specialist (10 years of experience);
(4) A BIM implementation specialist (20+ years of experience).

A presentation was held at the start of each interview in which the results of the research and the proposed strategy (according to Figure 18 and Figure 19) was presented. The participants were asked the following questions:

(1) Is this a common strategy to deal with the barriers that were identified in this research?
(2) Do you think this strategy will be effective in practice?
(3) Do you expect new barriers to arise when this strategy is applied?
(4) How do you suggest preventing or reducing new barriers?
(5) Do you have any tips to improve the proposed strategy?
(6) Do you have any other comments?

6.2 Results of the expert interviews

The results of the expert interviews are discussed individually. First, a brief summary is presented of the interview. Subsequently, points of attention that are presented by the participants are elaborated.

6.2.1 Results of the interview with a BIM critic

The participant was satisfied with the proposed strategy. Knowledge- and recurring sharing sessions are acknowledged as very important. Particularly the recurring sessions are recognized as significant as BIM constantly continues to develop. This is one of the reasons why it is inevitable that employees must be periodically kept up to date through recurring sessions. Furthermore, the importance of sharing lessons learned, and the identification of problems are confirmed.

The following five points of attention were mentioned by the participant:

1. *Sense of urgency: Highlight the sense of urgency by emphasizing that there is no turning back. It should no longer be an option to work without BIM.*
   Highlighting the sense of urgency is implemented in the proposed strategy as one of the goals of the powerful coalition of upper management, BIM experts, and early adopters. It is their responsibility to create a sense of urgency and develop a BIM vision that is communicated throughout the organization. The participant

emphasized the need to share present-day examples of why BIM can no longer be ignored. These examples can be presented during the first BIM session.

2. *How to deal with BIM for different types of projects? There should be a clear overview of the advantages and disadvantages of BIM for different sizes and types of projects. For example, BIM application for new buildings vs existing buildings (renovation projects) require different points of attention.*
One of the subjects addressed in the proposed strategy, mainly for perspective 3, is to emphasize the benefits of BIM for smaller projects. In line with the feedback from the participant, it is encouraged to develop a clear overview of when BIM is beneficial for a project. However, it might be difficult to develop a general guideline because there are several factors that can influence whether applying BIM is a favorable choice, more than just the size and type of projects (i.e. the type of client or the ambitions of the project).

3. *It should be emphasized that the PM does not have to have 'hardcore' knowledge of BIM. Instead, it should be guaranteed that the PM is able to obtain the information he requires. For this matter, a connection should be made to BIM viewers. The lack of (knowledge of) BIM viewers, generates the feeling of a lack of insights into a project. It should be ensured that the PM is able to look at the model. This may require training or purchasing the right tools.*
The proposed strategy focusses on this subject in the customized perspective approach of perspective 2 and 3. It is suspected that the lack of comfort to manage a BIM project partly originates from the mindset that PMs must have mastered BIM. However, in practice, it is constantly acknowledged that the PM does not have to know everything about BIM. The proposed strategy suggests methods to deal with this feedback, such as education on BIM viewers and clarifying the changes for the role of PM in a BIM project and organized guidance.

4. *Ensure that the required information can be retrieved in an accessible way. Consider, for example, an online option to gather information from BIM.*
This feedback is extremely useful. It is proposed to store the training and workshop slides, guidelines and step-by-step information on various topics on an online platform. In this way, it is highly accessible for PMs to obtain information about uncertainties that they have regarding BIM.

5. *Make BIM fun!*
The participant highlights the usefulness and necessity of keeping the sessions fun. This can be achieved through virtual reality and showing the various possibilities of BIM. For example, letting PMs walk through a building and showing the visualization tools. It is agreed that this should be a point of attention during the development of the training and workshops for the BIM sessions.

6.2.2 Results of the interview with upper management

The participant of upper management was convinced of the proposed strategy and thought it was a recognizable method to deal with barriers in practice. The perspectives found in the Q-study were familiar to the participant. It was agreed upon that the usefulness and necessity to work with BIM should be carried out throughout the organization. The need to provide training and guidance is highlighted because those who resist change often do so due to a lack of knowledge. It was acknowledged that it is crucial to identify barriers that are still perceived by PMs in order to lower the threshold to apply BIM.

The following two points of attention were provided by the participant:

1. *Keep in mind that there must be a balance between informing and over-informing.*
It was emphasized that it is crucial to scan whether people are still satisfied with the density of information to prevent over-informing. The participant has experienced that overloading people with information can be

counterproductive. Therefore, it is proposed to implement the change process in small steps. Furthermore, it should be regularly checked whether the target audience, those who you are doing it for, are still on board.

2. *Be careful with forcing change.*

It is recommended to be very careful because barriers can arise when change is imposed and forcing change can lead to negative experiences. The participant recommends sharing success stories, creating a strong foundation, and showing the necessity of the change. This feedback has been implemented into the proposed strategy, by proposing that meetings are interlaced with the common knowledge-sharing methods of an organization instead of making it mandatory to attend.

6.2.3 Results of the interview with a change management specialist

The participant who is specialized in change management recognized change management theories in the proposed strategy and states that the proposed strategy is in line with common methods to deal with similar issues. Points that are emphasized in the literature, such as creating readiness to overcome resistance through creating a sense of urgency, clarifying the difference between the current state and the new state, and mapping expectations reappear in the strategy.

The following two viewpoints were discussed:

1. *Embrace resistance.*

The participant argued that the worst resistance is no resistance because if you can overcome the resistance of employees, you can create real advocates. Active support must be shown towards those who portray resistance, and it should be emphasized that there is room within your organization to share concerns and barriers that are perceived. This point of attention can be accentuated during BIM sessions in the proposed strategy.

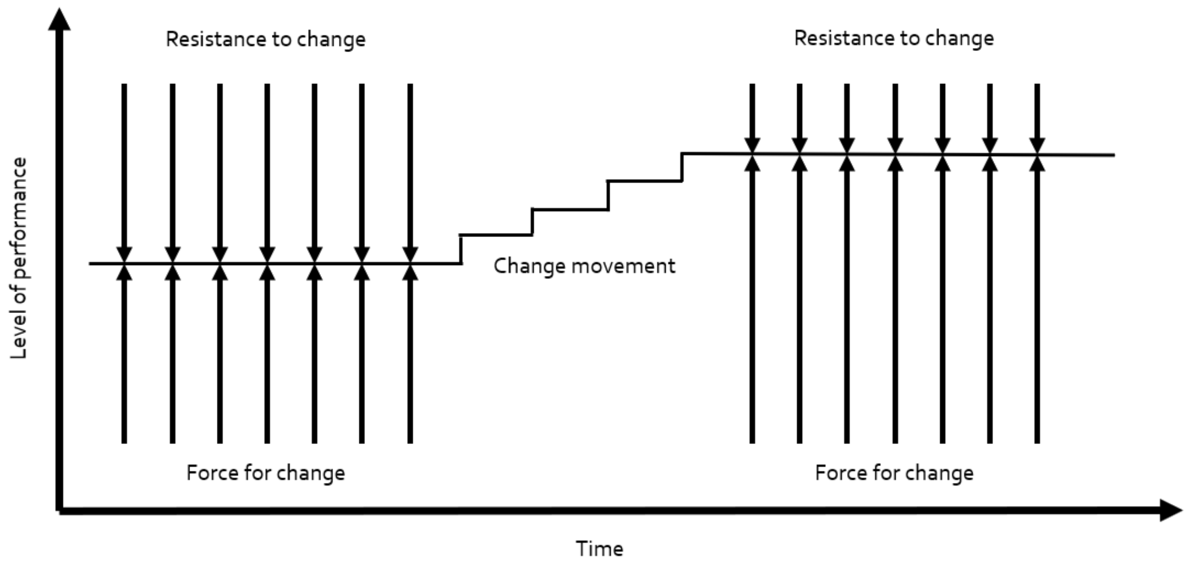


Figure 20 Lewin's force-field theory (Adapted from Lewin, 1951)

2. *Target the drivers of change.*

Based on Lewin's force-field theory, see Figure 20, the participant argued that it is also an option to focus solely on the drivers of change instead of those who portray resistance. Lewin's theory states that to realize change movement, three strategies can be pursued:

(1) Increase the forces for change;
(2) Decrease the resistance to change;

(3) Increase the forces for change *and* decrease the resistance to change.

In line with Lewin's theory, the participant suggested targeting the drivers of change, complementary to those who portray resistance, to achieve change movement. This viewpoint is incorporated into the proposed strategy by ensuring that it does not only focus on reducing resistance, but also ensures that BIM proponents are more motivated to apply BIM.

6.2.4 Results of the interview with a BIM implementation specialist

The BIM implementation specialist was satisfied with the proposed strategy. The separation of project- and people-related goals within the "BIM Insights" session was found particularly appealing. Within every project, there is a need to analyze the ways in which BIM can be of added value. On the other hand, it is also crucial to pay close attention to which people are present within the project and how to involve the right people.

The perspectives found in this research were also recognized by this participant. Approaching the perspectives in a customized manner was perceived as logical. The effectiveness of the proposed strategy increases because of the customized plan to tackle different barriers. In this way, you will have the best chance of removing the concerns of the opponents. By splitting up the project-related and people-related factors, the chance of responding appropriately increases and efficiency is enhanced.

The following point of attention was mentioned:

1. *Give people space to implement BIM in their own way.*

Besides the need for a step-by-step guide on how to implement BIM, it is also very important to allow employees to make BIM their own. It is advised to steer away from imposing change. At the start, people will require active guidance, however, at some point, they will have to be let go.

6.3 Conclusion of the evaluation phase

To summarize the evaluation phase, the proposed strategy was received positively and is expected to be effective in practice. The perspectives and corresponding barriers found in this research were recognized by the participants. Furthermore, the strategy was acknowledged as an appropriate way to deal with the barriers found in the research. The results of the interviews were particularly useful to gather points of attention that have been underexposed in the elaboration of the strategy. The points of attention provided by the experts complement each other, and the participants did not contradict each other in the individual interviews.

The following conclusions are highlighted. The sense of urgency should be emphasized in the strategy. Information on the topics 'BIM viewers', 'BIM for different types of projects', and 'knowledge required by PMs' should be easily accessible. It was suggested during the expert interviews to maintain the information in an online platform and to emphasize that PMs know that they can always refer to BIM experts for their concerns, questions, and information. Resistance should be embraced, and PMs must feel like they can share their concerns and barriers. Only when PMs feel that there is room to share issues that they perceive towards BIM application, they will openly talk about the specific aspects they are struggling with. Moreover, it is suggested that the drivers of change are also targeted with the strategy. BIM should be made fun all-around, and by stimulating the BIM drivers while also tackling the BIM opponents, change movement will be achieved. Lastly, there should be a balance between informing and over-informing. The latter can lead to an increase in resistance, which should be prevented.

Based on the evaluation, it is not necessary to make specific changes to the proposed strategy. Most points of attention are already explicitly or implicitly present in the strategy. The remaining points of attention should not be overlooked and are included in the recommendations. Table 16 provides an overview of the points of attention and in which ways the points of attention are implemented in the strategy.

Table 16 Overview of the points of attention from the evaluation phase

Participant	Points of attention	Where can it be found?
BIM critic	Highlight the sense of urgency	Primary goal of coalition upper management, BIM experts and early adopters
	Information should be easily accessible, i.e. online platform	Recommendations
	Make BIM fun	Implemented in the proposed strategy (see suggestions for education)
Member of upper management	Balance informing and over-informing	Recommendations
	Avoid forcing change	Sessions are implemented in recognized knowledge-sharing sessions
Change management specialist	Embrace resistance	Enable PMs to share their barriers during sessions (see sample survey)
	Target the drivers of change	Sessions are performed with everyone present and aim to also enthuse drivers
BIM implementation specialist	Give people space to implement BIM in their own way	No restrictions are made concerning how BIM is implemented

7 Discussion

In this chapter, the results of the research are discussed. First, the research findings are presented and related to literature. Second, the limitations of the research are presented. Third, internal validity and external validity are discussed. Lastly, the implications of the research are presented.

7.1 Research findings

The research findings are discussed and related to literature by highlighting which results align with the current literature and which research results contradict literature.

7.1.1 Barriers perceived by PMs

Before this study, many studies focused on the perceived barriers limiting the implementation of BIM in the building industry. One of the aims of the previously performed studies was to distinguish which barriers are contemporary. However, a research gap is found on the perspectives of specific stakeholders towards BIM application. Distinguishing perspectives can help visualize groups of people with similar views, aims to increase insights into the topic and aims to show how perceived barriers and benefits are prioritized against each other. In this research, the PMs' perspectives towards BIM application in the building industry were explored through Q-methodology.

The results of this research indicate that three perspectives of PMs can be distinguished, two of which perceive barriers more significantly than benefits of BIM implementation, leading to a resistance to initiate BIM application. These results support the hypothesis developed at the start of the research that resistance to BIM implementation is present among PMs in the building industry. This hypothesis was not yet explicitly tested by previous researchers. However, multiple papers have found resistance to change as a barrier towards BIM implementation (i.e. Bosch-Sijtsema et al., 2019; Chan et al., 2019; Enshassi et al., 2019; Jamal et al., 2019; Lui et al., 2019), which is confirmed by this research.

The two highest distinguishing barriers per perspective that lead to resistance of PMs to implement BIM according to this study are (1) a lack of comfort (perceived by PMs in perspective 2), and (2) the uncertainty whether the realized benefits of BIM will outweigh the investment (perceived by PMs in perspective 3).

(1) A lack of comfort is mentioned throughout literature and is often presented as an attachment to the comfortable routine. This research suggests that a lack of comfort can be closely linked to a lack of knowledge and familiarity with the change. Enshassi et al. (2019) found that when members must adjust the workflow that they are comfortable with, resistance is often encountered. Combined with a lack of knowledge about the specific changes that are required from employees this leads to a lack of comfort to embrace change (Enshassi et al., 2019). These results are also in line with research by Tauriainen et al. (2016) who found that PMs are often unfamiliar with BIM, leading to uncomfortable PMs who are afraid to implement BIM to their project because of the numerous unknowns.

(2) The uncertainty of whether the realized benefits of BIM outweigh the investment found in this research is in line with previous studies. Previous studies often mention the perceived barrier of 'uncertainty of success'. Keskin, Ozorhon, and Koseoglu (2019) argue that it is challenging to confirm whether the benefits outweigh the investment costs of implementing BIM. Respondents of a study by Migilinskas et al. (2013) fear that BIM has a high investment cost and that the success of applying BIM is too low. Furthermore, half of the interviewees of research by Zhou et al. (2012) state that they do not believe that the benefits of BIM outweigh the costs. Results of a study by Bui et al. (2016) further acknowledge this barrier and state that BIM is perceived as a risky

investment since the benefits of BIM are difficult to measure. To conclude, the perceived barrier of the uncertainty of success that was found to be significant in this study is in line with previous studies.

7.1.2 Consensus statements

The consensus statements of a Q-study are statements that are ranked similarly by all perspectives. When studying the consensus statements between the perspectives, all perspectives score two statements significantly lower than other statements: (1) My limited willingness to change in order to work with BIM *(Q-sort value of -2)*, and (2) The possible negative consequences of BIM implementation for my career *(Q-sort value of -3)*. These two statements were included in the Q-set because they were listed in more than 3 (primary or secondary) sources, implying that they are relevant to the opinion of PMs towards BIM. However, the results indicate that willingness to change and personal consequences are insignificant factors for PMs. These results contradict literature on this subject.

(1) Willingness to change is consistently mentioned as a barrier towards BIM implementation in recent literature (Chan et al., 2019; Chan, 2015; Enshassi et al., 2019; Liao & Ai Lin Teo, 2018; Straatman, Pel & Hendriks, 2012). Considering that the literature on this subject does not specify which actors portray unwillingness to change, it could be that PMs are not part of the actors who portray unwillingness to change. However, the participants of this research might have been hesitant to admit that they feel this way, simply did not relate to this barrier, or found the other statements relatively more significant. Research by Liao and Ai Lin Teo (2018) suggests that willingness to change is related to a person's understanding of and experience with BIM. This could explain why willingness to change is ranked as insignificant, whilst the lack of familiarity is ranked as significant and is related to a lack of BIM experience in this research (see perspective 2).

(2) Various articles argue that a fear of negative consequences to someone's career is a barrier leading to resistance towards BIM application (Chan, 2015; Kalinichuck & Tomek, 2013; Straatman, Pel & Hendriks, 2012). Equivalent to the discussion about the contradictory results regarding willingness to change, being afraid of personal consequences might be a barrier that the specific participants of this research do not relate to. On the other hand, the participants might have been hesitant to admit that this is a barrier they are struggling with. However, one participant stated that he/she did worry about the personal consequences of his/her career. Even this participant ranked this barrier as insignificant (Q-sort value of -2) to the other statements. This suggests that being afraid of personal consequences might simply be an insignificant barrier compared the other statements.

Nonetheless, it should also be considered that the insignificant ranking of both statements could be caused by socially desirable answers. There is a possibility that some of the participants do perceive these statements as significant. However, they might be afraid to indicate this on paper precisely because of the fear of negative consequences for their career. The researcher has tried to minimize the risk of socially desirable answers by emphasizing the anonymity of the study.

7.1.3 Correlation between age and resistance to change

This research found two perspectives of PMs who portray resistance towards implementing BIM to their projects. The most hesitant group, perspective 2, consisted of the oldest generation with the least amount of BIM experience. This result suggests that PMs of an older generation with little BIM experience could portray similar results as perspective 2: a lack of comfort, and a lack of familiarity with BIM possibilities, rules, and standards. However, the second group who perceived barriers towards BIM application found in this research consisted of the youngest generation. Note: The limited number of loaders of the two resistant perspectives (N=4 and N=3) should be considered when discussing the characteristics of the groups. Due to the small number of loaders, each participant has a high influence on the characteristics of the perspective, such as age. Conclusions drawn about the characteristics of the perspectives must, therefore, be deliberated carefully.

Whether or not there is a correlation between age and resistance to change has proven to be a challenging question throughout literature. Research by Davis & Songer (2009) addresses the stereotype of age in resistance to IT change in the AEC industry. Their research does not confirm that age is an important factor in the likelihood of resistance to IT change. Research by Robson and Littlemore (2011) also found a range of ages within the group of resistant individuals, including participants of the lowest age group (age 19-25). Furthermore, recent research by Milivojevic and Ahmed (2018) also argues that there is no correlation between age and resistance. Participants of their study state that they believe it is a challenge to interest the older generation in BIM application, which they call a generational gap. However, other participants acknowledge that there are plentiful seniors who are not resistant and portray willingness to change. In conclusion, there seems to be a limited correlation between age and resistance to change.

7.1.4 The proposed strategy to deal with barriers

The main goal of this research was to develop a strategy to deal with barriers that arose from the Q-study. Based on well-known recognized theories related to change management (i.e. Kotter and Bridges), the strategy was developed. It was a deliberate decision to base the strategy on theories that are broadly applicable to multiple organizations and for various change implementations. This decision was mainly based on the fact that most recent (BIM-related) papers on change management and implementation of new developments still consider the well-known recognized theories. It must be noted that this is only one of the directions that the strategy could have taken. Different types of theories could also have been opted for, such as the color theory (De Caluwe). Te proposed strategy would inevitably have been different if other types of theories were chosen.

The main activity of the proposed strategy is to carry out a customized approach for PMs who perceive BIM according to the identified perspectives. The effectiveness of the strategy is not only related to the content of the customized approach. The success of this strategy will depend on multiple external factors, such as the culture of an organization and how the strategy is delivered and received within the organization. Furthermore, the research was conducted on a limited participant size, most of whom originated from BMA. Even though the strategy was evaluated by four expert interviews, the strategy has not been tested in practice.

7.2 Limitations of the research

The following limitations of the research are identified: the size of the participant group, the diversity of the participant group, and a difference in portrayal during Q-discussion vs Q-sort.

The size of the participant group is a limitation of this research since only 24 participants took part in the Q-sessions. Even though this is in line with the guidelines of Q-methodology, combined with the high level of detail of the sessions and the carefully selected participants, the sample size is still limited. Therefore, the limited sample size should be considered when concluding the results of the Q-set.

Furthermore, not only the size of the participant group is a limitation, but it is also questioned whether the right people were selected to be a part of the P-set. The relatively large group of positive PMs (17/24) can be an indication that the P-set was not diverse enough. Participants were carefully selected to create a diverse group, concentrating on a range of age, work experience, experience with BIM, and attitude towards BIM. The results of the study can insinuate that the P-set was not as diverse as expected regarding attitude towards BIM. However, there may also be other underlying causes of the large positive perspective found in this research such as socially desirable answers.

Finally, some participants mentioned barriers that they experience in practice and showed signs of resistance and subsequently filled in the sorting table as a BIM supporter. It is difficult to say why this was the case. It could be that the participants, even though they perceived barriers, found the benefits of BIM to be more significant and would still initiate BIM use (with the barriers in mind). However, another reason could be that participants wanted to give a socially desirable answer. This limitation has been tried to minimize by emphasizing that the results of the research are anonymous. It is difficult to say whether socially desirable answers were provided during the Q-sessions. The participants who fall under this category were also asked to provide additional elaboration on the placement of their statements.

7.3 Internal and external validity

Reflecting on the validity of research is crucial to determine how credible the results of the research are. Two types of validity are considered: internal validity and external validity.

7.3.1 Internal validity

Internal validity reflects on how well the research is conducted and the extent to which the results are trustworthy. The research has been systematically set-up and the results have been evaluated through expert interviews. During the process, several actions were taken to increase internal validity.

To increase the validity of the Q-study results, the Q-set was formed carefully and systematically. The predetermined Q-set automatically limits the factors that are researched because it is impossible to include the full universe of statements due to the size of it. Therefore, it is crucial to systematically follow the required process to create a representative Q-set. There is a possibility that themes were missed during this process, as literature sources could have been overlooked. To minimize the chance of missing themes, supplementary interview sessions have been performed.

Furthermore, participants of the Q-sessions were explicitly asked if they missed statements during the Q-sessions. Several participants noted that the type of project and client is important to them in their consideration of whether they will initiate BIM use in their upcoming projects. The results of the Q-study could have been different if these statements were included in the Q-set. However, almost all participants stated that they perceived the Q-set to be a thorough representation of reality and the relevant factors when considering BIM application.

The creation of the Q-set does not only revolve around the content, the formulation of the statements is also of significant value. To avoid misunderstandings, with the risk of leading to unreliable answers, two pilot Q-sessions were performed in which the focus was solely on the formulation of the statements. Through the pilot sessions, a few statements were re-formulated to increase clarity and decrease misunderstandings during the actual sessions.

To further decrease the risk of misunderstandings, misinterpretations, and increase internal validity, the Q-sessions were performed face-to-face. By performing the sessions face-to-face, the researcher was able to observe the verbal responses and placements of the statements. If the researcher suspected that a specific statement seemed out of place on the grid, the participants were asked to clarify their statement placements. In this way, the researcher could indicate whether the participant understood the sorting grid and was placing the statements correctly.

Perhaps one of the most commonly mentioned disadvantages of Q-methodology is the subjectivity of the research, compared to other qualitative research methods, with the risk of bias (Cross, 2005). Based on a small participant group, the researcher interprets the results of the Q-sorts, with the possibility of leading to bias and subjective results. Bias decreases the internal validity of the research results. However, the researcher has tried to avoid bias by actively communicating and asking for explanations of statement placements during the Q-sessions instead of speculating.

Taking the previously mentioned limitations into account, which have actively been tried to minimize to the best of the researcher's ability, it is expected that the internal validity of this research is credible. It should be noted that the result of the research, the proposed strategy to deal with barriers, has not been validated in practice.

7.3.2 External validity

The external validity of research refers to the extent to which the results of the study can be generalized. The chosen methodology for this research, Q-methodology, is known to be unsuitable for statistical generalizing purposes (Baker et al., 2006; Valenta & Wigger, 1997; Wilkins, 2017). Considering the explorative nature of this research, statistical generalizability was not a goal of this research. Q-methodology aims to identify shared viewpoints and provide insights into a topic, rather than generalizing to a wider population. Once the perspectives are identified through Q-methodology, the predominance of those perspectives in the wider population can be tested through, for example, large group surveys (Valenta & Wigger, 1997).

The results of this study, similar to other studies of a qualitative nature, can be categorized under analytic generalization. Analytic generalization implies that the results of this study cannot make claims about statistical representative. Rather, the results of the study contribute 'to a general theory of the phenomenon being studied' (Yin, 2014). To increase the analytical generalizability, the participant group of this research was selected with high diversity in age, working experience, company, and attitude towards BIM. Subsequently, the literature study that formed the Q-set of this research consisted of a broad selection of recent articles, with a wide range of applied research methods and origin. In this way, the generalizability of the research is increased.

Besides the results of the research regarding perspectives of PMs towards BIM application in the building industry, the structure of the proposed strategy can be applied to other issues as well. The three-stepped framework: (1) perform an "Insights" session to classify which perspectives employees identify with regarding a certain issue/tool/application, (2) dealing with the critical barriers of perceived by employees of certain perspectives through a customized approach, and (3) perform recurring "Sharing" sessions in which feedback is provided and the strategy is adjusted if needed, can be applied to gain insights on other issues, besides BIM implementation, within an organization.

7.4 Implications

Considering the limitations of this research, the results of this research broaden the knowledge on the perspectives of PMs towards BIM and contribute to literature and practice. The results of this research contribute to the research gap presented at the start of the research concerning the lack of research on the PMs' perspectives towards BIM implementation and which factors influence their opinions on BIM. Before this research, studies focused on identifying individual perceived barriers and benefits rather than identifying perspectives. The advantage of identifying perspectives compared to singular barriers and benefits is that perspectives provide a much wider range of information about issues.

Through Q-methodology, perspectives are captured fully and limitations surrounding BIM implementation through a PMs' perspective are better understood. This research presents analytically generalizable results that can be used in future research and contribute to literature on this subject. This exploratory research identifies three perspectives of PMs and their corresponding contemporary barriers that require attention. Of the three perspectives, two perspectives are critical and confirm that barriers are still perceived that limit BIM initiation by PMs in projects in the building industry.

The practical implications of this research include a broadened understanding of the topic. Organizations can utilize the results of this research to further increase their understanding of (potentially) observed resistance to implement BIM by PMs. The results indicate the specific barriers leading to the reluctance that could be present within other organizations in the building industry. Furthermore, the proposed strategy can be implemented by organizations to find out whether PMs in their organization indeed relate to one of the perspectives found in this research and can subsequently apply the customized perspective approach. For BMA, this implies that the BIM experts who want to increase BIM implementation within their organization and clients' organizations, can apply a targeted approach to encourage BIM application. This research provides a proposed strategy to find out whether PMs relate to one of the perspectives, to reach those who are resistant, and to deal with their corresponding barriers in a customized manner. To reach those who require a customized approach and to decrease perceived barriers, preparatory actions must be performed by BMA or any other organization that wishes to implement this strategy.

8 Conclusion and recommendations

In this chapter, the conclusion of the research is presented by answering the sub-questions and research question. Subsequently, recommendations are provided for practice and future research.

8.1 Conclusion

The objectives of this research are to (1) discover perspectives of PMs towards BIM application, (2) develop a customized strategy to incentivize PMs to consider BIM for their projects, and (3) extend past research. To obtain those objectives, four sub-questions are addressed in this research. The answers to the sub-questions will be summarized in this section. Based on the answers to the sub-questions, the following research question is answered: **'Which strategy can be developed to overcome barriers perceived by project managers towards BIM application in the building industry?'.**

8.1.1 Answering the sub-questions

The first sub-question **'Which perceived benefits and barriers do project managers experience towards BIM application?'** has been answered through literature study and semi-structured interviews. The extensive amount of qualitative data resulting from the literature study and semi-structured interviews were thematically coded to find corresponding themes and sub-themes. The results of significant benefits and barriers that were subsequently used to form the Q-set can be found in Table 17. The benefits and barriers are found significant if when were mentioned in at least 2 (primary or secondary) sources.

Table 17 Answer to SQ1: Overview of perceived benefits and barriers

Perceived benefits	Perceived barriers
Efficiency	Lack of expertise
Cost reduction	Cost of investment
Coordination	Certainty of success
Reduce project duration	Willingness to change
Collaboration	Lack of rules and standards
Reduction of errors	Lack of demand
Visualization	Familiarity with BIM
Better quality	Attached to comfortable routine
Early detection of issues	Lack of awareness
Better understanding	Additional work
Decision making	Learning curve
Life cycle data	Organizational change required
Construction safety	Legal issues
Feedback	Afraid of personal consequences
Monitoring	Lack of support
	Complexity
	Unclear roles and responsibilities

The perceived benefits and barriers were used to create the Q-set of the Q-study. The sub-themes found in the literature study and semi-structured interviews were translated into statements. The statements were formulated in such a manner that they answered the sorting question of the Q-sessions: "Which factors are important to you when considering whether you will apply BIM in your next project?". The results of the Q-study were analyzed and interpreted. This resulted in three perspectives of PMs towards BIM application, see Figure 21, which provided an answer to the second sub-question of this research: **'Which perspectives can be distinguished of PMs towards BIM application?'**.

Perspective 1: (BIM) Supporters

- Convinced of the benefits of BIM application
- Find their own level of experience and other personal reasoning to not apply BIM irrelevant
- Only question BIM for certain type of projects and clients

Work experience: 16 years
BIM experience: 7 years
Expl. variance: 40%

69% Consultancy, **31%** Municipality

N=17

Perspective 2: Moderately hesitant

- Convinced of **some** benefits of BIM application
- Lack comfort to initiate BIM in projects due to lack of experience and knowledge (i.e. rules and standards)
- Not convinced of the quality of the building information model and cost/time reduction

Work experience: 25 years
BIM experience: 4 years
Expl. variance: 15%

50% Consultancy, **50%** Municipality

N=4

Perspective 3: Critical realists

- Convinced of **some** benefits of BIM application, especially for coordination, improving understanding and quality
- Not convinced of the reduced project duration
- Will the realized benefits outweigh the investments?
- Is BIM realistic for this project and/or client?

Work experience: 8 years
BIM experience: 5 years
Expl. variance: 11%

100% Consultancy, **0%** Municipality

N=3

Figure 21 Answer to SQ2: Overview of the perspectives found in this research

To summarize, three perspectives are found in this research. The first perspective [N=17 participants], also referred to as the group of (BIM) Supporters, consists of PMs who only perceive benefits of BIM application. This group ranked all barriers as insignificant to their consideration of whether to apply BIM to their projects. PMs in this perspective have the highest level of BIM experience and are the largest group of all perspectives (17/24 participants fall in this perspective).

The second perspective [N=4 participants], also referred to as the group of moderately hesitant PMs, consists of PMs who perceive various barriers towards BIM application. Besides acknowledging the benefits of BIM, this group ranked multiple barriers as significant to their consideration of whether to apply BIM to their projects. They perceive a lack of comfort to manage BIM projects due to a lack of experience and knowledge. Specifically, they lack familiarity with the possibilities, rules, and standards of BIM. Furthermore, perspective 2 is skeptic towards the quality of the BIM, and whether BIM leads to a cost and time reduction. The PMs in this group have the (relatively) lowest level of BIM experience and consist of the oldest generation (an average of 25 years of working experience).

The third perspective [N=3 participants], which can be referred to as critical realists, consist of PMs who are critical towards BIM application and question whether the benefits outweigh the investments. Several benefits of BIM are ranked as signification to this group, such as the improved quality of the project. However, the PMs in this perspective are unsure if BIM investments are worth it, especially when BIM is not used during the facility management phase. They are skeptical about whether clients are ready to reuse the data in BIM for facility management purposes and are unsure that BIM will reduce the project duration. PMs in this group are the youngest generation.

After the perspectives were identified, the most important barriers experienced by PMs were specified. By analyzing the Q-sorts of the perspectives, combined with the Q-discussion, it was possible to identify which critical barriers lead to the reluctance of PMs to apply BIM to their projects. According to the applied criteria to identify barriers, perspective 1 did not perceive any barriers. It was found that perspective 2 and 3 do perceive multiple barriers that lead to reluctance. An overview of the barriers that lead to the reluctance of PMs to apply BIM to their projects can be found in Table 18. This answers the third sub-question of this research: **'Which factors can be identified as barriers leading to the reluctance of PMs to apply BIM to their projects?'**. After the barriers were identified, the fourth sub-question of this research was addressed: **'How can factors that lead**

to reluctance to change be influenced?'. Through a literature study on change management theories and an analysis of proposed methods to influence resistance to change, provided by the participants of the Q-study, the sub-question was answered.

It was concluded that perspective 2 and perspective 3 require separate methods to influence their reluctance to change. Table 18 provides practical examples to deal with the barriers found in this research. To tackle their unique barriers, it is suggested to:

(1) Perspective **2**: Focus on **guidance** and **education;**
(2) Perspective **3**: Focus on **education.**

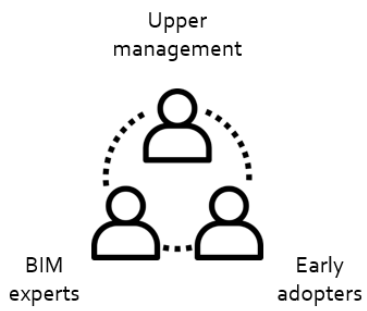
Table 18 Answer to SQ3 and SQ4: Overview of barriers perceived by PMs and how to deal with the barriers

Perspective 2: Moderately hesitant	
Perceived barriers: (1) The lack of comfort that I have to manage a project in which BIM plays a role; (2) The limited extent to which I am familiar with the possibilities of BIM; (3) The lack of clarity surrounding rules and standards of BIM; (4) Skeptical about the change: a. Not convinced of the quality of the building information model; b. Not convinced that BIM decreases project duration, reduces costs, or the benefits of BIM for tracking progress during construction.	How to deal with perceived barriers: **(1) Increasing the level of comfort by:** - Referring to experts within the organization and/or accompanying the PM throughout the project; - Emphasizing that the PM does not have to know everything about BIM; - Providing training (i.e. on BIM viewers, what changes in a BIM project and what remains the same); - Providing roadmaps (step-by-step, how-to information for each project phase with an emphasis on the role of PM). **(2) Increasing the knowledge of BIM possibilities by:** - Providing training about the possibilities of BIM, with an emphasis on the role of PM; - Sharing reference projects that show the possibilities of BIM. **(3) Increasing the knowledge of BIM rules and possibilities by:** - Providing training about the (important for PMs to know) rules and standards of BIM; - Providing roadmaps (points of attention regarding rules and standards for each project phase). **(4) Decreasing skepticism by:** - Sharing reference projects and success stories in which these benefits have been achieved; - Providing training (i.e. how to ensure that the quality of the BIM is up to standard).
Perspective 3: Critical realists	
Perceived barriers: (1) The uncertainty whether the realized benefits outweigh the investments of BIM implementation; a. They believe that BIM investments are not worth it for smaller, less complex projects; b. Is BIM worth it for clients who do not wish to be actively engaged and who do not wish to use BIM for facility management? (2) The lack of clarity about the changing role as PM when BIM is applied; (3) Skeptical about the change: a. Not convinced of the reduced project duration; b. Unsure if clients are ready and/or willing to reuse the data in the BIM.	How to deal with perceived barriers: **(1) Decreasing the level of comfort by:** - Providing training in which benefits of BIM are addressed, with an emphasis on smaller projects; - Sharing reference projects and success stories in which benefits have been achieved; - Providing training on how to convince your client to apply BIM for facility management. **(2) Increasing knowledge of the changing role as PM by:** - Providing training about the changing role as PM (i.e. through a workshop or case study with a walk-through of a BIM project in the role of PM); - Clarifying what changes, what remains the same, and what is expected from PMs. **(3) Decreasing skepticism by:** - Sharing reference projects and success stories in which these benefits have been achieved; - Providing training on how to convince your client to apply BIM for facility management.

8.1.2 Answering the research question

The answers of the sub-questions all build-up towards answering the main research question. The research question of this study was: **'Which strategy can be developed to overcome barriers perceived by project managers towards BIM application in the building industry?'**

A strategy was developed to be able to apply the customized approach to deal with barriers. The proposed strategy can be roughly divided into two phases, a preparatory and execution phase. During the preparatory phase, a sense of urgency should be created and carried out throughout the organization. Creating a sense of urgency implies explaining why the change is desired, and the positive effects that making the change will have on the organization. The aim of creating a sense of urgency is to convince PMs, and to make it appealing and stimulating to apply the change. Strong support from upper management is critical in this phase. By creating a powerful coalition between upper management, BIM experts, and early adopters, messages can be communicated throughout the organization and organization-wide support is developed. Besides creating and communicating a clear BIM vision, additional preparatory actions must be performed by BIM experts. Guidelines, training and roadmaps are examples of documentation and activities that must be prepared before executing the following phase of this proposed strategy. An overview of the proposed coalition and the corresponding goals can be found in Figure 22.



Upper management

Goals:
(1) Creating a sense of urgency;
(2) Creating a BIM vision (with BIM experts);
(3) Communicating the BIM vision;
(4) Making necessary changes in the process.

BIM experts

Goals:
(1) Performing and monitoring changes in the process;
(2) Organizing trainings, workshops and/or lunch lectures;
(3) Developing roadmaps;
(4) Providing guidance and support.

Early adopters

Goals:
(1) Promoting BIM application throughout the organization;
(2) Sharing success stories, lessons learned and reference projects;
(3) Creating awareness and enthusiasm;
(4) Supporting the BIM experts.

Figure 22 Part 1 of the answer to the research question: Proposed coalition and accompanying goals

The proposed strategy to perform the customized perspective approach is visualized in Figure 23. It is suggested to implement a "BIM Insights" session into the recognized knowledge-sharing methods of an organization. Ideally, this session should take place at moments where it is customary that everyone is present. The goal of **the "BIM Insights" session** is twofold. On the one hand, there is a **project-related goal** to determine why and how BIM is desired to be implemented to benefit projects. It is recommended to suggest PMs implement a BIM meeting at the start of each project in which the objectives and ambitions for the application of BIM in the project are determined in consultation with a BIM expert. On the other hand, there is a **people-related goal** of this session to create an inventory of the perspectives and barriers that are present in the group. Through a quick tool, for example, a survey similar to the sample survey presented in Appendix F, it can be determined whether PMs can identify with the found perspectives or perceive additional barriers. As soon as an overview is developed of the perspectives present in the group, the customized perspective approach can be applied.

To monitor whether the desired results are achieved, it is suggested to follow-up the "BIM Insights" session with **recurring "BIM Sharing" sessions**. Not only will recurring BIM sessions ensure that BIM awareness is periodically stimulated. The sessions will also ensure that feedback can be provided by the PMs, an inventory can be created of lessons learned, quick wins can be shared, and additional guidance can be provided if necessary. The sharing session aims to lower the threshold for hesitant PMs to get started with BIM. The aim of the sharing sessions is to provide hesitant PMs with a feeling of support from their colleagues. They will also gain confidence by seeing that other PMs are also going through a learning curve by developing, solving barriers, and learning new (BIM) skills.

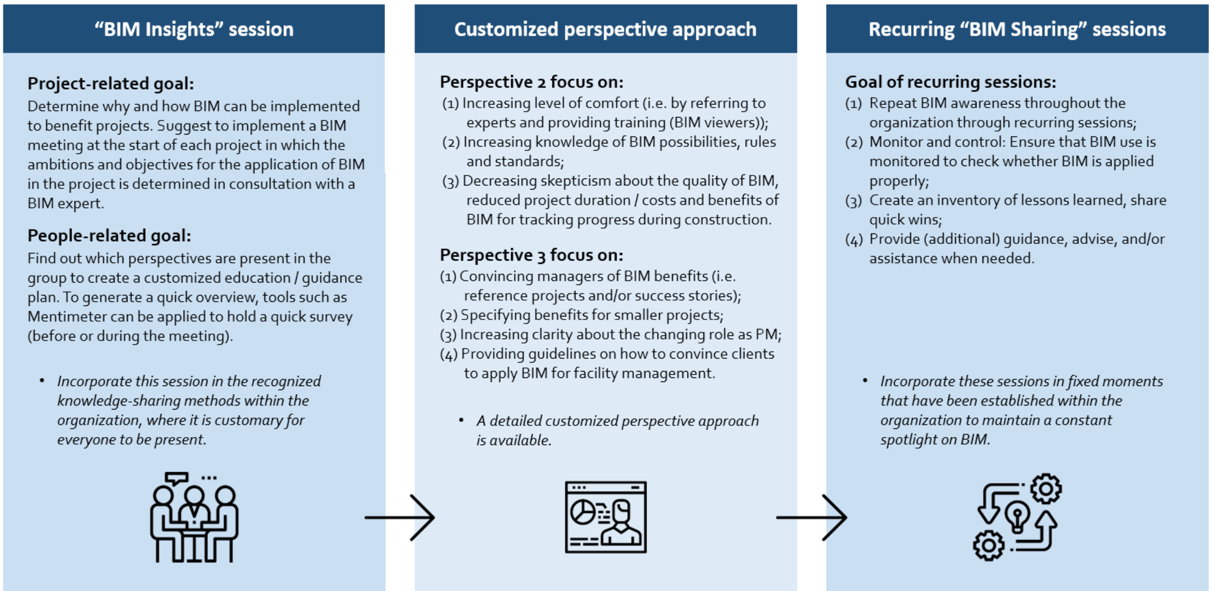


Figure 23 Part 2 of the answer to the research question: Proposed BIM sessions with a customized perspective approach

8.2 Recommendations

As a follow-up from the discussion and conclusion, the following recommendations are proposed for practice and future research.

8.2.1 Recommendations for practice

The following recommendations are made for practice. The first critical step is to ensure that BIM experts are available to lead the change, provide guidance, and respond to questions or concerns. Subsequently, it is suggested that the BIM experts of an organization perform the following preparatory steps to arrange the proposed strategy:

(1) Develop a short survey to rapidly determine which perspectives are present within the organization;
(2) Develop roadmaps and guidelines with step-by-step, how-to information addressed to PMs specifically on how to tackle different subjects that occur throughout a BIM project. This will highly increase the level of comfort that PMs have towards BIM application. Address the subjects presented throughout this research, such as when to apply BIM, the changing role as PM, and rules and standards;
(3) Develop slide-decks in which different barriers are addressed per slide to quickly customize a presentation. This way, when barriers or perspectives are identified, the BIM expert can instantly customize a presentation in which specific barriers are addressed through argumentation, reference projects, and/or success stories.

When the preparation is finished, it is recommended that organizations, such as BMA, start implementing the proposed strategy of this research. It is suggested to pay attention to the following points gathered from the evaluation phase:

(1) Ensure that information is always easily accessible to PMs: All information (i.e. guidelines, roadmaps, training material) on relevant topics found in this research should be easily accessible to PMs. It is suggested to do so via an online platform, to increase accessibility. Furthermore, BIM experts should be available for questions and concerns.

(2) Balance informing and over-informing: Avoid over-informing as this can increase resistance. Instead, ensure that it is known where information can be found, ideally online and easily accessible. Furthermore, highlight the presence of BIM experts within the organization who are available for assistance.

8.2.2 Recommendations for future research

The following recommendations are presented for future research:

(1) Due to the limited statistical generalizability of this research, future research could apply a different methodology (i.e. in-depth interviews or surveys) to further analyze the resistance to BIM implementation by PMs. This study was an exploratory study that has identified two groups of resistant PMs towards BIM implementation. Future research could study this subject with methodologies that are more suitable for generalizing to a wider population.

(2) The results of this research did not distinguish a group of fully opposing PM (i.e. a perspective that perceives predominantly barriers and limited benefits). It is hypothesized that a fully opposing group exists. Further research could investigate whether this is true;

(3) Further research could focus on other key players of BIM implementation within the building industry, such as the client and facility manager. A lack of demand from the client and facility managers was recognized by multiple PMs in this research. By performing similar Q-studies on other actors in the building industry, more in-depth barriers can be identified per actor. This way, a customized approach can be developed for various stakeholders, leading to a more personal and tailored manner to incentivize stakeholders to apply BIM to projects;

(4) Future research could further analyze the proposed strategy to deal with the barriers found in this research. A more in-depth analysis is recommended to gather whether the strategy will be effective in practice.

Reflection

Over the past few months, I have enjoyed the process of writing my thesis. Writing and performing literature studies are aspects of research that I genuinely enjoy doing. During these months, I have successfully broadened my knowledge of BIM implementation, change management, and how to perform research. Combined with the number of informative interviews that I performed; I can conclude that this was an exciting process to go through. Furthermore, the participants of the Q-study really enjoyed the Q-sorting session. Multiple times the participants informed me that they thought the sessions were fun to participate in. They appreciated the hands-on approach and thought it was a welcome change from conventional interviews.

This graduation research was initiated by a perceived resistance of project managers to implement BIM. This topic immediately spoke to me because I perceived a similar challenge during a previous research internship. After months of research on this topic, I still believe that this topic is relevant, and I am a strong believer that it is crucial for key players such as project managers to actively portray a positive attitude towards BIM to achieve successful implementation. Throughout this process, it was recognized by professionals that this subject is interesting, noteworthy, and contemporary, which made me want to continue this research.

I perceived the last phase of my research to be the most complicated one. Developing a strategy for the barriers found in the Q-study was a challenge. I decided to analyze change and transition management theories to deal with the barriers. At times, I felt unable to develop 'groundbreaking' advice, which I was hoping to provide. Overall, I am content with my advice and I believe that it suits the results of my research. The proposed strategy is set-up in a general format that is applicable to multiple organizations, which is an aspect that I perceive as valuable.

When reflecting on the past months, I can conclude that I am very proud of the research that I have performed. In retrospect, I do believe that I unintentionally rushed some parts. To improve my process, I could have taken more time for certain phases of my research and for consultation sessions with my supervisors or other professionals.

References

Ahmed, S. (2018). Barriers to implementation of building information modeling (BIM) to the construction industry: a review. *Journal of Civil Engineering and Construction*, *7*(2), 107-113.

Allison, H., (2010). 10 Reasons Why Project Managers Should Champion 5D BIM software. *VICO Software*.

Angelopulo, G. (2009). Q methodology and the measurement of subjectivity in corporate brand perception. South African Journal of Business Management, 40(3), 21-34.

Argyris, C. (2002). Double-loop learning, teaching, and research. *Academy of management learning & education*, *1*(2), 206-218.

Argyris, C., & Schön, D. (1978). Organizational learning: A theory of action perspective. Reading, MA: Addison-Wesley.

Auerbach, C., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis*. NYU press.

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering*, *11*(3), 241-252.

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15-28.

Babič, N. Č., & Rebolj, D. (2016). Culture change in construction industry: from 2D toward BIM based construction. Journal of Information Technology in Construction (ITcon), 21(6), 86-99.

Baker, R., Thompson, C., & Mannion, R. (2006). Q methodology in health economics. *Journal of health services research & policy*, *11*(1), 38-45.

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. *Automation in construction*, *24*, 149-159.

Boonstra, J. (2004). Some reflections and perspectives on organizing, changing, and learning. *Dynamics of organizational change and learning*, 447-475.

Bosch-Sijtsema, P. M., Gluch, P., & Sezer, A. A. (2019). Professional development of the BIM actor role. *Automation in construction*, *97*, 44-51.

Bridges, W. (1991). Managing transitions: Making the most of change. Reading, Mass: Addison-Wesley.

Brown, S. R. (1993). A primer on Q methodology. *Operant subjectivity*, *16*(3/4), 91-138.

Brown, S. R. (1996). Q methodology and qualitative research. *Qualitative health research*, *6*(4), 561-567.

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. *Procedia Engineering*, *164*, 487-494.

Cairns, R. C. (2012). "Understanding Science in Conservation: A Q Method Approach on the Galápagos Islands." Conservation and Society 10(3): 217-231.

Cameron, E., & Green, M. (2019). Making sense of change management: A complete guide to the models, tools and techniques of organizational change. Kogan Page Publishers.

Chan, C. T. (2015). BIM from Design Stage–Are Hong Kong Designers Ready?. In *LISS 2013* (pp. 271-276). Springer, Berlin, Heidelberg.

Chan, D. W., Olawumi, T. O., & Ho, A. M. (2019). Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong. *Journal of Building Engineering*, *25*, 100764.

Charef, R., Alaka, H., & Emmitt, S. (2018). Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. *Journal of Building Engineering*, *19*, 242-257.

Chen, S. F., Huang, S. F., Lu, L. T., Wang, M. C., Liao, J. Y., & Guo, J. L. (2016). Patterns of perspectives on fall-prevention beliefs by community-dwelling older adults: a Q method investigation. BMC geriatrics, 16(1), 132.

Chen, Y., Yin, Y., Browne, G. J., & Li, D. (2019). Adoption of building information modeling in Chinese construction industry. *Engineering, Construction and Architectural Management*.

Cross, R. M. (2005). Exploring attitudes: the case for Q methodology. *Health education research*, *20*(2), 206-213.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.

Davis, K. A., & Songer, A. D. (2002, August). Technological change in the AEC industry: a social architecture factor model of individuals' resistance. In *IEEE International Engineering Management Conference* (Vol. 1, pp. 286-291). IEEE.

Davis, K. A., & Songer, A. D. (2009). Resistance to IT change in the AEC industry: Are the stereotypes true?. *Journal of Construction Engineering and Management*, *135*(12), 1324-1333.

Dennis, A. R., Venkatesh, V., & Ramesh, V. (2003). Adoption of collaboration technologies: Integrating technology acceptance and collaboration technology research. *Working Papers on Information Systems*, *3*(8), 3-8.
Deutsch R. (2011). BIM and Integrated Design Strategies for Architectural Practice. John Wiley & Sons, Inc.
Dixit, M. K., Venkatraj, V., Ostadalimakhmalbaf, M., Pariafsai, F., & Lavy, S. (2019). Integration of facility management and building information modeling (BIM). *Facilities*.
Duivenvoorden, J. J., & Alwicher, K. A. E. (2018). Ruimte voor BIM in wet- en regelgeving. Retrieved February 19, 2020 from https://www.bimloket.nl/upload/documents/downloads/Rapportage%20Ruimte%20voor%20BIM%20in%20wet%20en%20regelgeving%20versie%202018.pdf
Eastman, C. M., Teicholz, P., Sacks, R., & Liston, K. (2008*). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators.* John Wiley and Sons.
Enegbuma, W. I., Aliagha, G. U., & Ali, K. N. (2015). Effects of perceptions on BIM adoption in Malaysian construction industry. *Jurnal Teknologi*, *77*(15).
Enshassi, M. A., Al Hallaq, K. A., & Tayeh, B. A. (2019). Limitation Factors of Building Information Modeling (BIM) Implementation. *The Open Construction & Building Technology Journal*, *13*(1).
Erwin, D. G., & Garman, A. N. (2010). Resistance to organizational change: linking research and practice. *Leadership & Organization Development Journal*, *31*(1), 39-56.
Eynon, J. (2016). *Construction manager's BIM handbook*. John Wiley & Sons.
Fazli, A., Fathi, S., Enferadi, M. H., Fazli, M., & Fathi, B. (2014). Appraising effectiveness of Building Information Management (BIM) in project management. *Procedia Technology*, *16*, 1116-1125.
Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, *75*, 1046-1053.
Greefhorst, D., Knibbe, F., & Huisman, A. (2018). BIM verzamelen, verbinden en visualiseren voor vergunningverlening. Retrieved February 19, 2020, from https://depilotstarter.vng.nl/sites/default/files/project_bestand/rapport_bim_verzamelen_verbinden_visualiseren_1.0_0.pdf
Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. Automation in construction, 19(8), 988-999.
Guest, G., Bunce, A. & Johnson, L. (2006). "How many interviews are enough? An experiment with data saturation and variability". *Field Methods*, *18*(1), 59-82.
Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study.
Hardin, B., & McCool, D. (2015). BIM and construction management: proven tools, methods, and workflows. John Wiley & Sons.
Hayes, J. (2018). *The theory and practice of change management*. Palgrave.
Herrington, N., & Coogan, J. (2011). Q methodology: an overview. *Research in Teacher Education*, *1*(2), 24-28.
Howard, R., Restrepo, L., & Chang, C. Y. (2017). Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling. *International Journal of Project Management*, *35*(2), 107-120.
Howard, R., Restrepo, L., & Chang, C. Y. (2017). Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling. *International Journal of Project Management*, *35*(2), 107-120.
Hultman, K. (1998). *Making change irresistible: Overcoming resistance to change in your organization*. Davies-Black Pub..
Hultman, K. (2006). Values-driven change: Strategies and tools for long-term success. iUniverse.
Huy, Q. N. (2002). Emotional balancing of organizational continuity and radical change: The contribution of middle managers. *Administrative science quarterly*, *47*(1), 31-69.
Jamal, K. A. A., Mohammad, M. F., Hashim, N., Mohamed, M. R., & Ramli, M. A. (2019). Challenges of Building Information Modelling (BIM) from the Malaysian Architect's Perspective. In *MATEC Web of Conferences* (Vol. 266, p. 05003). EDP Sciences.
Jedeloo, S., & van Staa, A. (2016). Q-methodologie, een werkelijke mix van kwalitatief en kwantitatief onderzoek?. *Tijdschrift Kwalon*, *14*(2).
Juan, Y. K., Lai, W. Y., & Shih, S. G. (2017). Building information modeling acceptance and readiness assessment in Taiwanese architectural firms. *Journal of Civil Engineering and Management*, *23*(3), 356-367.
Kaiser, H. F. (1991). Coefficient alpha for a principal component and the Kaiser-Guttman rule. *Psychological reports*, *68*(3), 855-858.
Kalinichuk, S., & Tomek, A. (2013). Construction industry products diversification by implementation of BIM. *International Journal of Engineering and Technology Innovation*, *3*(4), 251.

Keskin, B., Ozorhon, B., & Koseoglu, O. (2019). BIM Implementation in Mega Projects: Challenges and Enablers in the Istanbul Grand Airport (IGA) Project. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 881-888). Springer, Cham.

Kiaulakis, A., Vilutienė, T., Šarka, V., & Šarkienė, E. (2019). Construction project stakeholders' perceptions and expectations of their roles in BIM-based collaboration.

Kiefer, T. (2005). Feeling bad: Antecedents and consequences of negative emotions in ongoing change. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, *26*(8), 875-897.

Knight, R. (2015). Convincing skeptical employees to adopt new technology. *Harvard Business Review*.

Kotter, J.P. (1996). *Leading Change*. Harvard Business School Press, Boston.

Kotter, J. P., & Schlesinger, L. A. (1979). *Choosing strategies for change* (pp. 106-114). Harvard Business Review.

Lahdou, R. & Zetterman, D., (2011). BIM for Project Managers, Chalmers University of Technology

Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building information modeling (BIM) application in Malaysian construction industry. *International Journal of Construction Engineering and Management*, *2*(4A), 1-6.

Liao, L., & Ai Lin Teo, E. (2018). Organizational change perspective on people management in BIM implementation in building projects. *Journal of management in engineering*, *34*(3), 04018008.

Lindblad, H., & Guerrero, J. R. (2020). Client's role in promoting BIM implementation and innovation in construction. *Construction Management and Economics*, 1-15.

Lindblad, H., & Vass, S. (2015). BIM implementation and organisational change: A case study of a large Swedish public client. *Procedia Economics and Finance*, *21*, 178-184.

Lines, B. C., & Reddy Vardireddy, P. K. (2017). Drivers of organizational change within the AEC industry: Linking change management practices with successful change adoption. Journal of management in engineering, 33(6), 04017031.

Lines, B. C., Sullivan, K. T., Smithwick, J. B., & Mischung, J. (2015). Overcoming resistance to change in engineering and construction: Change management factors for owner organizations. International Journal of Project Management, 33(5), 1170-1179.

Lines, B. C., Sullivan, K. T., & Wiezel, A. (2016). Support for organizational change: Change-readiness outcomes among AEC project teams. *Journal of construction engineering and management*, *142*(2), 04015062.

Liu, N., Ruan, L., Jin, R., Chen, Y., Deng, X., & Yang, T. (2019). Investigation of individual perceptions towards BIM implementation-a Chongqing case study. *Engineering, Construction and Architectural Management*.

Liu, R., Issa, R., & Olbina, S. (2010, June). Factors influencing the adoption of building information modeling in the AEC Industry. In *Proceedings of the international Conference on Computing in Civil and building Engineering* (pp. 139-145).

Liu, S., Xie, B., Tivendal, L., & Liu, C. (2015). Critical barriers to BIM implementation in the AEC industry. *International Journal of Marketing Studies*, *7*(6), 162-171.

Mäki, T., & Kerosuo, H. (2015). Site managers' daily work and the uses of building information modelling in construction site management. *Construction management and economics*, *33*(3), 163-175.

Miedema, J.J. (2019). Toetsen van Kotters model op de implementatie van 3D & 4D bij projecten van VolkerWessels Infra NL. (Master's Thesis). University of Twente.

Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The benefits, obstacles and problems of practical BIM implementation. *Procedia Engineering*, *57*, 767-774.

Milivojevic, N., & Ahmed, A. (2018, April). Evaluating learning management mechanisms and requirements for achieving BIM competencies: an in-depth study of ACE practitioners. In *CIBSE Technical Symposium 2018* (pp. 1-13). CIBSE.

Newcomer, K. E., Hatry, H. P., & Wholey, J. S. (2015). Conducting semi-structured interviews. *Handbook of practical program evaluation*, *492-505*.

Noardo, F., Ellul, C., Harrie, L., Overland, I., Shariat, M., Arroyo Ohori, K., & Stoter, J. (2019). Opportunities and challenges for GeoBIM in Europe: developing a building permits use-case to raise awareness and examine technical interoperability challenges. *Journal of Spatial Science*, 1-25.

Olsson, P. O., Axelsson, J., Hooper, M., & Harrie, L. (2018). Automation of building permission by integration of BIM and geospatial data. *ISPRS International Journal of Geo-Information*, *7*(8), 307.

Oreg, S. (2006). Personality, context, and resistance to organizational change. *European journal of work and organizational psychology*, *15*(1), 73-101.

Rafferty, A. E., & Jimmieson, N. L. (2017). Subjective perceptions of organizational change and employee resistance to change: direct and mediated relationships with employee well-being. *British Journal of Management*, *28*(2), 248-264.

Robson, L., & Littlemore, M. (2011). The transition from CAD to BIM within architectural practices: the individual and resistance to change. *Built Nat Environ Res Pap*, *4*(2), 254-274.
Rokooei, S. (2015). Building information modeling in project management: necessities, challenges and outcomes. *Procedia-Social and Behavioral Sciences*, *210*, 87-95.
Salawu, K. J., Hammedi, W., & Castiaux, A. (2019). What about passive innovation resistance? Exploring user's resistance to technology in the healthcare sector. *Journal of Innovation Economics Management*, (3), 17-37.
Saunders, M., Lewis, P., Thornhill, A., Booij, M., & Verckens, J. P. (2011). Methoden en technieken van onderzoek. Pearson Education.
Sawhney, A., Khanzode, A.R., & Tiwari, S. (2017). Building Information Modelling for Project Managers. *RICS*. Retrieved from https://www.rics.org/globalassets/rics-website/media/knowledge/research/insights/bim-for-project-managers-rics.pdf
Schmolck, P. (2014). PQMethod Manual. Retrieved December 22nd, 2019, from http://schmolck.org/qmethod/-pqmanual.htm
Seale, C. (2012). *Researching Society and Culture (Third Edition).* Los Angeles: SAGE Publications Inc.
Siebelink, S., Voordijk, J. T., & Adriaanse, A. (2018). Developing and Testing a Tool to Evaluate BIM maturity: Sectoral Analysis in the Dutch Construction Industry. *Journal of construction engineering and management*, *144*(8), 05018007.
Smith, P. (2014b). BIM implementation–global strategies. *Procedia Engineering*, *85*, 482-492.
Straatman, J., Pel, W., Hendriks, H. (2012). *Aan de slag met BIM; gewoon doen! Handreiking Virtueel Bouwen.* Zoetermeer, Nederland: Stichting Research Rationalisatie Bouw.
Stylianou, A. C., & Jackson, P. J. (2007). A comparative examination of individual differences and beliefs on technology usage: Gauging the role of IT. *Journal of Computer Information Systems*, *47*(4), 11-18.
Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in construction
Succar, B. (2010, May). The five components of BIM performance measurement. In *CIB World Congress* (p. 14).
Sun, C., Jiang, S., Skibniewski, M. J., Man, Q., & Shen, L. (2017). A literature review of the factors limiting the application of BIM in the construction industry. *Technological and Economic Development of Economy*, *23*(5), 764-779.
Talke, K., & Heidenreich, S. (2014). How to overcome pro-change bias: incorporating passive and active innovation resistance in innovation decision models. *Journal of Product Innovation Management*, *31*(5), 894-907.
Tan, P. J. B. (2013). Students' adoptions and attitudes towards electronic placement tests: A UTAUT analysis. *American Journal of Computer Technology and Application*, *1*(1), 14-23.
Tauriainen, M., Marttinen, P., Dave, B., & Koskela, L. (2016). The effects of BIM and lean construction on design management practices. Procedia engineering, 164, 567-574.
Teddlie, C., & Tashakkori, A. (Eds.). (2003). Handbook of mixed methods in social & behavioral research. Sage.
Ten Klooster, P.M., Visser, M., & de Jong, M. D. (2008). Comparing two image research instruments: The Q-sort method versus the Likert attitude questionnaire. Food quality and preference, 19(5), 511-518.
Teo, T. (2009). The impact of subjective norm and facilitating conditions on pre-service teachers' attitude toward computer use: A structural equation modeling of an extended technology acceptance model. *Journal of Educational Computing Research*, *40*(1), 89-109.
Valenta, A. L., & Wigger, U. (1997). Q-methodology: Definition and application in health care informatics. *Journal of the American Medical Informatics Association*, 4(6), 501-510.
Van der Voordt, T. (1998). Methoden en Technieken van Onderzoek. Interne Rapportage.
Van Exel, J., & De Graaf, G. (2005). Q methodology: A sneak preview.
Vass, S., & Gustavsson, T. K. (2017). Challenges when implementing BIM for industry change. *Construction management and economics*, *35*(10), 597-610.
Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D. (2003), "User acceptance of information technology: Toward a unified view", MIS Quarterly, Vol. 27, No. 3, pp. 425-478.
Verschuren, P., & Doorewaard, H. (2010). Het ontwerpen van een onderzoek. Eleven. Den Haag.
Watts, S., & Stenner, P. (2012). *Doing Q methodological research: Theory, method & interpretation*. Sage.
Webler, T., S. Danielson, et al. (2009). Using Q method to reveal social perspectives in environmental research. Greenfield MA, Social and Environmental Research Institute.
Wilkins, D. (2017). Using Q methodology to understand how child protection social workers use attachment theory. *Child & Family Social Work*, *22*, 70-80.
Xiao, H., & Noble, T. (2014). BIM's impact on the project manager. *RCOM A*, 693.
Xue X., Shen Q., Fan H., Li H. and Fan S. (2012). IT supported collaborative work in A/E/C projects: A ten-year

review, Automation in Construction, Vol. 21, 1–9. http://doi.org/10.1016/j.autcon.2011.05.016
Yan, H. & Demian, P. (2008). Benefits and barriers of building information modelling. In *Proceedings of the 12th International Conference on Computing in Civil and Building Engineering.* Beijing, China.
Yin, R.K., (2014), Case study research: Design and methods. Sage, Fifth edition.
Yuan, H., Yang, Y., & Xue, X. (2019). Promoting Owners' BIM Adoption Behaviors to Achieve Sustainable Project Management. *Sustainability*, *11*(14), 3905.
Zabala, A., Sandbrook, C., & Mukherjee, N. (2018). When and how to use Q methodology to understand perspectives in conservation research. *Conservation biology*, *32*(5), 1185-1194.
Zhao, X., Pienaar, J., & Gao, S. (2018). Critical Risks Associated with BIM Adoption: A Case of Singapore. In *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate* (pp. 585-596). Springer, Singapore.
Zhou, L., Perera, S., Udeaja, C., & Paul, C. (2012). Readiness of BIM: a case study of a quantity surveying organisation.
Zhou, Y., Ding, L., Rao, Y., Luo, H., Medjdoub, B., & Zhong, H. (2017). Formulating project-level building information modeling evaluation framework from the perspectives of organizations: a review. *Automation in construction*, *81*, 44-55.

Appendices

Appendix A: Semi-structured interview guide

In this appendix, the semi-structured interview guide is presented. A Dutch and English version is provided. The Dutch version was used for this research.

INTERVIEW GUIDELINE

Name:________________ Gender: M / F

Job title:______________ Experience in years:_____ Of which with BIM:______

General:

(1) Interviewer explains the goal of this interview and topic of research

Themes that will be covered:

a. BIM use in the AEC industry
b. Personal experiences with BIM
c. Viewpoints on BIM

(2) Interviewer asks for permission to record the interview

Personal questions:

(1) Can you tell me something about your position within the company?
(2) How did you get to your current position in the company?

Questions:

(1) Is BIM widely used in projects that you participate in?
 a. If so, how is BIM received in those projects?
 b. If not, why is BIM not applied?
(2) What are your experiences with BIM?
 a. Which benefits of BIM do you perceive?
 b. Which barriers do you still encounter when working with BIM?
(3) Do you encounter people with a strong opinion about BIM?
 a. Positive or negative?
 b. Where do you think those opinions come from?
(4) Are there any important aspects that I should include in my research?
(5) Are you willing to participate in a pilot Q-sort?

Naam:________________ Geslacht: M / V

Functie:_______________ Werkervaring [jaar]:_____ Waarvan met BIM [jaar]:_________

Algemeen:

(1) Uitleg geven waarom dit interview gedaan wordt, uitleg over onderzoek

Thema's die behandeld zullen worden:

a. BIM gebruik in de AEC industrie
b. Ervaringen met BIM
c. Meningen over BIM

(2) Toestemming vragen of het gesprek opgenomen mag worden

Persoonlijk:

(1) Kunt u wat vertellen over uw functie binnen het bedrijf?

(2) Hoe bent u in deze functie gekomen?

Vragen:

(1) Wordt BIM veel gebruik in projecten waar u aan meewerkt?
   a. Zo ja, hoe wordt BIM ontvangen?
   b. Zo nee, waarom wordt er niet met BIM gewerkt?

(2) Wat zijn uw ervaringen van BIM in de praktijk?
   a. Wat ervaart u als voordelen van het werken met BIM?
   b. Waar loopt u nog tegen aan?

(3) Komt u mensen tegen met een sterke mening over BIM?
   a. Positief of negatief?
   b. Waar denkt u dat die meningen vandaan komen?

(4) Zijn er nog belangrijke aspecten die ik mee kan nemen in mijn onderzoek?

(5) Wilt u deelnemen aan een proef Q-sort?

Appendix B: Collecting the universe of opinions

In this appendix, supplementary information is provided on the collection of the universe of opinions.

This research has selected primary and secondary sources to gather the universe of opinions, namely a literature study and semi-structured interviews. Originally, 162 statements were found in these sources. Through thematic coding, the statements which were divided into 42 codes (sub-themes), which were part of 2 code groups (themes). The two recurring themes throughout literature and interviews were the perceived benefits and barriers of BIM applications. Table 19 provides an overview of the universe of opinions gathered from the sources used in this research. To narrow down the universe of opinions to develop the final Q-set, the following criteria were applied:

(1) The codes should be listed in at least 2 (primary or secondary) sources;
(2) There should be an equal distribution of positively and negatively formulated statements.

Table 19 Universe of opinions gathered from primary and secondary sources

	Kiaulakis et al., 2019	Keskin, Ozorhon and Koseoglu, 2019	Enshassi et al., 2019	Chan et al., 2019	Bui et al., 2016	Chan, 2015	Migilinskas et al., 2013	Straatman, Pel and Hendriks, 2012	Zhou et al., 2012	Yan & Demian, 2008	Semi-structured interview 1	Semi-structured interview 2	**Total**
Efficiency	x	x		x	x	x	x			x	x	x	9
Costs		x		x	x	x	x			x	x	x	8
Coordination				x		x	x		x		x		5
Reduce project duration		x		x		x	x				x		5
Collaboration		x		x		x	x					x	5
Reduction of errors	x			x							x	x	4
Visualization				x			x		x		x		4
Better quality		x		x		x							3
Early detection of issues						x	x				x		3
Better understanding				x					x		x		3
Decision making				x						x	x		3
Life cycle data				x		x							2
Construction safety				x		x							2
Feedback						x					x		2
Monitoring		x		x									2
Better estimations				x									1*
Productivity	x												1*
Competitive advantage				x									1*
Communication						x							1**
Lack of expertise	x	x	x	x	x	x			x	x	x		9
Cost of investment		x	x	x	x	x	x		x		x	x	9
Certainty of success	x	x	x	x	x		x			x		x	8
Willingness to change			x	x	x	x		x				x	6
Lack of rules and standards	x	x		x	x	x	x						6

Lack of demand	x		x	x		x			x				6
Familiarity with BIM			x		x	x		x			x		5
Attached to comfortable routine			x	x	x			x				x	5
Lack of awareness		x						x	x			x	5
Additional work		x	x			x					x	x	5
Learning curve			x			x	x			x			4
Organizational change required	x	x		x								x	4
Legal issues			x	x	x						x		4
Afraid of personal consequences						x		x				x	3
Satisfied with status quo					x					x		x	3**
Lack of support			x		x		x						3
Complexity		x				x							2
Unclear roles and responsibilities			x			x							2
Fragmented construction process			x										1*
Lack of software			x										1*
Lack of information sharing				x									1*
Cultural change required			x										1*

* A red colored number implies that the corresponding codes are not included in the Q-set based on the criteria discussed.
** Satisfied with status quo has not been included in the Q-set because of its resemblance with the other codes in this theme such as attached to comfortable routine and willingness to change

Appendix C: Guideline applied during Q-sorting sessions

This appendix provides the form that was used as a guide during the Q-sort sessions and filled in during or after each session.

BIM en projectmanagers

Bedankt voor uw deelname aan het onderzoek naar de perspectieven van projectmanagers tegenover BIM applicatie. Om een beter beeld te krijgen van de verschillende meningen vanuit projectmanagers over BIM wordt Q-methodologie toegepast. Q-methodologie kenmerkt zich door data verzameling aan de hand van sorteersessies. De deelnemers worden gevraagd om verschillende factoren te prioriteren en te verdelen op een vastgesteld format. Alle gegevens zullen uiteraard anoniem worden behandeld.

Heeft u nog vragen naar aanleiding van dit onderzoek? Neem dan contact op met Valery Lambermon op: v.lambermon@student.tudelft.nl

---

Als aanvulling op de Q-studie willen wij u graag nog de volgende vragen stellen.

1. Uw functie: ______________________________
2. Het bedrijf waar u werkt: ______________________________
3. Hoeveel jaar werkervaring heeft u: ______________________________
4. Uw opleiding (niveau/richting): ______________________________
5. Heeft u ervaring met BIM? Ja/nee
6. Zo ja, aantal jaren ervaring met BIM? ______________________________
7. Hoe denkt u over BIM? ______________________________
8. Zou u BIM gebruik initiëren in projecten? Ja/nee/soms

In deze Q-studie zullen wij u vragen om verschillende factoren op belangrijkheid te sorteren in hoeverre u deze meeneemt in uw overweging al dan niet BIM toe te passen in uw projecten. De volgende stappen zullen worden gevolgd om tot het eindresultaat te komen:

1. Er zijn 32 statements geprint op losse kaartjes. U heeft daarnaast ook een sorteerblad gekregen (A3).
2. U begint met het lezen van alle kaartjes als antwoorden op de volgende hoofdvraag: **"Welke factoren zijn voor u belangrijk in uw overweging of u BIM gaat toepassen in uw volgende project"** Sorteer vervolgens de kaartjes in 3 stapels: 'Minst belangrijk, 'Neutraal', en 'Meest belangrijk'.
3. Nadat alle kaartjes gesorteerd zijn, neemt u eerst de kaartjes van de stapel 'Meest belangrijk'. Selecteer vervolgens 1 kaart die volgens u het meest belangrijk is wanneer u overweegt of u BIM gaat toepassen in uw volgende project. Plaats deze kaart onder de kolom "+3". Vervolgens selecteert u uit de overgebleven kaartjes de vier kaartjes die daarna het meest belangrijk zijn in uw overweging en plaatst deze onder de kolom "+2". Hiermee gaat u door tot alle kaartjes op zijn (ook als u daarmee aan de linkerkant van het scoreblad uitkomt; het gaat in dit onderzoek om relatieve belangrijkheid). Let up: u moet de indeling op het grid respecteren; d.w.z. u kunt de kaartjes alleen op de hokjes leggen!
4. Doe nu hetzelfde voor de kaartjes van de stapel 'Minst belangrijk'. De kaart die u het minst belangrijk vindt plaatst u in kolom "-3", enzovoorts.
5. Tot slot neemt u het "neutrale" stapeltje en plaatst u de kaartjes op de lege plaatsen van het scoreblad.
6. Bekijk na het plaatsen van alle kaartjes nogmaals het scoreblad en herschik waar nodig.
7. Als u klaar bent met sorteren, kunt u doorgaan naar het invulformulier

Invulformulier

1. Noteert u hieronder de nummers van de kaartjes op de plek waar u ze heeft neergelegd:

Welke factoren zijn voor u belangrijk in uw overweging of u BIM gaat toepassen in uw volgende project?

Minst belangrijk ←――――――――――――――――――――→ Meest belangrijk

-3	-2	-1	0	+1	+2	+3

2. Kunt u de kaart die u op "+3" heeft neergelegd nader toelichten?

Kaart #__, Uitleg:

3. Kunt u de kaartjes die u op "+2" heeft neergelegd nader toelichten?

Kaart #__, Uitleg:

Kaart #__, Uitleg:

Kaart #__, Uitleg:

Kaart #__, Uitleg:

4. Kunt u de kaart die u op "-3" heeft neergelegd nader toelichten?

Kaart #__, Uitleg:

5. Kunt u de kaartjes die u op "-2" heeft neergelegd nader toelichten?

Kaart #__, Uitleg:

Kaart #__, Uitleg:
Kaart #__, Uitleg:
Kaart #__, Uitleg:

6. Zijn er naast deze 32 factoren nog andere factoren die u belangrijk vindt in uw overweging of u BIM gaat toepassen in uw volgende project? Zo ja, waar zou u deze geplaatst hebben op het spectrum "-3", "3"?

7. Ervaart u barrières tijdens het werken met BIM in project? (Hoe gaat u daar mee om? Probeert u om deze barrières zo overkomen? Zo ja, wat heeft u ervaren als effectieve manieren om deze barrières op te lossen?'

8. Hoe denkt u dat projectmanagers enthousiast kunnen worden gemaakt voor het werken met BIM in hun projecten?

Mag ik u eventueel benaderen voor vervolgonderzoek? Ja / nee

Hartelijk dank voor uw medewerking! Ik zal de resultaten anoniem verwerken in mijn afstudeeronderzoek naar de perspectieven van projectmanagers over BIM.

Appendix D: Overview of the participants in P-set

This appendix provides an overview of the characteristics of the participants in the P-set.

The P-set for Q-methodology is carefully selected to ensure that a wide range of opinions are included in the research. To avoid unreliable results of the Q-study, the P-set does not only consist of employees of BMA. Of the total 24 participants that took part in this research, 14 participants are employees of BMA. The additional 10 participants are employees at one other consultancy firm (DVP) and the municipality of Rotterdam and Amsterdam. Furthermore, the goal of the P-set was to equally distribute age, work experience, BIM experience and attitude toward BIM. Table 20 provides an overview of the participants in the P-set and their corresponding characteristics.

Table 20 Overview of the participants in the P-set

#	Function	Company	Education	Predominantly active field	Work experience [years]	BIM experience [years]
1	Consultant	Brink Management/Advies	CME	Design	1,5	1.5
2	Senior consultant	Brink Management/Advies	Architecture	Design/construct	20	10
3	Board member	Brink Management/Advies	Architecture	Design/construct	35	35
4	Senior consultant	Brink Management/Advies	CME	Design	4	4
5	Project manager	Municipality Rotterdam	Civil engineering	Design/construct	12,5	0
6	Project manager	Municipality Rotterdam	Architect	Design/construct	16	0
7	Senior consultant	Brink Management/Advies	Construction	Construct	15	10
8	Senior manager	Brink Management/Advies	Construction	Construct	21	10
9	Consultant	Brink Management/Advies	Architecture	Construct	4	4
10	Senior manager	Brink Management/Advies	Civil engineering	Construct	35	5
11	Senior consultant	Brink Management/Advies	CME	Design/construct	9	9
12	Project manager	DVP	CME	Design	11	3
13	Senior manager	Brink Management/Advies	Architecture	Construct	14	4
14	Project manager	Municipality Rotterdam	Architecture	Design/construct	35	10
15	Project manager	Municipality Rotterdam	Architecture	Design	35	15
16	Senior manager	Brink Management/Advies	Construction	Design/construct	7	4
17	Consultant	Brink Management/Advies	CME	Design/construct	3	3
18	Junior consultant	Brink Management/Advies	Real estate	Design/construct	1	1
19	Senior consultant	Brink Management/Advies	TPM	Design/construct	12	5

20	Project manager	Municipality Rotterdam	Architecture	Design/construct	26	5
21	Project manager	Municipality Rotterdam	Civil engineering	Design/construct	33	7
22	Technical manager	Municipality Amsterdam	Civil engineering	Design/construct	23	2
23	Technical manager	Municipality Amsterdam	Civil engineering	Design/construct	19	1
24	Partner / Project manager	DVP	CME	Design/construct	10	5

Appendix E: In-depth results of Q-methodology data analysis

In this appendix, various tables and figures are presented to provide detailed information about the results of the Q-study. The tables and figures are referred to throughout the report.

Table 21 Factor loadings of 2-factor solution (Principal analysis with Varimax solution)

Q-sort	Factor 1	Factor 2
1	0.6184X	0.3657
2	0.2287	0.4628X
3	0.8180X	0.2188
4	0.6374X	0.2337
5	0.8291X	0.0856
6	0.7904X	-0.0702
7	0.7484X	0.0724
8	0.7674X	0.2904
9	-0.1238	0.6603X
10	0.2832	0.6133X
11	0.8777X	0.2021
12	0.6489X	0.4063
13	0.5689	0.6007X
14	0.7602X	0.2405
15	0.6449X	0.5417
16	0.8223X	0.1789
17	0.5487X	0.3698
18	0.5691X	0.3395
19	0.7105X	0.5122
20	0.1049	0.7218X
21	0.8150X	0.1174
22	0.0993	0.7473X
23	0.8955X	0.0862
24	0.8279X	0.3351

X This indicates the significant factor loading for the corresponding Q-sort. This means that the factor loading is significant (larger than 0.44);

A data analysis was performed on 2-4 factor solutions with a principal analysis and varimax rotation. A 2-factor solution, as presented above, was one of the reasonable options together with the 3-factor solution. Considering the added value of the third factor, it was decided to disregard the 2-factor solution.

Table 22 Factor loadings of 4-factor solution (Principal analysis with Varimax rotation)

Q-sort	Factor 1	Factor 2	Factor 3	Factor 4
1*	0.5830**	-0.0087	0.6234**	0.3266
2	0.1146	0.2691	0.1549	0.8250X
3	0.8213X	0.0846	0.3131	0.0456
4	0.5783X	0.0889	0.1618	0.4699
5	0.7863X	-0.0139	0.0912	0.3686
6	0.7578X	0.0199	-0.2275	0.276
7	0.7597X	0.212	-0.1388	-0.0443
8	0.7655X	0.4208	-0.0857	0.0439
9	-0.1314	0.2766	0.7904X	0.0716
10	0.3345	0.6260X	0.3333	-0.3575
11	0.8603X	0.0384	0.2992	0.1984
12	0.6474X	0.2351	0.4159	0.0661
13	0.5724	0.5134	0.3632	0.0095
14	0.7474X	0.3823	-0.1497	0.12
15	0.6373X	0.4853	0.2679	0.091
16	0.8271X	0.2073	0.0534	0.0165
17	0.5178X	0.2276	0.2768	0.2625
18	0.5199X	0.3749	-0.0556	0.3708
19	0.6947X	0.4897	0.1856	0.1495
20	0.0515	0.8021X	-0.0207	0.3515
21	0.8223X	0.1173	0.0827	0.0045
22	0.0774	0.7381X	0.2106	0.1406
23	0.8918X	0.022	0.1441	0.0952
24	0.8190X	0.3012	0.1654	0.1159

X This indicates the significant factor loading for the corresponding Q-sort. This means that the factor loading is significant (larger than 0.44);
* This Q-sort is confounding on two factors (see **). This means that the sort is significant for more than one loading, for example, see sort 1.

When analyzing the 4-factor solution with principal analysis and varimax rotation, it was concluded that this factor solution was unsuitable for this research. Factor 3 and 4 only include one Q-sort, meaning that these factors are unacceptable according to Brown (1993). The distinguishing statements of the 4-factor solution were also significantly lower than the other solutions, ranging from 2 to 7 statements. The combination of the characteristics of this factor solution lead to the conclusion to disregard it for the remainder of this research.

Table 23 Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	100	39	75	50	61	39	31	34	36	23	77	58	56	42	58	55	47	37	59	19	45	28	70	62
2	39	100	20	44	36	33	16	27	25	6	30	25	34	20	34	14	31	37	36	48	20	19	16	36
3	75	20	100	50	66	59	58	62	19	37	86	56	64	66	62	75	36	47	64	17	64	27	81	73
4	50	44	50	100	66	47	56	41	17	27	62	48	41	56	36	52	48	53	52	16	50	27	47	59
5	61	36	66	66	100	64	56	58	-5	14	73	61	48	52	58	72	47	47	64	17	66	20	69	70
6	39	33	59	47	64	100	45	62	-20	22	66	34	30	69	52	58	41	39	56	14	55	5	69	62
7	31	16	58	56	56	45	100	70	-3	34	59	44	58	62	42	61	23	50	58	17	69	9	55	75
8	34	27	62	41	58	62	70	100	6	39	64	61	59	70	70	69	55	53	75	41	69	25	67	72
9	36	25	19	17	-5	-20	-3	6	100	34	17	20	30	-5	20	-3	12	5	16	22	5	30	-5	16
10	23	6	37	27	14	22	34	39	34	100	33	48	58	41	59	39	31	22	53	31	39	44	27	47
11	77	30	86	62	73	66	59	64	17	33	100	67	56	72	62	75	53	48	67	19	69	25	87	77
12	58	25	56	48	61	34	44	61	20	48	67	100	56	45	67	66	73	39	61	30	58	25	64	62
13	56	34	64	41	48	30	58	59	30	58	56	56	100	53	67	56	52	48	72	37	58	47	56	73
14	42	20	66	56	52	69	62	70	-5	41	72	45	53	100	56	70	48	55	59	41	53	37	69	72
15	58	34	62	36	58	52	42	70	20	59	62	67	67	56	100	59	58	59	83	41	56	37	64	67
16	55	14	75	52	72	58	61	69	-3	39	75	66	56	70	59	100	44	47	61	30	64	30	73	70
17	47	31	36	48	47	41	23	55	12	31	53	73	52	48	58	44	100	45	56	23	52	25	56	44
18	37	37	47	53	47	39	50	53	5	22	48	39	48	55	59	47	45	100	53	31	55	41	55	48
19	59	36	64	52	64	56	58	75	16	53	67	61	72	59	83	61	56	53	100	47	66	42	64	80
20	19	48	17	16	17	14	17	41	22	31	19	30	37	41	41	30	23	31	47	100	12	59	14	31
21	45	20	64	50	66	55	69	69	5	39	69	58	58	53	56	64	52	55	66	12	100	9	72	75
22	28	19	27	27	20	5	9	25	30	44	25	25	47	37	37	30	25	41	42	59	9	100	22	31
23	70	16	81	47	69	69	55	67	-5	27	87	64	56	69	64	73	56	55	64	14	72	22	100	72
24	62	36	73	59	70	62	75	72	16	47	77	62	73	72	67	70	44	48	80	31	75	31	72	100

Table 24 Factor scores for perspective 1: (BIM) Supporters

Statements	Z-scores
9. The early detection of (design) issues	1.836
8. The improved quality of the project	1.673
6. The reduction of errors during the execution phase	1.346
14. The feedback process that BIM stimulates during the design phase	1.221
3. The possibility to coordinate work of different parties	1.186
1. The positive effect on efficiency	1.08
10. The possibility to improve the understanding of the design	0.963
5. The positive effect on cooperation between the parties involved	0.958
7. The 3D visualization possibilities	0.899
2. The cost reduction of the project	0.573
12. The possibility to reuse the data in the building information model	0.559
11. The effect on the speed of decision-making	0.478
4. The reduced project duration	0.299
13. The effect on construction safety during implementation	0.244
15. The ability to track progress during construction	0.211
17. The investment costs of BIM implementation	-0.055
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	-0.312
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	-0.422
30. The limited support from upper management to work with BIM	-0.456
25. The additional work of working with BIM	-0.473
21. The limited demand from chain partners to work with BIM	-0.48
27. The organizational change required	-0.489
26.The learning curve required (the time it takes to become familiar with the material)	-0.509
16. The limited availability of staff with BIM expertise	-0.628
20. The lack of clarity surrounding rules and standards of BIM	-0.643
31. The complexity of BIM software	-0.755
22. The level of experience that I have with BIM	-1.086
24. The limited extent to which I am familiar with the possibilities of BIM	-1.136
23. The lack of comfort that I have to manage a project in which BIM plays a role	-1.17
32. The lack of clarity about the changing role as PM when BIM is applied	-1.236
19. My limited willingness to change in order to work with BIM	-1.454
29. The possible negative consequences of BIM implementation for my career	-2.223

The factor scores of perspective 1 portray a precise distribution of the perceived benefits and barriers. This implies that the PMs in this perspective, according the their Q-sort, do not find any barriers significant to their consideration whether to apply BIM to their projects.

-3	-2	-1	0	1	2	3
29. The possible negative consequences of BIM implementation for my career	24. The limited extent to which I am familiar with the possibilities of BIM	21. The limited demand from chain partners to work with BIM	4. The reduced project duration	1. The positive effect on efficiency	8. The improved quality of the project	9. The early detection of (design) issues
	23. The lack of comfort that I have to manage a project in which BIM plays a role	27. The organizational change required	13. The effect on construction safety during implementation	10. The possibility to improve the understanding of the design	6. The reduction of errors during the execution phase	
	32. The lack of clarity about the changing role as PM when BIM is applied	26.The learning curve required (the time it takes to become familiar with the material)	15. The ability to track progress during construction	5. The positive effect on cooperation between the parties involved	14. The feedback process that BIM stimulates during the design phase	
	19. My limited willingness to change in order to work with BIM	16. The limited availability of staff with BIM expertise	17. The investment costs of BIM implementation	7. The 3D visualization possibilities	3. The possibility to coordinate work of different parties	
		20. The lack of clarity surrounding rules and standards of BIM	18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	2. The cost reduction of the project		
		31. The complexity of BIM software	28. The legal issues surrounding BIM applications (i.e. ownership of the model)	12. The possibility to reuse the data in the building information model		
		22. The level of experience that I have with BIM	30. The limited support from upper management to work with BIM	11. The effect on the speed of decision-making		
			25. The additional work of working with BIM			

Figure 24 Average Q-sort perspective 1

Table 25 Factor scores for perspective 2: Moderately hesitant

Statements	Z-scores
9. The early detection of (design) issues	2.413
20. The lack of clarity surrounding rules and standards of BIM	1.412
7. The 3D visualization possibilities	1.211
12. The possibility to reuse the data in the building information model	1.077
26. The learning curve required	0.949
27. The organizational change required	0.949
23. The lack of comfort that I have to manage a project in which BIM plays a role	0.776
3. The possibility to coordinate work of different parties	0.774
6. The reduction of errors during the execution phase	0.639
16. The limited availability of staff with BIM expertise	0.588
10. The possibility to improve the understanding of the design	0.554
24. The limited extent to which I am familiar with the possibilities of BIM	0.255
1. The positive effect on efficiency	0.25
8. The improved quality of the project	0.143
11. The effect on the speed of decision-making	0.125
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	0.11
5. The positive effect on cooperation between the parties involved	0.074
31. The complexity of BIM software	-0.12
21. The limited demand from chain partners to work with BIM	-0.202
14. The feedback process that BIM stimulates during the design phase	-0.26
25. The additional work of working with BIM	-0.26
22. The level of experience that I have with BIM	-0.327
30. The limited support from upper management to work with BIM	-0.503
13. The effect on construction safety during implementation	-0.58
4. The reduced project duration	-0.748
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	-0.766
15. The ability to track progress during construction	-0.84
2. The cost reduction of the project	-0.96
32. The lack of clarity about the changing role as PM when BIM is applied	-1.269
19. My limited willingness to change in order to work with BIM	-1.394
17. The investment costs of BIM implementation	-1.397
29. The possible negative consequences of BIM implementation for my career	-2.673

The factor scores of perspective 2 portray a distribution of perceived barriers and benefits. This implies that there are certain barriers that PMs in this perspective find significant during their consideration to apply BIM to their projects.

-3	-2	-1	0	1	2	3
29. The possible negative consequences of BIM implementation for my career	2. The cost reduction of the project	25. The additional work of working with BIM	1. The positive effect on efficiency	27. The organizational change required	20. The lack of clarity surrounding rules and standards of BIM	9. The early detection of (design) issues
	32. The lack of clarity about the changing role as PM when BIM is applied	22. The level of experience that I have with BIM	8. The improved quality of the project	23. The lack of comfort that I have to manage a project in which BIM plays a role	7. The 3D visualization possibilities	
	19. My limited willingness to change in order to work with BIM	30. The limited support from upper management to work with BIM	11. The effect on the speed of decision-making	3. The possibility to coordinate work of different parties	12. The possibility to reuse the data in the building information model	
	17. The investment costs of BIM implementation	13. The effect on construction safety during implementation	28. The legal issues surrounding BIM applications (i.e. ownership of the model)	6. The reduction of errors during the execution phase	26. The learning curve required	
		4. The reduced project duration	5. The positive effect on cooperation between the parties involved	16. The limited availability of staff with BIM expertise		
		18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	31. The complexity of BIM software	10. The possibility to improve the understanding of the design		
		15. The ability to track progress during construction	21. The limited demand from chain partners to work with BIM	24. The limited extent to which I am familiar with the possibilities of BIM		
			14. The feedback process that BIM stimulates during the design phase			

Figure 25 Average Q-sort perspective 2

Table 26 Factor scores for perspective 3: Critical realists

Statements	Z-scores
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	2.001
3. The possibility to coordinate work of different parties	1.824
10. The possibility to improve the understanding of the design	1.484
9. The early detection of (design) issues	1.252
8. The improvement quality of the project	1.173
20. The lack of clarity surrounding rules and standards of BIM	0.844
26.The learning curve required (the time it takes to become familiar with the material)	0.748
5. The positive effect on cooperation between the parties involved	0.627
32. The lack of clarity about the changing role as PM when BIM is applied	0.559
16. The limited availability of staff with BIM expertise	0.504
15. The ability to track progress during construction	0.395
27. The organizational change required	0.395
25. The additional work of working with BIM	0.34
6. The reduction of errors during the execution phase	0.232
14. The feedback process that BIM stimulates during the design phase	0.177
17. The investment costs of BIM implementation	0.122
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	-0.055
1. The positive effect on efficiency	-0.285
30. The limited support from upper management to work with BIM	-0.395
22. The level of experience that I have with BIM	-0.45
12. The possibility to reuse the data in the building information model	-0.504
11. The effect on the speed of decision-making	-0.517
2. The cost reduction of the project	-0.517
7. The 3D visualization possibilities	-0.559
31. The complexity of BIM software	-0.572
13. The effect on construction safety during implementation	-0.693
21. The limited demand from chain partners to work with BIM	-0.722
24. The limited extent to which I am familiar with the possibilities of BIM	-0.79
23. The lack of comfort that I have to manage a project in which BIM plays a role	-0.967
19. My limited willingness to change in order to work with BIM	-1.484
4. The reduced project duration	-1.606
29. The possible negative consequences of BIM implementation for my career	-2.56

The factor scores of perspective 3 portray a distribution of perceived barriers and benefits. This implies that there are certain barriers that PMs in this perspective perceive as significant during their consideration to apply BIM to their projects.

-3	-2	-1	0	1	2	3
29. The possible negative consequences of BIM implementation for my career	24. The limited extent to which I am familiar with the possibilities of BIM	12. The possibility to reuse the data in the building information model	25. The additional work of working with BIM	20. The lack of clarity surrounding rules and standards of BIM	3. The possibility to coordinate work of different parties	18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation
	23. The lack of comfort that I have to manage a project in which BIM plays a role	11. The effect on the speed of decision-making	6. The reduction of errors during the execution phase	26.The learning curve required (the time it takes to become familiar with the material)	10. The possibility to improve the understanding of the design	
	19. My limited willingness to change in order to work with BIM	2. The cost reduction of the project	14. The feedback process that BIM stimulates during the design phase	5. The positive effect on cooperation between the parties involved	9. The early detection of (design) issues	
	4. The reduced project duration	7. The 3D visualization possibilities	17. The investment costs of BIM implementation	32. The lack of clarity about the changing role as PM when BIM is applied	8. The improvement quality of the project	
		31. The complexity of BIM software	28. The legal issues surrounding BIM applications (i.e. ownership of the model)	16. The limited availability of staff with BIM expertise		
		13. The effect on construction safety during implementation	1. The positive effect on efficiency	15. The ability to track progress during construction		
		21. The limited demand from chain partners to work with BIM	30. The limited support from upper management to work with BIM	27. The organizational change required		
			22. The level of experience that I have with BIM			

Figure 26 Average Q-sort perspective 3

Table 27 Q-sort values of all perspectives

	Q-sort values		
Statements	**Factor 1**	**Factor 2**	**Factor 3**
1. The positive effect on efficiency	1	0	0
2. The cost reduction of the project	1	-2	-1
3. The possibility to coordinate work of different parties	2	1	2
4. The reduced project duration	0	-1	-2
5. The positive effect on cooperation between the parties involved	1	0	1
6. The reduction of errors during the execution phase	2	1	0
7. The 3D visualization possibilities	1	2	-1
8. The improved quality of the project	2	0	2
9. The early detection of (design) issues	3	3	2
10. The possibility to improve the understanding of the design	1	1	2
11. The effect on the speed of decision-making	1	0	-1
12. The possibility to reuse the data in the building information model	1	2	-1
13. The effect on construction safety during implementation	0	-1	-1
14. The feedback process that BIM stimulates during the design phase	2	-1	0
15. The ability to track progress during construction	0	-1	1
16. The limited availability of staff with BIM expertise	-1	1	1
17. The investment costs of BIM implementation	0	-2	0
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	0	-1	3
19. My limited willingness to change in order to work with BIM	-2	-2	-2
20. The lack of clarity surrounding rules and standards of BIM	-1	2	1
21. The limited demand from chain partners to work with BIM	-1	0	-1
22. The level of experience that I have with BIM	-1	-1	0
23. The lack of comfort that I have to manage a project in which BIM plays a role	-2	1	-2
24. The limited extent to which I am familiar with the possibilities of BIM	-2	1	-2
25. The additional work of working with BIM	0	-1	0
26. The learning curve required (the time it takes to become familiar with the material)	-1	1	1
27. The organizational change required	-1	1	1
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	0	0	0
29. The possible negative consequences of BIM implementation for my career	-3	-3	-3
30. The limited support from upper management to work with BIM	0	-1	0
31. The complexity of BIM software	-1	0	-1
32. The lack of clarity about the changing role as PM when BIM is applied	-2	-2	1

Table 28 Descending array of differences between factors 1 and 2

Statements	Factor 1	Factor 2	Difference
2. The cost reduction of the project	0.573	-0.96	1.533
8. The improved quality of the project	1.673	0.143	1.53
14. The feedback process that BIM stimulates during the design phase	1.221	-0.26	1.481
17. The investment costs of BIM implementation	-0.055	-1.397	1.342
15. The ability to track progress during construction	0.211	-0.84	1.051
4. The reduced project duration	0.299	-0.748	1.047
5. The positive effect on cooperation between the parties involved	0.958	0.074	0.884
1. The positive effect on efficiency	1.08	0.25	0.83
13. The effect on construction safety during implementation	0.244	-0.58	0.823
6. The reduction of errors during the execution phase	1.346	0.639	0.707
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	-0.312	-0.766	0.454
29. The possible negative consequences of BIM implementation for my career	-2.223	-2.673	0.451
3. The possibility to coordinate work of different parties	1.186	0.774	0.413
10. The possibility to improve the understanding of the design	0.963	0.554	0.41
11. The effect on the speed of decision-making	0.478	0.125	0.353
30. The limited support from upper management to work with BIM	-0.456	-0.503	0.046
32. The lack of clarity about the changing role as PM when BIM is applied	-1.236	-1.269	0.033
19. My limited willingness to change in order to work with BIM	-1.454	-1.394	-0.06
25. The additional work of working with BIM	-0.473	-0.26	-0.212
21. The limited demand from chain partners to work with BIM	-0.48	-0.202	-0.278
7. The 3D visualization possibilities	0.899	1.211	-0.312
12. The possibility to reuse the data in the building information model	0.559	1.077	-0.518
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	-0.422	0.11	-0.532
9. The early detection of (design) issues	1.836	2.413	-0.577
31. The complexity of BIM software	-0.755	-0.12	-0.635
22. The level of experience that I have with BIM	-1.086	-0.327	-0.759
16. The limited availability of staff with BIM expertise	-0.628	0.588	-1.216
24. The limited extent to which I am familiar with the possibilities of BIM	-1.136	0.255	-1.392
27. The organizational change required	-0.489	0.949	-1.438
26. The learning curve required (the time it takes to become familiar with the material)	-0.509	0.949	-1.458
23. The lack of comfort that I have to manage a project in which BIM plays a role	-1.17	0.776	-1.946
20. The lack of clarity surrounding rules and standards of BIM	-0.643	1.412	-2.055

Table 29 Descending array of differences between factors 1 and 3

Statements	Factor 1	Factor 3	Difference
4. The reduced project duration	0.299	-1.606	1.904
7. The 3D visualization possibilities	0.899	-0.559	1.458
1. The positive effect on efficiency	1.08	-0.285	1.366
6. The reduction of errors during the execution phase	1.346	0.232	1.114
2. The cost reduction of the project	0.573	-0.517	1.09
12. The possibility to reuse the data in the building information model	0.559	-0.504	1.063
14. The feedback process that BIM stimulates during the design phase	1.221	0.177	1.044
11. The effect on the speed of decision-making	0.478	-0.517	0.995
13. The effect on construction safety during implementation	0.244	-0.693	0.937
9. The early detection of (design) issues	1.836	1.252	0.584
8. The improved quality of the project	1.673	1.173	0.5
29. The possible negative consequences of BIM implementation for my career	-2.223	-2.56	0.337
5. The positive effect on cooperation between the parties involved	0.958	0.627	0.331
21. The limited demand from chain partners to work with BIM	-0.48	-0.722	0.242
19. My limited willingness to change in order to work with BIM	-1.454	-1.484	0.03
30. The limited support from upper management to work with BIM	-0.456	-0.395	-0.061
17. The investment costs of BIM implementation	-0.055	0.122	-0.177
31. The complexity of BIM software	-0.755	-0.572	-0.183
15. The ability to track progress during construction	0.211	0.395	-0.184
23. The lack of comfort that I have to manage a project in which BIM plays a role	-1.17	-0.967	-0.203
24. The limited extent to which I am familiar with the possibilities of BIM	-1.136	-0.79	-0.346
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	-0.422	-0.055	-0.367
10. The possibility to improve the understanding of the design	0.963	1.484	-0.521
22. The level of experience that I have with BIM	-1.086	-0.45	-0.636
3. The possibility to coordinate work of different parties	1.186	1.824	-0.638
25. The additional work of working with BIM	-0.473	0.34	-0.813
27. The organizational change required	-0.489	0.395	-0.884
16. The limited availability of staff with BIM expertise	-0.628	0.504	-1.132
26. The learning curve required (the time it takes to become familiar with the material)	-0.509	0.748	-1.257
20. The lack of clarity surrounding rules and standards of BIM	-0.643	0.844	-1.487
32. The lack of clarity about the changing role as PM when BIM is applied	-1.236	0.559	-1.794
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	-0.312	2.001	-2.312

Table 30 Descending array of differences between factors 2 and 3

Statements	Factor 2	Factor 3	Difference
7. The 3D visualization possibilities	1.211	-0.559	1.769
23. The lack of comfort that I have to manage a project in which BIM plays a role	0.776	-0.967	1.743
12. The possibility to reuse the data in the building information model	1.077	-0.504	1.581
9. The early detection of (design) issues	2.413	1.252	1.161
24. The limited extent to which I am familiar with the possibilities of BIM	0.255	-0.79	1.046
4. The reduced project duration	-0.748	-1.606	0.857
11. The effect on the speed of decision-making	0.125	-0.517	0.642
20. The lack of clarity surrounding rules and standards of BIM	1.412	0.844	0.568
27. The organizational change required	0.949	0.395	0.554
1. The positive effect on efficiency	0.25	-0.285	0.536
21. The limited demand from chain partners to work with BIM	-0.202	-0.722	0.52
31. The complexity of BIM software	-0.12	-0.572	0.452
6. The reduction of errors during the execution phase	0.639	0.232	0.407
26. The learning curve required (the time it takes to become familiar with the material)	0.949	0.748	0.201
28. The legal issues surrounding BIM applications (i.e. ownership of the model)	0.11	-0.055	0.165
22. The level of experience that I have with BIM	-0.327	-0.45	0.123
13. The effect on construction safety during implementation	-0.58	-0.693	0.114
19. My limited willingness to change in order to work with BIM	-1.394	-1.484	0.09
16. The limited availability of staff with BIM expertise	0.588	0.504	0.084
30. The limited support from upper management to work with BIM	-0.503	-0.395	-0.108
29. The possible negative consequences of BIM implementation for my career	-2.673	-2.56	-0.114
14. The feedback process that BIM stimulates during the design phase	-0.26	0.177	-0.437
2. The cost reduction of the project	-0.96	-0.517	-0.443
5. The positive effect on cooperation between the parties involved	0.074	0.627	-0.553
25. The additional work of working with BIM	-0.26	0.34	-0.601
10. The possibility to improve the understanding of the design	0.554	1.484	-0.93
8. The improved quality of the project	0.143	1.173	-1.03
3. The possibility to coordinate work of different parties	0.774	1.824	-1.05
15. The ability to track progress during construction	-0.84	0.395	-1.235
17. The investment costs of BIM implementation	-1.397	0.122	-1.518
32. The lack of clarity about the changing role as PM when BIM is applied	-1.269	0.559	-1.828
18. The uncertainty whether the realized benefits outweigh the investments of BIM implementation	-0.766	2.001	-2.767

Appendix F: Survey sample

This appendix provides a sample version of survey questions that can be distributed throughout an organization. In this way, a quick overview can be developed of the perceived barriers that require attention. The critical barriers found in this research have been placed in the first part of the survey. The second part of the survey asks for additional perceived barriers to ensure that no barriers are overlooked. A survey can easily be distributed through online tools such as Mentimeter.

Please indicate whether you find the following barriers important in your consideration to apply BIM to your projects:

	1. Not important at all	2. Not very important	3. Neutral	4. Somewhat important	5. Very important
A lack of comfort to manage a project in which BIM plays a role	O	O	O	O	O
The limited extent to which I am familiar with the possibilities of BIM	O	O	O	O	O
The lack of clarity surrounding the rules and standards of BIM	O	O	O	O	O
My lack of confidence of the quality of the building information model	O	O	O	O	O
My lack of confidence that BIM will decrease the project duration	O	O	O	O	O
My lack of confidence that BIM will reduce costs of projects	O	O	O	O	O
The uncertainty whether BIM benefits will outweigh the investments	O	O	O	O	O
The lack of clarity about the changing role as PM when BIM is applied	O	O	O	O	O

Please indicate whether you perceive other barriers towards implementing BIM into your projects: