INFLUENCE OF COLLABORATION ON THE MANAGEMENT OF BIM BASED CONSTRUCTION PROJECTS

An analysis of the perspectives of project team members

Master thesis by Sebastián Vélez Malo

Influence of collaboration on the management of BIM based construction projects

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Master thesis by

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Preface

I would like to introduce the result of several months of hard work, researching about the "Influence of collaboration on the management of BIM-based construction projects" as a requirement for graduating as a Master of Science in Construction Management and Engineering at Delft University of Technology.

The topic of this research has caught my attention since the beginning of the master program, when I started to get familiar with the utilities of BIM processes to improve the performance of construction project management. During the execution of this research, I have had the opportunity to interview several experienced professionals in the field, which has enriched my knowledge about the importance of collaboration in order to make the use of BIM possible. I would like to thank all the contributors to this research for their important input.

I would also like to thank the graduation committee who has been an important support, guiding me to perform this research in the best way possible. Thanks to Yan Liu, who has been the principal mentor during this process, helping me to put my ideas together throughout several meetings, and who has been very open and helpful every time I needed support. Thanks to Samantha Copeland who has been very friendly contributing to make sure the ideas were presented in the proper way. And thanks to the chair supervisor Hans Bakker, for believing in this research and contributing with his important insight.

Finally, I would like to thank my family and friends who have been part of this achievement by giving me the strength to overcome the difficulties presented on the road, especially the support and guidance given by my parents throughout this entire process. I deeply appreciate the support that each person has given me.

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Sebastián Vélez Malo

Executive Summary

The AEC industry has shown a slower development when compared to other industries, this has aroused interest among researchers to help the industry achieve its objectives. As a result, one important contribution to the industry has been proven to be the encouragement of effective collaboration among project team members, which in fact, is considered as a central element of success in construction projects. Additionally, the birth of new technologies like BIM has facilitated these collaborative practices among team members. Thus, many studies have focused on understanding the implementation of BIM and the benefits of its use. However, most of these have focused on the technical aspects of BIM itself, and not enough attention has been given to the collaborative aspects of its use.

Consequently, this research has focused on studying the collaborative aspects of the use of BIM in construction projects, with the objective of enriching current literature about the topic. More specifically, on the identification of perspectives that members of project teams have on the most important features of BIM collaboration, with the intention of understanding the feeling of members in order to approach to them in a more accurate way, which will more likely engage members in a collaborative environment. With this objective in mind, the main research question has been formulated: *In what way can collaboration be promoted in BIM-based construction projects to improve management practices?*

In order to answer this question, a list of sub questions has been previously answered by using three methodologies for data collection. First, literature review has been performed in order to point out the most relevant contribution from previous studies about the subject of interest. As a result of this overview, a list of relevant features has been created, which has been later presented to respondents using Q-methodology. This methodology merges qualitative and quantitative methods to investigate the subjective views or perspectives of those directly involved in a particular topic. A list of 29 statements were sorted by 15 selected participants from different organizations in The Netherlands, which are currently involved in the execution of construction projects. For the sorting procedure, participants were given a predefined sorting scheme, where they classify each one of the statements in a rank from least important to most important according to their personal opinion.

Furthermore, the analysis of the collected data was performed, which gave sufficient information to identify the existence of three perspectives among fourteen participants, while one participant was considered as a non-loader since his perspective did not show any link to the other perspectives. The identified perspectives were named as follows:

- Perspective 1, Protocols Sticklers. This perspective is supported by 6 respondents. They show a perceived high importance to the creation of protocols and policies to follow during the project, supported by training personnel and recruitment of qualified staff to meet the main objective of compliance to protocols to facilitate effective management.
- Perspective 2, Team-oriented. This perspective supported by 5 respondents is characterized by their perceived high importance of aspects related to human relations and team-working mentality in order to achieve effective management of construction projects.

- Perspective 3, Task-oriented. This perspective is supported by 3 participants of the Q-study. The main characteristic of this perspective is their focus on the BIM activities that will enhance collaboration among project team members, and therefore improving the results obtained throughout the execution of projects.

After the identification of the different perspectives between project team members, the aspects considered to be the most relevant by each perspective were compared to the guidelines provided by the PMI for the management of construction projects. The result of this comparison showed that even though some of the relevant features are briefly covered by the bodies of knowledge, more emphasis should be put on the collaboration aspects itself. For this reason, it was concluded that the inclusion of a framework would enhance the current guideline in terms of engaging project team members to collaborate more efficiently throughout the execution of a BIM-based construction project.

The proposed framework consists of: first, the performance of a thorough analysis to identify the perspectives of each member of a project team. The objective of this analysis is to understand how the group is composed, in order to apply the proper strategy to engage each individual into a collaborative environment within the team. Secondly, the strategy adopted to engage team members in a collaborative environment, should consider a combination of the following actions in order to guarantee the existence of the necessary antecedents for effective collaboration in BIM-based projects: Create agreed upon protocols, explicitly share benefits of BIM use, point-out common objectives, include experienced and skilled personnel in the team and ensure reliable methods for communication. A summary of the framework is shown in the next figure:

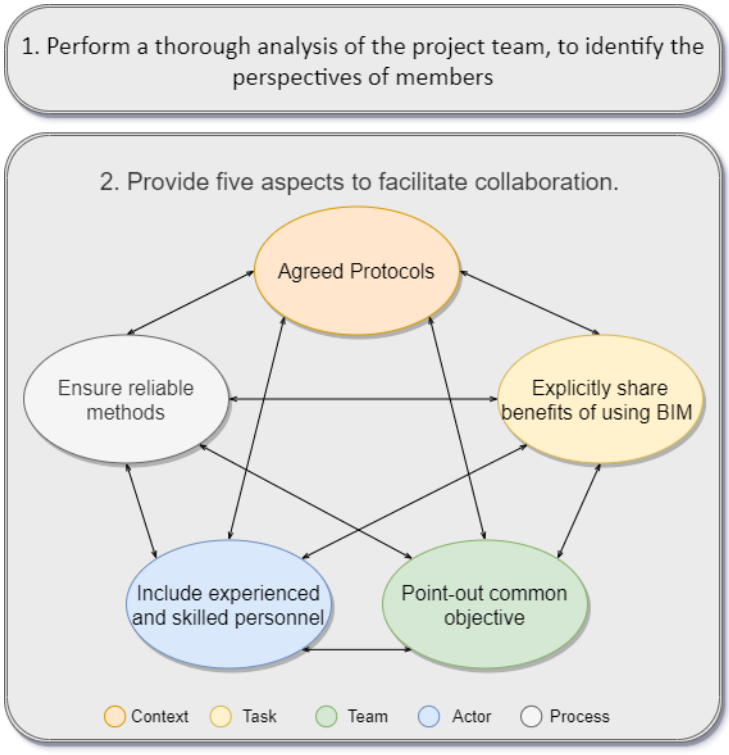

Figure 0-1 Overview of proposed framework

However, the use of the framework will depend on the perspective that each member has, trying to make use of their perceived importance of a certain aspect of collaboration to share with the rest of the team, as well as working on the aspects they believe to be of less importance, in order to highlight the benefits of its implementation and engage them to promote a collaborative environment. A summary of the proposed suggestions to engage members with different perspectives is represented in Figure 0-2.

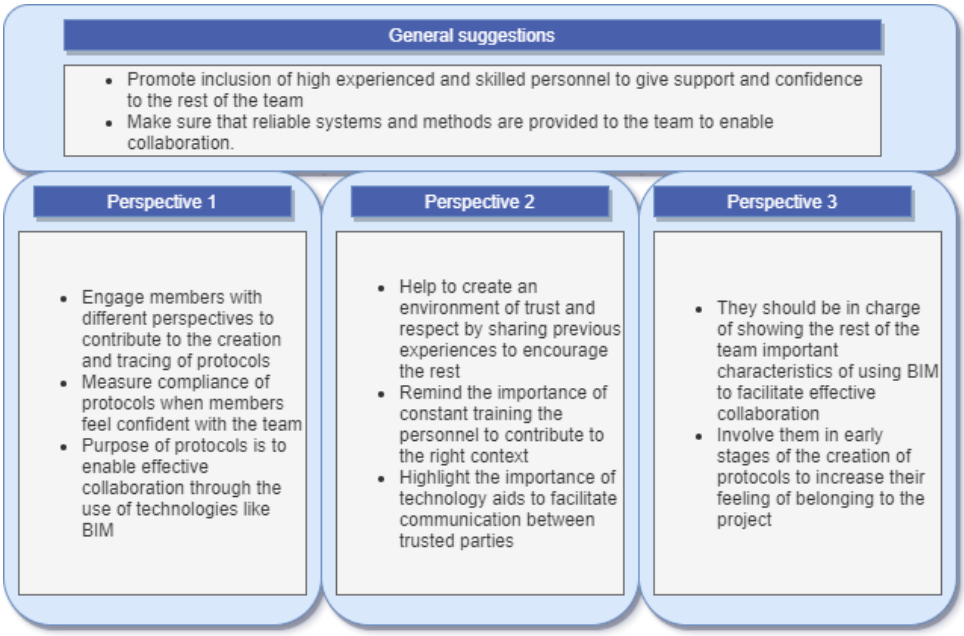

Figure 0-2 Overview of directed suggestions

The framework was discussed with two experts in the field of managing construction projects. These discussions confirmed the relevance of the proposed framework as an effective tool to promote collaboration. However, their input was considered in order to polish the framework, adding the implementation of collaboration workshops on a regular basis to verify the compliance of the planned collaboration, as well as the inclusion of collaboration terms in contract documents in order to prevent derailments from certain actors.

This research enriches the limited existing literature regarding the collaboration aspects of the implementation and benefits of using BIM technologies in construction projects. Moreover, the results of this research provide a practical framework which can be used by organizations to enhance collaboration practices in BIM-based construction projects. Furthermore, it is recommended for future research to perform a deeper analysis of each perspective found in this study, as well as confirming the results of this study through the use of different methodologies.

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List of Abbreviations

AEC. ..... Architecture Engineering and Construction
BIM ..... Building Information Management
PM ..... Project Manager
ICT ..... Information and Communication Technologies
PMBOK ..... Project Management Body of Knowledge
CME ..... Construction Management and Engineering
PMI ..... Project Management Institute
BbCN ..... BIM-based Construction Network

1. Introduction

Despite the importance of the Architectural Engineering and Construction (AEC) industry around the world, it's development is slow in comparison to other industries according to Heigermoser et.al. (2019) Therefore, big hopes have been put into the advance of technology to overcome this shortage of development. Some studies show that the AEC industry is moving towards a more technological dependent environment (Gu & London, 2010). Among these technologies, the development of Information Communication Technologies (ICT) plays an important role in the industry acting as a catalyst that mitigates information deficiencies (Adwan & Al-Soufi, 2016). Hence, regarding the AEC industry in specific, a helpful process known as Building Information Modelling (BIM) has been introduced in the last decades, which was adopted to support information and communication flows throughout a digital environment that combines information provided by multiple different project team members as stated by Jacobsson & Linderoth (2012).

1.1 Problem Definition

With the intention to improve the productivity of the AEC industry in mind, a big effort has been spent in finding the way to obtain better results in the management of construction projects. Historically, the AEC industry has suffered delays, cost overruns or quality decreases in their projects due to compromises in budget or time (Flyvbjerg et al., 2002). Therefore, the focus of scholars has been put into finding ways to obtain a better Project Management process that helps to overcome these problems. For instance, the study conducted by Demirkesen & Ozohorn (2017) stated that effective project management is crucial for higher performance levels in construction industry.

Additionally, Suprapto (2015) states that collaboration is considered a central element of success in construction projects. Therefore, a focus on collaboration aspects is needed, in order to enhance project management, and thereby contribute to the development of the industry. Moreover, recent studies assert that the introduction of BIM in the industry has been shown to be an important contributor to collaboration in construction projects (Adwan & Al-Soufi, 2016; Heigermoser et al., 2019; Turk, 2016). Nevertheless, despite that collaboration making use of BIM processes and tools has been shown to enhance management of projects, not many projects executors make use of this technological contribution due to several reasons which are under scrutiny by researchers like the resistance to changes, costs involved, lack of clarity, among others (Enshassi et al., 2019; Gu & London, 2010; Jamal et al., 2019). Furthermore, despite the fact that contribution of BIM to facilitate collaboration among construction project teams has proven to be paramount, not enough research has focused on collaboration aspects, while more technical aspects have attracted the attention of the majority of researchers in this topic (Oraee et al., 2017).

Moreover, most of current research has focused on identifying barriers that prevent the implementation of BIM and how to overcome them (Lambermon, 2020). But not enough focus has been put on understanding the needs and experiences presented by people in the industry. Therefore, the identification of perspectives presented by project team members, in respect to the important aspects of collaboration through BIM, is considered an important contribution to current literature. The inclusion of

the industry's viewpoint in current guides for Project Management as the Construction Extension to the PMBOK Guide, will contribute to support the use of BIM to enhance collaboration in construction projects.

1.2 Objectives

The aim of this research is to contribute to the development of the AEC industry by presenting the features of BIM collaboration that improves project management practices. Therefore, in the first stage of this report the focus will be on finding those features. Next, they will be presented to actors currently involved in the execution of construction projects, to understand their perspectives about the importance of these features, for the enhancement of their management practices. Then, existing guides for construction projects are evaluated, to verify the inclusion of the perspectives presented by representatives from the industry. In other words, the main objectives of this research are the following:

1. To discover the features of BIM collaboration that the people involved in construction projects consider as important to focus on, in order to facilitate the management of projects.
2. To evaluate existing guides for management of construction projects, and verify the inclusion of the industry's viewpoint in them, regarding the more important aspects of collaboration through the use of BIM.
3. To contribute to the existing literature regarding the importance of collaborative practices in the management of BIM-based construction projects.

1.3 Research question

With the main objectives set in the previous section, the main question aims to give the research a clear focus. In order to facilitate answering the main research question, a list of sub-questions is presented. These will be elaborated-on later in the body of the report. Both main research question and sub-questions are presented below.

"In what way can collaboration be promoted in BIM-based construction projects to improve management practices?"

1. *What does collaboration in Construction Project Management entail?*
2. *What are the elements of collaboration through use of BIM in AEC industry?*
3. *What perspectives do project team members have in respect to the importance of collaboration through BIM, in the management of projects?*
4. *How are the most relevant features according to each perspective addressed in existing guides for the management of construction project?*

1.4 Scope

In order to meet the requirements of the Construction Management and Engineering (CME) Master, which is focused on developing professionals that will contribute to enhance the construction industry from a management perspective, this research will focus on the perspectives from project team members of the construction industry only. Therefore, the scope of the research will limit its analysis to the perspectives of people currently involved in the development, design and construction phases of construction projects. The maintenance phase is not taken into consideration in this research.

Furthermore, in order to facilitate the data collection, the scope of this research is limited to Dutch companies or companies operating in The Netherlands. However, since many of these companies are operating abroad, some of the respondents are currently involved in international projects, and therefore the identified perspectives can represent a broader viewpoint. But the generalization would require further research.

1.5 Report Structure

The research report has been divided in 7 chapters. First, an introduction is given in chapters 1 and 2; Chapter 1 explains the reason why the research has been performed, the objectives and gives a description of the entire report, while chapter 2 explains the chosen strategy and approach during the research. Then, an exploratory phase is detailed in the following chapters; Then chapter 3 covers a literature review where all the terms and concepts used in the research are explained, chapter 4 explains how the data collection from industry respondents is performed and chapter 5 shows the analysis of the responses given by interviewees. To conclude, the final phase of the research is explained; Chapter 6 presents the suggestions on how to include the identified perspectives in existing guides, as well as the opinion of experts in the field, while chapter 7 discusses about the findings of the research and recommendations for future research.

2. Research Design

In this chapter, a breakdown that explains the design of the research project is presented. First, the strategy followed to conduct this research is explained, followed by the approach taken in the following chapters.

2.1 Research strategy

In order to achieve the objectives described in the previous chapter, it is important to set a strategy to follow. Therefore, the selected strategy is presented in this section. First of all, it is important to understand the nature of this research, which in this case is identified as an exploratory research because of the aim to investigate the perspectives of project team members in respect to the importance of BIM collaboration in the management of construction projects, and to implement their viewpoints in existing management guides. Therefore, considering the aforementioned nature, the appropriate strategy has been selected from five social science research methods suggested by Yin (2017): experiment, survey, archival analysis, history and case study. Thus, following three conditions suggested by Yin, a case study research method is the most suitable for the following reasons: First, the form of the research question poses the aim to develop a proposition. Second, the research does not require control over behavioral events. And third, the research focuses on contemporary events. In respect to this research, the case can be considered as the perspectives presented by project team members from construction companies currently involved in the development of projects.

Moreover, the data collection for this strategy could be carried out by different methodologies. In this research the selection of the appropriate data collection has been divided in 3 sections. First, literature study has been selected to account for all the relevant information already researched in previous studies, this methodology will lead to answers for sub-questions 1 and 2. Then, in order to attend to the perspectives of project team members, Q-methodology has been selected because it is designed to facilitate the expression of personal points of view in respect to a specific subject (Watts & Stenner, 2012). Furthermore, the analysis of the data obtained through the use of this method will help to answer sub-question 4. Finally, the method used in the last phase of this research is the expert interviews, used to validate the outcome of the research. More information of each of the aforementioned methods is detailed next.

2.1.1 Literature Study

A literature study is focused on creating strong a basis about the topic under research. This study is conducted through the coverage of relevant literature previously posted by researchers about the topic of interest. In this research, different platforms like Scopus, Google Scholar and the TU Delft library have been used in order to gather information related to mainly two topics: First, Sub-question 1 will be covered by investigation regarding the management of construction projects, in order to explain the concepts that will be used throughout the research as well as the influence that collaboration in general has on the effectiveness of management practices. Then, sub-question 2 will be covered by the introduction of BIM as a method to facilitate collaboration based on previous literature on the topic. The

outcome of this research provides the input for the development of the Q-set, which will be further explained later in the report.

2.1.2 Q-methodology

The main data collection method of this research is Q-methodology, the method was developed by William Stephenson in the 1930s with the objective to bring a scientific framework that reduces subjectivity (Stewart, 1989). Q-methodology merges qualitative and quantitative methods to investigate the subjective views of those directly involved in a particular topic (Coogan & Herrington, 2011), and reveal a series of shared viewpoints. Therefore, this method has been considered the most appropriate to understand how the people involved in the execution of projects feel towards the use of BIM collaboration.

The method begins with the selection of opinions, in the form of statements or images that will be later presented to participants. The collection of opinions in this case is preformed through the coverage of existing literature. Then the next step is the selection of participants which should be aimed towards a relevant and heterogeneous group of people regarding the topic of interest, in order to obtain a wider range of views. Next, comes the data collection where the selected statements are presented to the targeted group of people to sort the statements in a pre-defined scheme, giving as a result different Q-sort per participant. Finally, all the gathered data is analyzed to identify the groups of shared viewpoints among the respondents. This whole process is thoroughly covered by Watts & Stenner (2012) in their book "Doing Q-methodology Research" which has been the guide for this research and further developed in chapters 4 and 5.

2.1.3 Expert interviews

Semi-structured interviews with experts in the field of project management is the selected method to perform the validation of the suggestions based on the data analysis of perspectives given by Q-methodology. This is an important step to verify if the suggestions made by this study are beneficial for people involved in the industry, therefore, a few questions regarding the suggested implementations to existing guides are presented to people with vast experience, to let them openly comment about them and their applicability and usefulness in the industry.

2.2 Research approach

The approach followed in this research is to separate the work in three phases: 1 Introductory, 2 Exploratory and 3 Delivery. Each one of these phases brings an important contribution to the report. First, the introductory phase explains the purpose of the research and the approach selected to obtain the expected results. Then, the exploratory phase is where most part of the research takes place; in this phase all the related information is obtained by exploring the existing literature as well as performing Q-interviews to people involved in the management of projects. Lastly, the delivery phase is where all the information obtained from the aforementioned sources, is combined to produce a list of suggestions to be implemented in existing guides with the ultimate goal of enhancing the effectiveness of construction project management. An overall graphical description of the approach is presented in Figure 2-1.

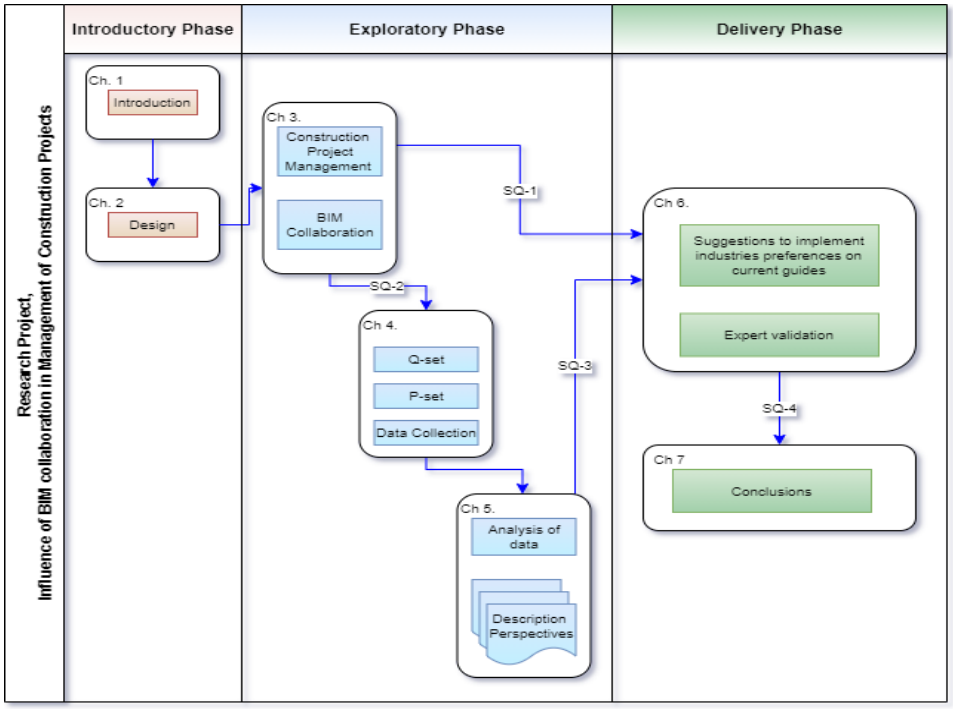

Figure 2-1 Diagram of the research approach

The introductory phase is comprised by the introduction (Ch. 1) and the design adopted in this research (Ch. 2). The aim of these chapters is to give a clear idea of the relevance of the research, the pre-set objectives and the approach taken in order to obtain the expected results. Then, the exploratory phase begins with chapter 3, which covers the information obtained through exploring the most relevant literature regarding: first the Management of construction projects, which will answer sub-question 1. And second, the influence of BIM collaboration, which will answer sub-question 2. Moreover, the latter answer will be the starting point for chapter 4, where this information is organized, and later presented to respondents in order to obtain their contribution, by showing their preferences in what they consider to be the most important aspects from BIM collaboration that influence the enhancement of management. This interaction with the respondents is done by the steps suggested by Q-methodology. To conclude, this information is further analyzed in chapter 5, which describes the results obtained in the previous chapter, showing the differences and similarities in the perspectives presented by respondents, and thus, answering sub-question 3 of this research.

The last phase presents the deliverables of the research. Firstly, chapter 6 compares the content of existing guides with the results obtained from participant responses to create suggestions about what should be implemented to account for the needs of the industry. These suggestions are then presented to experts in the management of projects field, in order to have their opinion about the usefulness in the industry, this process is known as the validation and will give a response to sub-question 4. Finally, chapter 7 starts by giving an answer to the previously proposed research questions, giving a final conclusion regarding the importance of collaboration through BIM to manage construction projects effectively. Moreover, recommendations for future research as well as the limitations of this study are presented. The report finalizes with a personal reflection based on the obtained results.

3. Literature Review

This chapter creates a strong basis for the theory and terms used throughout the report, by presenting the results of an extensive review of current literature regarding the topic under research. First, the topic covering the management of construction projects is covered, due to the main focus of the research is aimed to contribute to this practice. Then, the contribution of collaboration in the management of construction projects is explained throughout the review of literature that broaches the subject. Finally, the inclusion of BIM processes as a technology that enables collaboration in construction projects is investigated throughout the review of updated literature.

3.1 Management of Construction Projects

Historically, the use of management practices has been part of construction projects long before they were taken into consideration by researchers. The construction of ancient buildings like the pyramids of Egypt or the Machu Picchu fortress must have needed the guidance of big groups of people in order to achieve their objective. However, in the last decades, researchers have shown the interest to study this subject in detail, in order to enhance the performance of people or groups in charge of projects. The uniqueness nature that characterize projects makes the task very difficult to accomplish, but even though it is impossible to have a straightforward guide that ensures success, the development of certain guidelines that facilitate the work of managers to obtain the expected results is considered of relevant contribution. This section will define the most important concepts to understand what the management of construction project entail, followed by a review of an existing guide for the management of construction projects.

Definition of Projects

A project is defined as a "*temporary endeavor undertaken to create a unique product or result*" by the Project Management institute (PMI). This definition describes in simple words the meaning of projects, however, more detailed explanation is given by Turner (1998), who presents five characteristics that an activity must have in order to be classified as a project, they are the following:

1. It has a defined objective or purpose, with a well-defined end-product or results.
2. It is unique, a one-time activity.
3. It is temporary.
4. It requires resources from different organizations or functions.
5. It brings along unfamiliarity and risks.

These characteristics represent the main differences that a project has in comparison with any other activity of mass production. And therefore, they should be treated differently in order to attain specific challenges that arise during the development of a project. Moreover, these characteristics are important to consider in the scope of this research, since its focus is put on the management of projects, and not in organizational procedures.

Additionally, another characteristic presented by projects, is its division in phases from the beginning to the culmination of the project. These phases are usually evaluated to make a decision about whether or not the project moves into the next phase, some adjustment is needed or if the project stops. The names given to these phases differ in various studies (Leybourne, 2007; Murray, 2009; Turner, 1998), but they are similar to the names used by the PMI, which are the ones used in this research and can be seen in Figure 3-1.

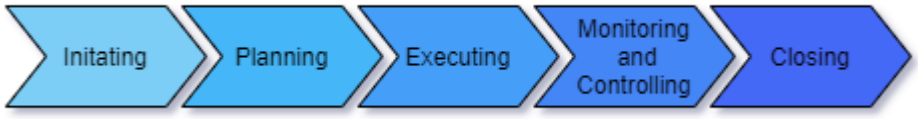

Figure 3-1 Phases of a project

Project Management

Once the concept of projects is well defined, it is important to state the need of good practices of project management in order to ease the achievement of the proposed results. Basically, the goal of every project aims to achieve 3 main objectives, these being: time, cost and quality (Nicholas & Steyn, 2017); Time represents the period on which the project should be carried out. The cost refers to the specific budget assigned to execute the project. And quality, refers to the final outcome expected to be delivered at the completion of the project. Therefore, the management procedure aims to achieve these goals upon the execution of a project. The increasing complexity presented by recent projects, makes this goal difficult to achieve, and therefore, more emphasis should be allocated to improvement of management practices.

Project management is performed by a team, led by a team-leader who follows certain methodology to achieve short-term and long term objectives (Nicholas & Steyn, 2017). Therefore, due to the various meanings that could be understood by the term, it is important to state the differences that the term present:

- The person, also known as *Project Manager (PM),* is the person in charge of planning the execution of projects, as well as directing and integrating the efforts of other individuals in order to achieve the objectives.
- The team, also known as *Project Team*, refers to the group of people involved in the development of the project, led by the PM. Usually the team disarms after the completion of the project.
- The methodology, is the procedure followed by the PM and the project team to plan and control the development of a project.

Furthermore, the development of the knowledge on how to manage projects has given room for international organizations to present certain guidelines or standards about the minimum knowledge needed by a professional to perform good practices of project management, known as “Bodies of Knowledge” (BOK). Among the most important professional organizations are: the PMI (Project Management Institute) based in USA, IPMA (International Project Management Association) based in Europe, APM (Association for Project Management) based in UK, and PRINCE2 (PRojects IN Controlled

Environments, Version 2) also based in UK (Nicholas & Steyn, 2017). However, the largest organization is the PMI and probably the most widely known (Bosch-Rekveldt, 2011), and therefore, this guideline is the one selected to further be analyzed in this research.

Hence, the definition adopted in this research is the one given by the PMI (2016a), which states that project management is "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements*". Furthermore, this application is closely related to each phase presented in Figure 3-1, by the application of the following 10 knowledge areas independently on each phase: Integration management, scope management, time management, cost management, quality management, human resource management, communication management, risk management, procurement management and stakeholder management. However, the scope of this guideline is focused on a broad vision of projects, to be followed by different industries including the AEC industry. Therefore, in order to attend to this industry, PMI dedicated a specific extension for the construction industry (PMI, 2016b), which will be covered in the following section.

Focus on Construction Projects

Construction works often present characteristics of a project, since it intends to provide a final asset in a certain period of time, in unique conditions due to its variant location, working environments or affected people, among others. Moreover, these projects often require the contribution from different disciplines (civil, structural, electrical, mechanical, etc.) to its completion, besides the usual high degree of risk given by unexpected conditions. Therefore, special attention should be put on understanding the management of construction projects separately than projects in general. Hence, the Project Management Institute presents the Construction Extension to the PMBOK Guide, to attend to specific principles that are not common in the management of general projects.

The nature of construction projects led to the inclusion of 2 areas of knowledge to cover specific practices in the industry, which are: health, safety, security and environmental management, and financial management. Moreover, the construction extension includes an overview on advances in technology and management techniques that can be applied to these type of projects, in order to enhance the performance of management practices. These advances include the use of technologies, Building Information Modelling (BIM) and emerging management techniques like the focus on change management or the constantly changing digital technologies, in order to evolve management practices simultaneously with the capacity that technology and updated techniques offer.

3.2 Collaboration in construction projects

Collaboration is known as the outcome of a certain action or decision taken by an agreement of relevant stakeholders of a domain, in an interactive process that follows shared rules or norms (Wood & Gray, 1991). However, the concept of collaboration is defined differently depending on the field of interest. Since the focus of this research is put on construction projects, the meaning of collaboration for this field it is introduced next.

Due to the several difficulties faced by the AEC industry to achieve the goal of their projects, collaborative practices have been implemented in construction projects with positive results, showing a reduced number of scope changes along the development of a project, as well as an increase in the satisfaction of clients (Bosch-Rekveldt, 2011). Moreover, these findings complement previous work from Anderson et al. (2004) which suggests that the creation of collaborative project teams can help to improve effectiveness of management and therefore, project performance. Or even more broadly, Tapscott & Williams (2007) state that in a current business in the twenty-first century, in order to remain competitive in a very challenging industry full of complex projects, it should be a rule to "collaborate or perish". Certainly, a survey conducted in Canada highlights collaboration as the most important opportunity for improvement in the local industry, which is supported by similar results in other countries (Shen et al., 2010). Knowing the positive results of collaborative teams in the construction sector, is important to understand what does the term collaboration mean for people in the sector.

In the context of construction projects, the term "collaboration" has been linked with other terms used in the industry like: alliance, joint ventures, networking, and partnering. However, a study performed in the UK (Hughes et al., 2012) aimed to analyze what the term "collaboration" mean to people involved in the construction industry, concluded that from their perspective, collaboration is a "*non-adversarial team-based environment, where through the early involvement of key members and the use of the correct contract, everyone understands and respects the input of others and their role and responsibilities*". The role in the industry played by various respondents of the aforementioned study present a slight difference on the perceived meaning of the word collaboration, but the previous definition combines them into one shared perceived meaning. Furthermore, the study highlights the contribution from all members to achieve the common aim by a method of "pain-share, gain-share" where the responsibilities and liabilities are equally shared as the rewards.

Therefore, in a construction project context, the term collaboration entails the action of sharing relevant information among key members of a project in the correct time, in order to facilitate the management practices that aim for achieving the main goals of the project, mentioned in the previous sub-section, namely time, cost and quality.

Consequently, the development of collaboration literature and its influence on the management of construction projects has introduced new concepts like the Construction Collaboration Technologies (CCT), which refers to a virtual shared workspace that allows the storage, tracing and access to information that facilitates easier management of construction projects (Nikas et al., 2007). In addition, perhaps one of the most important new concept introduced in the construction industry is the Building Information Modelling (BIM), which refers to the process of creating models that contain physical and functional characteristics of a building asset, which is expected to improve collaboration practices in the construction industry (Turk, 2016). The latter has been increasingly used in construction projects, and put under scrutiny by several researchers. The research presented in this report focusses on the collaboration features offered by BIM, and this topic will be covered in the following subsection.

3.3 BIM collaboration

The introduction of BIM concept in the AEC industry has been a revolutionary methodology which is increasingly used for professionals. First, a brief description and introduction to BIM is given, followed by the analysis of BIM as a collaboration enabler.

3.3.1 Introduction to BIM

BIM definition

The acronym BIM could be understood for either "Building Information Modelling" or "Building Information Model". The first refers to the process while the second refers to the model as an artefact. For purposes of making the use of the term clear along this research, the first option is the one used from this point on, since the focus of the research is about the collaboration features that the process offers and not related to the model as an artefact. Consequently, the definition of BIM also varies due to this differences in perspectives. Considering BIM as a process, the definition given by Miettinen & Paavola (2014) is that "*BIM is a set of technologies and organizational solutions that are expected to increase collaboration in the construction industry and improve quality of design, construction and maintenance of buildings*". The process-based definition has also been combined with a model-oriented perspective where both aspects are considered, following a structure-function behavior paradigm, and thus can also be stated as "BIM is a structured digital representation of a building that functions as a communication backbone and shared source of required information which behaves as a socio-technical system" (Turk, 2016). Nevertheless, the definition given by the PMI is considered the most accurate for this research because it highlights the importance of its use for management purposes. This definition states that:

> *"BIM is an information-based system of processes involving the generation and management of digital representations of physical and functional characteristics of construction projects"*

State of BIM use

The origins of BIM go back to the early 1990's where the concept was introduced, however it was not until a decade and a half later when positive outcomes of its uses were beginning to be reported (Linderoth, 2010). Its implementation has been very slow in the industry due to different barriers like the development of appropriate technology, the financial investment needed, resistance to change and the lack of clarity or awareness (Lambermon, 2020). Nevertheless, in the last decade the use and implementation of BIM in construction projects has experienced significant growth based on the developments of technology, the benefits that the process presents, as well as regulations required by governmental organizations (Turk, 2016). For example, the BIM adoption rate increased from 28% to 71% in the US within five years between 2007 and 2012, and similar trends followed in UK, Australia, China and Malaysia (Du et al., 2020).

Similarly, the development of the literature regarding the use of BIM has significantly increased in the last decades. However, a thorough analysis performed about the literature about BIM in a period of 10 years (2006-2016), showed that most of the focus is put on the technical aspects like the designs or the model

itself, while behavioral aspects as collaboration or the context surrounding the use of BIM is not sufficiently attended by existing literature (Oraee et al., 2017). Moreover, based on the available literature about collaboration with the use of BIM, researchers agree on the importance of collaborative aspects, considering as a key aspect influencing effective management of projects

3.3.2 Collaboration through the use of BIM

The aforementioned study aimed to analyse the current state of literature regarding collaboration on BIM-based construction networks. For this reason, it has been considered as an important source for this research. The study first identified all the articles related to BIM, using the bibliometric source *Scopus*, finding 1031 articles in a period of 10 years. Then, the study identified that 271 articles mentioned the term "collaboration" in its abstract/title/keywords, meaning that around 25% of the articles related to BIM consider the concept of collaboration in their studies. Finally, after a thorough examination of this reduced list, 62 articles were found to consider collaboration as the focal point of the study. Furthermore, the findings of this study based on the content of these refined list suggests the use of a *collaboration pentagon* as a comprehensive analysis tool.

The collaboration pentagon includes five antecedents that are suggested to be considered in studies about collaboration aspects in BIM-based projects. The study of antecedents to promote collaboration has been firstly introduced by Wood and Gray (1991) in a broader perspective to be used by different industries. Later, the Co-Spaces Collaborative Working Model (CCWM) by Patel et al. (2012) suggested that the collaboration antecedents should be categorized into context, tasks, support, interaction processes, individuals, teams and overarching factors. Furthermore, another study focused on innovation in Project Management practices, identified five antecedents that would enable effective collaboration in projects; *process, artefact, structure, agent* and *context* (Poirier et al., 2016). Based on these previous studies, Oraee et al. (2017) has defined the antecedents that should be considered to enable effective collaboration in BIM-based construction networks as process, task, actor, team and context. These five factors are represented in the collaboration pentagon (Figure 3-2), and it is suggested that "effective collaboration will only occur where all major antecedents meaningfully interact with each other".

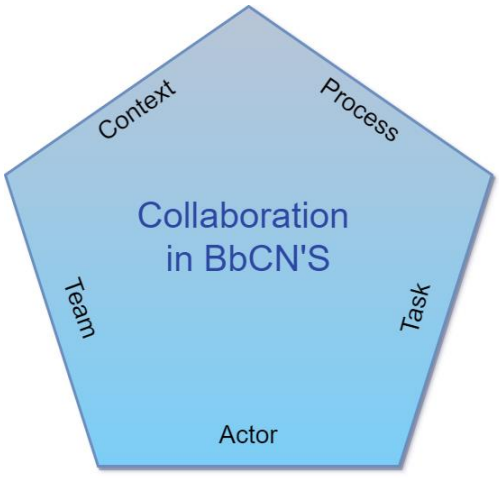

Figure 3-2 Collaboration Antecedents Pentagon (Oraee et al., 2017).

The use of the collaboration pentagon framework as a theoretical lens for this research is considered of high relevance because of its focus on management practices, and not only in technical aspects of the collaboration through BIM. Therefore, the analysis of perspectives shown by project team members will consider this antecedents, in order to understand the current state of members of the industry, and identify which aspects needs more attention in order to ensure effective collaboration in practice. The aforementioned antecedents are described as follows.

- **Process** refers to a series of actions to convert resources into products with the use of technology, the focus of this aspect highlights the utilization of tools and software, as well as the existence of reliable network-based systems as key facilitators of successful collaboration in BbCN's.
- **Task** refers to the characteristics of BIM activities to be completed, that will influence the performance of BbCN's in terms of collaboration.
- **Actor** refers to the performance of project team members in terms of social and interaction activities, and the influence that the level of skills, knowledge or experience have on effective collaboration.
- **Team** refers to the role of configuring relational procedures like defining roles and responsibilities, designing relationships or ensuring knowledge sharing.
- **Context** refers to the specific environment under which all the other antecedents are set within, where the lack of legal framework to manipulate an organizational environment has been found to hinder effective collaboration.

The definition of the terms that will be used in the following sections of this report have been presented in this chapter with the objective of forming a strong basis to be related to the findings of this research. Especially, the introduction of the antecedents needed to enable effective collaboration in BIM based projects have been presented, which will form part of the theoretical lens to identify different perspectives among members of project teams. In the following chapter, the methodology used to perform this identification is presented.

4. Performing Q-study

In order to obtain the perspective from different actors in the construction industry, the Q-study is conducted by applying the following steps: First the selection of the statements to be presented to respondents (Q-set). Then, the selection of participants that will participate in the research is explained. Finally, the execution of the interview to obtain the qualitative data from participants is presented. This will lead to the following chapter which will analyze the results of the obtained data.

4.1 Selection of statements (Q-set)

The first step for the Q-study is the elaboration of a list of statements to be presented to the respondents in a later stage. In order to make sure the list is appropriate and encompasses the aspects related to the contribution of BIM collaboration in the Management of Construction projects, different articles related to the topic were considered to extract a draft list of statements. Once the draft is ready, a thorough revision of the statements is performed to reduce the list and avoid similarities. The entire process is explained as follows:

4.1.1 Formulating the sorting question

The beginning of the process to select the statements is the elaboration of a question that will lead the respondents to sort the statements. The objective of using Q-methodology is to reveal different perspectives that actors of the AEC industry present in respect to the influence of BIM collaboration on Project Management. The following sentence has been presented to participants of the Q-study prior to the introduction to the statements:

"for the collaboration through BIM to facilitate effective Project Management it is important to…"

The process of selecting the sorting question has been thoroughly discussed with peers and throughout pilot tests in order to make it simple and clear to understand for respondents. Nevertheless, in order to avoid misperceptions or differences in the way that each respondent interprets the sorting question, a clear explanation of the objective of the question was expressed verbally at the beginning of each interview. This explanation stated the importance of two factors to be considered in relation to one another: 1) Collaboration through BIM and 2) Effective Project Management. The idea is that respondents sort the statements based on the importance that each feature from BIM collaboration has on facilitating effective Project Management.

4.1.2 Obtaining Universe of Statements (Q-concourse)

Once the sorting question has been defined, the collection of a universe of statements, also known as the Q-concourse, has been performed. According to Watts & Stenner (2012), there are two main categories on how to perform the statements sampling: 1) Structured sets, which are selected after a breakdown of the general topic into categories and subcategories, and 2) Unstructured sets, which are developed with more freedom based only on the sources selected such as literature research, questionnaires or

interviews. As for this research, the unstructured option was selected in order to expand the options beyond the limits of pre-defined categories and include a broader set of statements. What is considered more important for an effective Q-set is that this needs to be well balanced offering different options for the respondent, as well as ensure that the coverage of the field is broad enough to allow perceptions to be extracted (Donner, 2001). Additionally, the unstructured sampling is shown to be used in a big percentage of Q-studies, e.g. eight out of the eleven articles selected to analyze in the study by Dziopa & Ahern (2011), used this sampling method.

4.1.2.1 Criteria for selection of literature.

In order to start the selection of statements to be presented to respondents, first, the selection of the literature to be used to extract those statements is carefully reviewed in order to guarantee reliable content. For this purpose, five aspects were considered for the selection of articles; Keywords, analysis of the abstract, relevance of journals, time of publication and the number of citations.

- **Keywords**

In order to find related articles, specific keywords related to the topic under research were used. These words are: “BIM”, “Collaboration”, “Construction project” and “Management”.

- **Analysis of the abstract**

After the first selection of articles, a quick read of the abstract helps to confirm the relevance of the topic covered in regards to the objective of the research.

- **Relevance of journals**

In order to base the Q-concourse on high quality data, the relevance of the journals where the selected articles were published was analyzed. In order to determine relevant journals, first two main topics were considered, being those BIM and Project Management. For each topic, a list of journals with a high citation index was selected to be the main source of articles used in this research. Additionally, the list was verified in a discussion with a current researcher on the topic, see Table 4-1.

Table 4-1 List of relevant Journals for articles selection

BIM	Project Management
Computer-aided and Infrastructure Engineering	International Journal of Project Management
Archives of Computational Methods in Engineering	Journal of Management in Engineering
Automation in Construction	Project Management Journal
Building Research & Information	Journal of Construction Engineering and Management
Journal of Computing in Civil Engineering	Journal of Civil Engineering and Management
	Engineering Construction and Architectural Management
	International Journal of Managing Projects in Business

- **Time of publication**

BIM literature is evolving very quick in the last years with the development in technology, therefore, it is important to make sure that up to date information is included, so new findings are taken into account. For this reason, the year of publication of each article has been checked. Mainly, articles published in the last five years were selected for extracting the statements. However, based on their importance and relevance to the topic, two exceptions were made, Becerik-Gerber et al. (2012) and Singh et al. (2011).

- **Number of citations**

Last but not least important, is the number of citations that an article has. By using highly cited articles it is ensured that the article has been considered relevant for researchers in the topic. However, the fact that an article does not present a big number of citations does not necessarily mean that the article is not relevant, but this could instead be related to the novelty of the publication. Therefore, this criterion has been considered mainly for older articles.

4.1.2.2 Selection of literature for Q-concourse

Taking into consideration the above mentioned criteria, a first draft list of 30 articles was selected to contribute to the Q-concourse. Then, these articles were thoroughly analyzed, which led to a final reduction of the list to 11 articles. These articles were considered to be the most relevant from the draft list, in respect to the contribution of BIM collaboration to construction project management, and excluded those articles related to the technical aspects of the use of BIM. Moreover, the coverage and balance of the final list of 11 articles was broad, and the use of more articles just started to show more repetitiveness of statements. The final list of articles used to generate the Q-concourse is presented in Table 4-2.

Table 4-2 Articles contributing to Q-concourse

Authors, Year	Name
Becerik-Gerber et al., 2012	BIM-Enabled Virtual and Collaborative Construction Engineering and Management
Du et al., 2020	BIM for improved project communication networks: empirical evidence from email logs
Ghaffarianhoseini et al., 2017	Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges
Heigermoser et al., 2019	BIM-based Last Planner System tool for improving construction project management
Liu et al., 2017	Understanding effects of BIM on collaborative design and construction: An empirical study in China
Oraee et al., 2017	Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review
Oraee et al., 2019	Collaboration barriers in BIM-based construction networks: A conceptual model
Ozorhon & Karahan, 2017	Critical Success Factors of Building Information Modeling Implementation
Singh et al., 2011	A theoretical framework of a BIM-based multi-disciplinary collaboration platform
Wang & Song, 2017	The relation of perceived benefits and organizational supports to user satisfaction with building information model (BIM)
Zou et al., 2017	A review of risk management through BIM and BIM-related technologies

4.1.2.3 Q-concourse

Once the selection of articles that contribute to the Q-concourse has been made, a thorough review of each one of the eleven selected articles was performed. During this process, all the relevant ideas regarding the influence of BIM collaboration to Project Management were extracted. Consequently, this process led to an initial list of 78 statements presented in (Appendix B). However, this list was performed without checking for overlapping ideas coming from different sources, which needed to be assessed before the list was presented to respondents. This process is explained in the following section.

4.1.3 Development of Q-set

The last step for the creation of Q-set, is narrowing down the Q-concourse (N=78) to a lower number of items to be presented to respondents. Literature differs on the matter of what is an optimal number of items for the Q-set. However, it is agreed that this list should provide the respondent with enough options to cover the topic of interest and sufficient variety to distinguish perspectives from different groups of people. Most of the literature suggests to include a number between 20-60 items (Donner, 2001; Webler et al., 2009). Thus, the objective of the research was to generate around 30 items, so the respondents are not overwhelmed by the number of statements to sort at first sight, and by doing so, ensuring that the duration of the interviews are not too long, which helps to obtain more positive responses to accept the interview.

Consequently, following the creation of the Q-set, each one of the statements was categorized. Firstly, a subcategory was assigned to each statement based on its meaning, this procedure presented a total of 12 subcategories among the 78 statements from the draft list. The selection of subcategories was performed by reading each statement and assigning a description in one word, trying to capture the essence of the statement. Then, an assessment of the list of subcategories was performed in order to identify similarities, which led to the final list of 12 subcategories.

Once the subcategories were selected, each one of these were linked to one of the five antecedents for collaboration in BIM-based projects presented in Figure 3-2, with the objective to understand the perspectives that respondents present in respect to their importance in contributing to effective management practices. The link was based on the description of each antecedent described in chapter 3. First, the subcategories *policies* and *education* were linked to the context because they refer to the environment in which the project takes place and its regulations. The subcategories of *interaction*, *trust*, *relationship* and *combination* refer to the relational procedures that should be taken care of, and therefore have been linked to the team antecedent. *Simplification* and *monitoring* subcategories focus on the characteristics of BIM activities, so they have been linked with the task antecedent. The *support* category is related to the improvement of individual performance, which has linked it with the actor antecedent. Finally, *information*, *access* and *planning* were linked to the process antecedent based on their focus on the provision of the right procedures to convert resources into products. The entire list of categories and subcategories used in this research are shown in Figure 4-1.

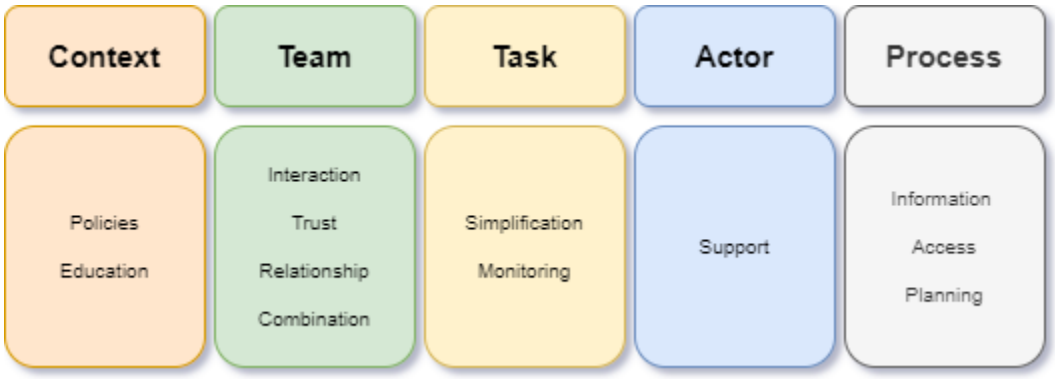

Figure 4-1 Categories of Statements

Based on these categories and subcategories, the total list of 78 statements was reduced to a total number of 29. In order to achieve this reduction, each subcategory was analyzed individually. Then, the statements belonging to each subcategory were compared and combined when possible to reduce repetitiveness. Additionally, some of the statements were created by either combining different statements, or slight changes were made in order to adjust them better to the sorting question presented in section 4.1.1. After performing this task, more accurate statements were defined to constitute the final Q-set presented to the respondents of the Q-interviews. The final list is comprised of 29 statements, six related to the context antecedent, nine related to the team antecedent, five to the task antecedent, 3 to the actor antecedent and six to the process antecedent as shown in Table 4-3.

Table 4-3 Final Q-set

#	Statements	Subcategory	Category
1	Build-up trust among project team members	Trust	Team
2	Combine traditional and BIM methods to increase trust among actors.	Interaction	Team
3	Compare different design options to support decision making	Support	Actor
4	Combine BIM and construction planning processes	Monitoring	Task
5	Create a BIM policy and protocols for the organization to which to adhere	Policies	Context
6	Create as-built renders with contribution of all of the involved parties in construction	Combination	Team
7	Create models that allow the interoperability among users to be easier	Relationship	Team
8	Enable open access to BIM models, to receive feedback from all project actors	Access	Process
9	Facilitate collaboration among geographically dispersed teams	Combination	Team
10	Have a good relationship between roles of PM and BIM manager	Relationship	Team
11	Have building materials delivered just in time by suppliers	Planning	Process
12	Maintain collaboration among different disciplines and organizations	Trust	Team
13	Merge the input from various professionals in the digital model	Combination	Team
14	Obtain the right information at the right time	Support	Actor
15	Pair senior leadership to the formation of project team	Policies	Context
16	Perform checks on digital models to facilitate construction of complex design concepts	Monitoring	Task
17	Perform constant monitoring and assessment control through the use of BIM	Monitoring	Task
18	Prevent on-site clashes and waste activities that lead to cost and time overruns	Simplification	Task
19	Promote team-working mentality among project members	Trust	Team
20	Provide BIM trainings to existing personnel	Education	Context
21	Provide technological and top management support to BIM users	Support	Actor
22	Recruit BIM qualified staff	Education	Context
23	Redistribute job responsibilities by the creation of BIM roles	Policies	Context
24	Rely on more skilled individuals to monitor the team progress	Education	Context
25	Share project data across involved organizations in a fast and effective way	Information	Process
26	Use digital representation of models to transfer information easier	Simplification	Task
27	Use BIM for in-depth communication instead of only for information exchange	Information	Process
28	Use learnings from previous experiences with BIM in future plans	Planning	Process
29	Use of 4D schedule for simplified comprehension of executors of the project	Planning	Process

4.2 Selection of participants (P-set)

The P-set represents the group of people that are responsible for conducting the sorting of statements. It is important to select people that is relevant to the problem under analysis. Therefore, the criteria considered for the process of selecting the participants are the following:

- *Only people involved in the AEC industry.* – The objective of using Q-methodology is to analyze the perspectives presented by people related to the AEC industry, since their job experience will include the practical problems that the industry presents. Therefore, it is important to contact employees currently involved in the construction industry
- *Type of Organization.* - Within the AEC industry, various organizations are in charge of the project in different stages of the construction. The phase determines the type of organization based on their perspective on when the project starts and finishes for them. However, because the scope of this research does not reach the operation and maintenance phase, these actors are excluded from the P-set.
- *Job Position.* – The role that each person has, even within the same organization might be very different. These differences could carry with them a particular point of view. Therefore, it is considered important to include in the P-set, people who are involved in projects from a managerial perspective because of their objective experience facing problems and the knowledge that those experiences bring along. This could include people belonging to the management team of the project itself or people involved in managing BIM processes.

Furthermore, the experience obtained throughout the time working in the industry by each participant is very important to have a better picture of what the real problems are in construction projects. However, this aspect was not a subject of restriction to participate in the sorting process. The reason is that due to the novelty of BIM in the industry, it requires a combination of both, experienced professionals with a wide viewpoint of the subject and young professionals who are more familiar with the use of technology. Therefore, it is important to have a broad set of participants. Moreover, in order to understand better the differences between participants, they were asked to provide their work experiences (years) as well as their experience using BIM in their roles.

Clearly, Figure 4-2 demonstrates how these distributions worked out in this research. First, the upper left graph gives an image of the type of organizations where the participants work. The group is represented by a majority of Engineer/Designer organizations. However, representatives from other stages in the construction process are also included. Then, the upper right graph shows a quite regular distribution of participants from three job positions, this ensures having a balanced P-set. Next, the lower left graph represents the different working experience of the P-set, which also shows a well-balanced distribution. Finally, the lower right graph represents the years of BIM experience. Even though the representation of 10+ years experienced people in the field is very little (n=1), it is acceptable since the introduction to BIM in the industry is relatively new.

Additionally, another important aspect to consider when selecting the P-set, is deciding the number of participants. Literature differs in suggesting a number. However, considering the fact that Q-methodology considers the number of participants as the variable, and the objective is to extract particular viewpoints

to understand and compare (Brown, 1980), the necessary number does not need to be big. In fact, Watts & Stenner (2012) suggest that the amount of participants should be around half of the number of items as in the Q-set, and if bigger, should not reach the same number of items in the Q-set. Moreover, other studies suggest numbers ranging from 12 to 40 participants (Webler et al., 2009). Hence, taking all of these recommendations into account, this research has considered 15 as an appropriate number of participants to interview. The final list of interviewees is shown in Appendix A.

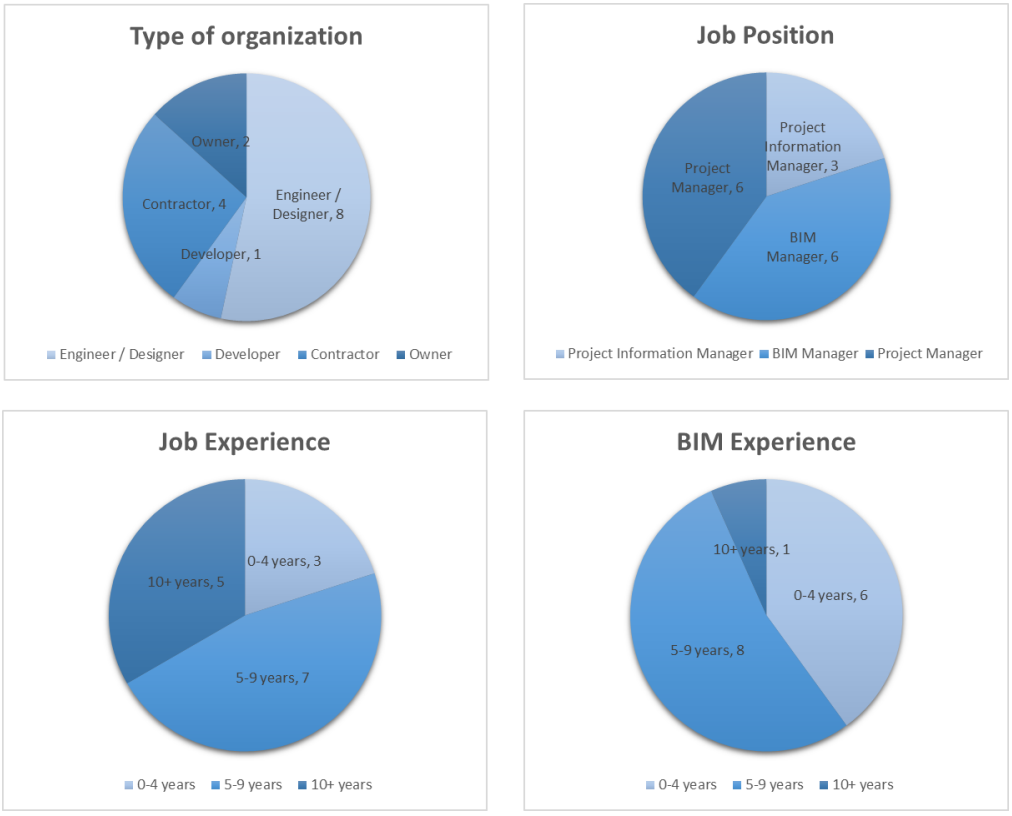

Figure 4-2 Distribution of Participants

Consequently, a total number of 32 people were contacted until obtaining the predefined number of 15 respondents. In order to obtain the information of whom to contact, networking was performed relying on previously known people that are currently working in the AEC industry. First, a brief description of the selection criteria was explained, in order to select the correct people. Another method applied was the use of the social network LinkedIn, which provides an easy access database of potential interviewees. However, when this method was applied, a first contact with the person was established to introduce the research project and make sure they met the defined criteria. Lastly, and probably the most important source of contacts, was the recommendations made by the interviewees; since they already experienced the sorting process and the details that entails. Overall, the balanced distribution of the P-set aims to minimize the bias of certain type of organizations or job positions.

4.3 Data Collection (Q-sorting)

The next step of the Q-study is the collection of data, which in terms of Q-methodology is represented by the sorting schemes created by the respondents. This process is the last step to obtain the data from respondents, which will be further analyzed in the following chapter.

4.3.1 Shape of the sorting grid

All participants will receive the Q-set (Table 4-3) which should be read after the sorting question presented earlier in section 4.1.1. Then, they will proceed to sort each statement, based on their perceived importance, firstly into three boxes from “least important”, “neutral” and “most important”, and then into a pre-set sorting scheme. The distribution of this sorting scheme usually follows a fixed normal distribution (Watts & Stenner, 2012). A fixed distribution, actually helps the respondent to perform the sorting procedure more focused on the topic itself. Moreover, it is important to define the range and slope of the distribution.

The range used in the sorting scheme goes from least important to most important, and its length will depend on the size of the Q-set. Brown (1980) suggests a (-4 to +4) for Q-sets of approximate 40 statements. Therefore, this research uses a smaller range (-3 to +3) based on the 29 items of the Q-set. Additionally, the selected slope of the sorting scheme is steeper rather than flatter. Moreover, the steeper distribution will force the participants to select only 4 statements on the edges of the scheme, which will bring a more meaningful outcome regarding what they do consider more or less important. The selected distribution is shown in Figure 4-3.

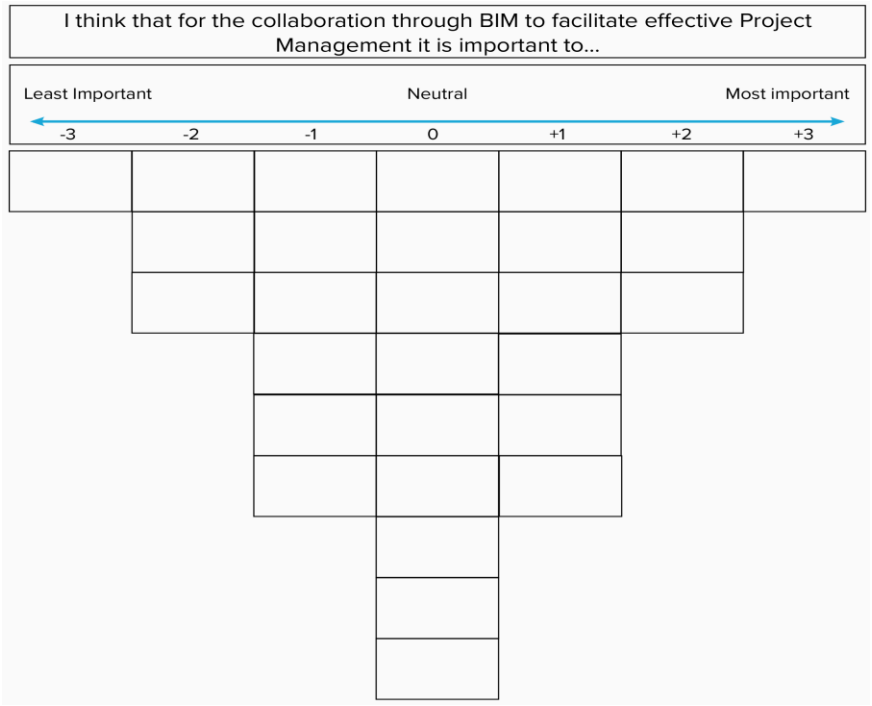

Figure 4-3 Sorting scheme

4.3.2 Sorting Platform

Once the sorting scheme has been set, the execution of the Q-interview should be planned. It is suggested to perform this type of interview in a physical meeting with participants, because this eases the interaction with the respondents during the Q-sorting procedure. Another important factor is to be present during the sorting procedure in order to solve any doubts or questions the participant might face. However, due to the difficulty of having face to face meetings due to the pandemic, a shared virtual collaboration workspace called Mural was used. The portal allows the creation of personalized workspace, where the layout of the Q-interview was created (See Appendix C). This interactive shared workspace simulated the physical interview quite accurately, replacing the frequently used cards that contain the statements, by virtual sticky notes that could be easily dragged around from place to place in the virtual board. Additionally, a virtual video-call took place at the same time in order to have a fluent communication with the respondents during the Q-sorting procedure.

4.3.3 Pilot tests

After doing some own tests of the Q-interview layout, two pilot interviews were held with the purpose of getting familiar with the use of the platform as well as checking if the content of the statements were clear enough. By doing so, small details could be taken care off before the real interview, which should run smoothly from the first time. Therefore, the intention of the pilot tests is to obtain constructive feedback to enhance the set-up of the interview from relevant sources.

For this reason, different backgrounds were selected for this exercise. First, someone from the AEC industry was selected to have a good idea if the statements were clear enough. This contribution helped to rephrase some statements and a final touch to the sorting question to clarify its purpose. Then, the second pilot was conducted more focused on the visualizing and interaction issues of the interview. This test helped to change position of certain boxes, enlarge font size for certain sentences and correcting some grammar mistakes, to make it easier for respondents to better understand and facilitate their sorting procedure. By doing so, ensuring they are focused only on the content of the interview, which guarantees a better outcome.

Additionally, another important aspect found during these tests, is realizing about the approximate duration of the interview. After running the 2 pilot tests, the duration was around 30-40 minutes, which was an important fact when contacting the potential respondents, to clarify it would not take much time of their working schedules.

4.3.4 Conduction of the Q-sorting

The final step to obtain the data in the Q-study is conducting the interviews. As previously explained, these were performed online. Therefore, a detailed set of instructions was handed to respondents before the meeting. This document starts with a brief introduction of the research, followed by a small form to be filled with background information of the respondent. Then, a detailed list of instructions on how to proceed with the interview was presented. The document is shown in Appendix D.

Each interview started with a brief introduction of the research, before the start of the sorting procedure. For this process, the respondents were given 3 boxes to place the statements regarding their choices between “More important” “Neutral” and “Less important”. Once they finished with this step, they started dragging and sorting the statements from the “more important” box into the sorting scheme (Figure 4-3). This step is essential in order to make the respondent focus more on the aspects they consider to be the most important ones. Then, they will follow the same procedure with the box of “less important” and finalize filling in the sorting scheme with the statement located in the “neutral” box. Once they have finished sorting the statements they are suggested to have a final look in the scheme in order to verify their choices, any change is still possible in order to make them feel fully satisfied with their responses.

Finally, the interview ends with a short list of questions regarding the choices made in the sorting process. This will help further in this research to understand better the reasons why they made their choices, especially those statements that were placed on the edges of the sorting scheme. The following list of questions was discussed after every sorting procedure:

- *Can you elaborate on why did you choose the statements in ‘+3’, ‘+2’ and ‘-3’ boxes?*
- *How satisfied are you in your day to day experience, regarding the statement positioned in ‘+3’ box?*
- *Besides the statements presented, can you think of any other collaborative action that enhances management of construction projects?*
- *If so, where would you have placed it in the previous sorting scheme?*

This chapter has detailed all the procedure of how the Q-study have been performed until the data collection. The following chapter will present the data collected throughout the Q-interviews and present an analysis of this data to discover different perspectives among the responses by respondents.

5. Industry Perspectives

This chapter aims to identify the perspectives shown by people working in the AEC industry regarding the importance of collaboration to facilitate the management of BIM-based projects. In order to do so, first, all the data obtained during the Q-sorting process is analyzed in section 5.1, to understand how many perspectives are identified from the 15 participants that contributed to this research. Then, in section 5.2, each one of these perspectives will be described in detail, highlighting their characteristics. After this, the differences and similarities that the identified perspectives present are explained in section 5.3. To finalize, Section 5.4 wraps-up the most important information regarding the discovered perspectives, and therefore, solving sub question #3 of this research: "*What perspectives do project team members have in respect to the importance of collaboration through BIM, in the management of projects?*"

5.1 Analysis of data (Q-study)

After conducting the Q-interviews detailed in the previous chapter, all the information obtained from 15 participants is analyzed. The outcome of these interviews are the Q-sorts, which describe their choices on what they do consider to be the more important contributors to effective management of construction projects. In order to perform this analysis of the responses, the free software PQ Method was used. The last version (2.35) published in November 2014 of the software created by Peter Shelmock was used in this research. The utility of this tool specifically tailored for Q-studies allows an easy introduction of the Q-sorts and statements prior to the execution of the analysis.

Once all the data has been introduced, the program starts by providing a correlation matrix (Appendix E) where each Q-sort is compared to each other. The values of this matrix ranges from negatively correlated (-100) denoting differences between Q-sorts, to fully correlated (100) denoting similarities. Subsequently, an analysis based on the values of the correlation matrix is performed, in order to find out a certain amount of clusters with a shared viewpoint regarding the topic in study. This reduction of data, clustering the Q-sorts in groups is called the *factor analysis*, where the factors represents the number of perspectives found within the obtained data. This analysis will bring different options where the best choice will be selected.

5.1.1 Factor Analysis

The first step of the analysis is the selection of the appropriate number of factors. In order to do so, Q-methodology suggests a reduction of factors. The selected software offers two choices to perform this analysis, a) Centroid Factor Analysis and b) Principal Component Factor Analysis. Both methods bring similar results and they are generally accepted by Q-methodologists, and even though the first option is more frequently used in Q-studies, Principal Component Analysis was chosen for this study because it is more widely spread among researchers outside Q-methodology and provides a mathematically based answer.

As a result of this option, the eigenvalues of each factor is presented in Figure 5-1. The eigenvalues of a factor are an indication of its statistical strength (Watts & Stenner, 2012), therefore big eigenvalues are expected in a factor in order to be selected. Furthermore, the Kaiser-Guttman criterion suggests that only

values of 1.00 and above should be considered for further analysis (Kaiser, 1991). In this study, the blue dots in Figure 5-1 denote the factors that meet this criterion (2, 3, 4 and 5) . Clearly, factor 1 is not considered since the idea of this research is to find more than one perspective.

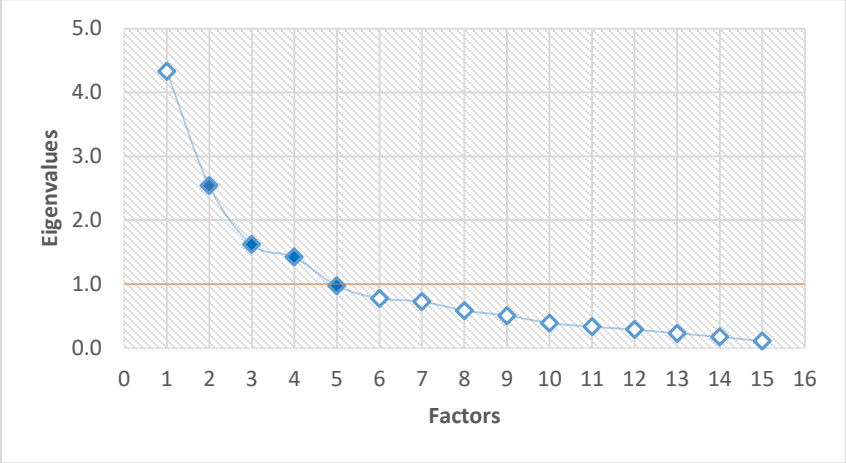

Figure 5-1 Eigenvalues of unrotated factors

After the reduction of factors, PQ Method offers two options to perform the rotation of factors, Manual Rotation and Varimax Rotation. Again, both methods are widely accepted and no one method presents a significant advantage over the other. Nevertheless, congruently with the selection of method for reduction of factors, Varimax Rotation is chosen to obtain a more mathematically based solution. Furthermore, in this step the rotation has been performed only to the factors that met the Kaiser-Guttman criterion. Thus, obtaining the loading factors as shown in Table 0-4 (Appendix E).

Loading factors represent the correlation coefficient that each Q-sort has with the representative Q-sort of each factor and it ranges between -1 and 1 depending on its positive or negative correlation (Webler et al., 2009). Therefore, four tables are considered for further analysis. Moreover, two important aspects are suggested when analyzing this information; First, the minimum amount of contributing Q-sorts to a factor solution should be two, in order for the factor to be considered (Brown, 1993). Second, it is considered that a Q-sort contributes to a factor if its correlation is higher than 2.58 times the standard error (SE) (Brown, 1993), which is calculated as follows:

$$Standard\ Error\ = {}^{1}/_{\sqrt{N}} = {}^{1}/_{\sqrt{29}} = 0.186$$

The Standard Error for this study is 0.186, since N represents the number of statements in the Q-set. Therefore, Q-sorts are considered to contribute to a factor if its positive correlation is higher than **0.48**. Moreover, the following criteria are considered to make a decision about the final set of factors to consider (Webler et al., 2009).

1. **Simplicity**: Low number of factors facilitates the understanding of viewpoints. However, simplicity should not be taken too far since some relevant information about people's perspective might get lost.

2. **Clarity**: A choice of factor solution is considered strong when each Q-sort presents only one contributing loading factor per perspective. You should try to minimize the number of "confounders" (people who load on multiple factors) and "non-loaders" (people who do not load on any factor).
3. **Distinctness**: Lower correlations between factors are better, as highly correlated factors are saying similar things. Nevertheless, it is not necessarily bad to have high correlations, as long as the factor is otherwise satisfactory.
4. **Stability**: As you compare the results of using different numbers of factors, you will notice certain groups of people tend to cluster together. This is an indicator that those individuals really do think similarly. A good set of factors will preserve as many as possible of these stable clusters.

Once all the criteria for selection have been set, a thorough analysis of all the options will select the most appropriate set of perspectives. Firstly, as previously stated, only the sets of two to five factors are considered for further analysis based on their eigenvalues. The value for a five-factor solution is lower than 1.00, however it is still considered based on its proximity to 1.00. Then, since the cumulatively explained variance its recommended to be greater than 50% in order to account for more than half of everything that the Q-sorts have in common (Watts & Stenner, 2012), the solution of 2-factors should not be considered due to its variance of 46% as shown in Table 5-1.

Table 5-1 Characteristics of factor solutions

	2-factor	3-factor	4-factor	5-factor
Eigenvalues	2.54	1.62	1.42	0.97
Cumulatively explained variance	46%	57%	66%	73%
Sorts per factor	7-5	6-5-3	6-5-3-1	5-6-2-1-1
Contributing sorts	12	14	15	15
Confounders	1	0	0	0
Non-loaders	2	1	0	0
Acceptable factors	2	3	3	3

Furthermore, a distribution of the contributing sorts per factor (correlation > 0.48) has been performed as observed in Table 0-4 (Appendix E). Regarding this aspect, the two-factor solution presents only 12 contributing sorts, since two non-loaders and one confounder are identified, which does not comply with clarity criterion. On the other hand, even though four or five factor solutions present no confounders nor non-loaders, they include factors with only one contributive Q-sort, therefore, they should not be considered as a viable option. The option of a three-factor solution complies with all the criteria required, by presenting an eigenvalue greater than 1.00, cumulatively explained variance greater than 50%, three acceptable factors formed by six Q-sorts loading in factor one, five Q-sorts loading in factor two, and three Q-sorts loading in factor three. One Q-sort is considered as a non-loader to any of the factors, and therefore will not be furtherly considered. Therefore, this solution has been selected for further analysis which will be explained next.

5.1.2 Identification of Perspectives

Once the solution has been selected, a deeper analysis of this option is presented in the following section. In Table 5-2 the loading factor of every Q-sort in to the three selected factors is shown. Factor one is represented by Q-sorts number 3, 4, 7, 9, 13 and 15, factor two by Q-sorts numbers 6, 8, 10, 11 and 12, while factor three by Q-sorts number 1, 5 and 14; Q-sort number 2 has been left out of further analysis since it is categorized as a non-loader for not presenting a loading factor greater than 0.48 as calculated in the previous sub-section. In the table, the contributing loading factors are represented by the symbol "X". They constitute the three different groups with a common perspective that will be analyzed in detail.

Table 5-2 Factor loading of the three-factors solution

Q-sort	**Factor 1**	**Factor 2**	**Factor 3**
1	-0.14	0.20	**0.85 X**
2	0.05	0.21	0.11
3	**0.52 X**	0.47	-0.33
4	**0.51 X**	0.25	-0.12
5	0.24	0.00	**0.60 X**
6	0.30	**0.71 X**	0.34
7	**0.73 X**	-0.04	0.11
8	-0.03	**0.69 X**	0.24
9	**0.69 X**	0.27	-0.12
10	0.40	**0.66 X**	0.06
11	-0.06	**0.81 X**	0.11
12	0.18	**0.76 X**	-0.32
13	**0.80 X**	-0.05	0.08
14	-0.19	0.18	**0.84 X**
15	**0.48 X**	0.39	0.40
	6 sorts	5 sorts	3 sorts

5.2 Interpretation of perspectives

The next step is the description of the identified perspectives. Each factor represents a similar viewpoint regarding the importance of collaboration through BIM in the management of construction projects. Each perspective is examined separately and their characteristics are presented in the following subsection. First, a demographic analysis of the members of each group is presented in order to check their background and identify any link to their preferences. Then, an analysis of each characteristic that shows the common viewpoint for that factor is presented. In order to perform this analysis, an average of the score given to each statement by respondents loading in each factor is calculated, this value is known as the Z-score, where each statement has its own Z-score value per factor. The seven highest and seven lowest statements per factor are visualized in Figures Figure 5-2, Figure 5-3 and Figure 5-4, the entire list can be seen in Appendix E, Table 0-5. Additionally, based on the Z-score list, a common Q-sort per factor

that represents the viewpoint of the project team members with a certain perspective is created. The placement of each statement in the factor Q-sort is known as “factor array”.

Furthermore, the interpretation of perspectives is followed by an analysis of distinguishing and consensus statements that each factor present. The distinguishing statements are those that characterize a factor, because they were clearly placed in a different location of the sorting scheme than in other factors. The significance of these statements needs to be at least at the P<.05 level (represented by *) although some may even be significant at the P<.01 level (represented by **) (Coogan & Herrington, 2011). On the other hand, consensus statements are considered those that are similarly placed in the sorting scheme by different factors. Therefore, they will provide insight on where agreements could be reached by the different perspectives.

5.2.1 Perspective 1, Protocol Sticklers

This perspective is comprised by 6 respondents, 3 of them are Project Managers and 3 of them are BIM Managers, so no Information Managers were involved in this perspective. Furthermore, they work for Engineering, Developers or Contractor organizations, but no owner’s representatives. Regarding their experience, it is a balanced group in terms of general job experience as well as BIM experience. Nevertheless, due to the novelty of BIM implementation, there are no “+10 years” experienced participants in either of the groups. Next, an analysis of the choices made by representatives of this perspective is presented, based on the seven highest and seven lowest ranked statements of this factor as shown in Figure 5-2, as well as on the distinguishing statements shown in Table 5-3.

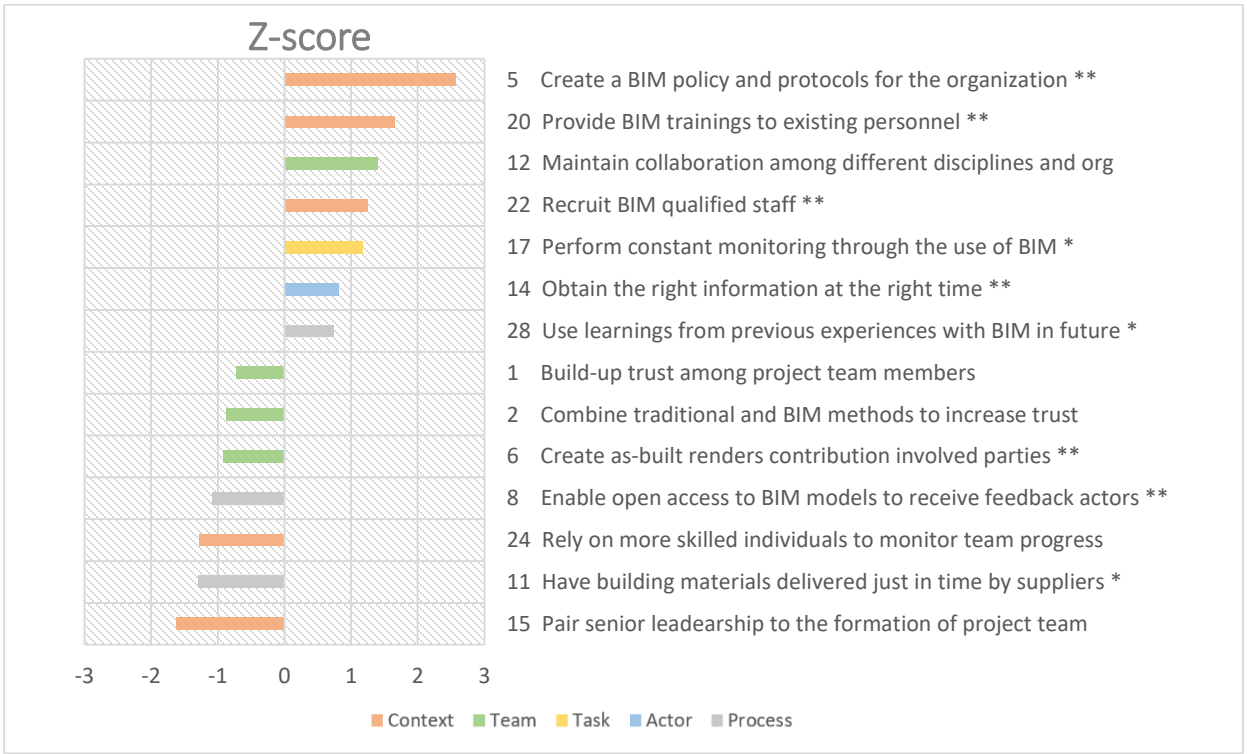

Figure 5-2 Z-scores of the most and least important statements for Factor 1

One of the most important characteristic shown in this group of respondents is their high perceived importance of having a well-structured BIM policy and protocols to follow during their projects (St 5; Z-scr=2.58), as represented by its high Z-score in Figure 5-2. Therefore, this group of project team members have been named as Protocol Sticklers, which describes someone who always follows a defined procedure. They consider that having a set of protocols and procedure is the most important aspect to ensure good use of BIM collaboration in projects. For example, they state the following:

"H*aving a clear protocol within an organization will ensure good implementation of changes, BIM protocols are like a bible in the implementation stage*". Participant #13

"*It is important that the procedure is the same, regardless of who is using the models, so in that way information is more objective*." Participant #3

Additionally, this is supported by their high preference for the importance of providing BIM training to existing personnel (St 20; Z-scr=1.66), or recruiting BIM qualified and experienced staff (St 22; Z-scr=1.25). Therefore, their focus is put on counting on members with high BIM education, regardless if they are new or old members of the project team. According to Protocol Sticklers, the fact of collaborating with BIM-experienced personnel facilitates the engagement of the rest of the project team. Furthermore, these preferences show a clear difference in responses from members of the other perspectives, and thus, they are part of the distinguishing statements list shown in Table 5-3. Some of the most relevant comments regarding their viewpoint are presented next:

"*Maybe some really qualified people should lead the implementation of BIM, but everybody should be taken on board, making them all aware of the new rules."* Participant #7

"*BIM modelers must understand the difference between a BIM model and simply a 3D model.*" Participant #9

Moreover, another unique characteristic of this group is the agreement they show towards the relatively low importance of giving open access to the models to all actors (St 8; Z-scr=-1.08). For example, Respondent #13 states that even though it is important to have open access to models, they should not be open to every actor, but only for representatives of each involved organization. By doing so, the communication is not chaotic, having to attend to everyone's opinion, but only to representatives of a certain actor after an internal discussion. Another aspect considered of low importance to this group is the use of BIM collaboration to have materials delivered in time by suppliers (St 11; Z-scr=-1.30). One of the reasons presented by respondents, is that good managerial practices should make sure materials are delivered at the proper time, but not the other way around, this means that focusing on this issue will not have a relevant influence on the way that the management of a project is performed.

Table 5-3 Distinguishing statements for factor 1

	Factor 1		Factor 2		Factor 3	
No. Statement	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**
5 Create a BIM policy and protocols for the organization	3	2.58**	2	1.18	-3	-1.93
20 Provide BIM trainings to existing personnel	2	1.66**	0	0.05	0	-0.26
22 Recruit BIM qualified staff	2	1.25**	0	-0.35	-2	-1.35
17 Perform constant monitoring through the use of BIM	1	1.18*	-1	-0.72	0	0.38
14 Obtain the right information at the right time	1	0.82**	0	-0.13	-1	-0.73
28 Use learnings from previous experiences with BIM in future	1	0.74*	-1	-0.44	0	-0.12
23 Redistribute job responsibilities creating new BIM roles	0	-0.00**	-2	-1.32	-1	-1.31
18 Prevent on-site clashes and waste activities	-1	-0.63**	1	0.63	3	1.93
6 Create as-built renders contribution involved parties	-1	-0.93**	-2	-1.92	1	0.76
8 Enable open access to BIM models to receive feedback	-2	-1.08**	2	1.32	1	0.85
11 Have building materials delivered just in time by suppliers	-2	-1.30*	-3	-2.17	-1	-0.49

To summarize this group, their main concern is put on the development of BIM policies and protocols to follow along the project to facilitate collaboration, and therefore, facilitate effective management of projects. Furthermore, as a support to this believe, they prioritize continuous education of personnel to ensure they follow the protocols, and by doing so, ease collaboration among different disciplines and/or organizations. A complete look on the average Q-sort for the protocol stickler perspective is shown in Figure 0-2.

5.2.2 Perspective 2, Team-oriented

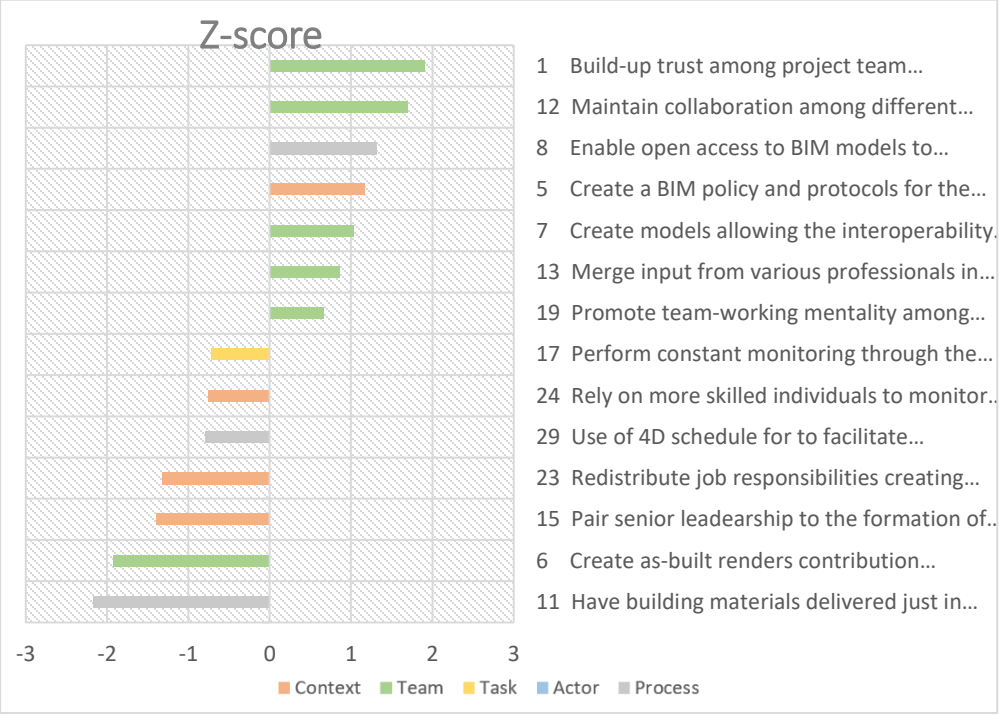

Figure 5-3 Z-scores of the most and least important statements for Factor 2

This perspective is shown in this research by five respondents, represented by three people working in an engineering organization and two for a contractor organization. Additionally, their positions are also balanced between Project Managers (n=1), BIM Managers (n=3) and Information Manager (n=1). Nevertheless, the main difference is at the experience they present. In this aspect, every member with this perspective has had at least 5 years working experience as well as BIM experience.

What characterizes this perspective is their feeling towards the importance of good human relations among members of a project team, and thus, the perspective has been named "team-oriented". As shown in Figure 5-3, the highest ranked statement of this factor is to build-up trust among team members (St 1; Z-scr=1.91), which at the same time, is a distinguishing statement for this perspective as shown in Table 5-4. Thus, this perspective prioritizes focusing on personal aspects, that will lead to better collaborative practices among well trusted members. Furthermore, this description of the perspective is supported by the high importance shown towards the fact of enabling open access to BIM models for all project actors (St 8; Z-scr=1.32) or promoting team-working mentality in the project (St 19; Z-scr=0.67). this perspective also has shown to perceive high importance in respect to the use of BIM protocols (St 5; Z-scr=1.18), but the main difference with the "Protocol Sticklers" is that this is not seen as the main goal, but more of a nice way to support team-members to collaborate easier. Comments made by respondents supporting the description of their viewpoints are shown next:

"*Good collaboration is based on trust among team members and trust in the model itself*"
Participant #12

"*It is important that everyone in the project team has open access to the models, so they can see what they need as well as obtaining constructive feedback*" Participant #8

"Getting staff to collaborate with each other is very important. Is good to avoid people working on their own, which has shown that things just don't get done" Participant #11

Additionally, this perspective presents a low belief on the importance of the creation of as-built renders (St 6; Z-scr=-1.92) to manage a project effectively. In their opinion, this has no influence on the way a project is managed, especially before the maintenance phase. This opinion supports the team-oriented perspective, since respondents with this perspective focus more on the good practice of personal aspects, than in technical products to facilitate effective management.

"I think as-built renders is just a nice to have, and it usually depends on what the client decides to do with the BIM model, especially if they plan to do maintenance based on BIM" Participant 10

Table 5-4 Distinguishing statements for factor 2

	Factor 1		Factor 2		Factor 3	
No. Statement	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**
1 Build-up trust among project team members	-1	-0.72	3	1.91**	-1	-0.96
5 Create a BIM policy and protocols for the organization	3	2.58	2	1.18**	-3	-1.93
10 Have good relationship between roles of PM and BIM manager	0	-0.59	1	0.64**	-1	-0.47
18 Prevent on-site clashes and waste activities	-1	-0.63	1	0.63**	3	1.93
22 Recruit BIM qualified staff	2	1.25	0	-0.35**	-2	-1.35
17 Perform constant monitoring through the use of BIM	1	1.18	-1	-0.72**	0	0.38
6 Create as-built renders contribution involved parties	-1	-0.93	-2	-1.92**	1	0.76
11 Have building materials delivered just in time by suppliers	-2	-1.3	-3	-2.17**	-1	-0.49

In summary, the team-oriented perspective believes that the most important aspect to focus on to enhance the management of projects, is in personal relations that should be based on trust among members. Furthermore, despite a few similarities shown with the "Protocol Sticklers" perspective, its difference is well supported by the big score divergence among the most relevant statements for each category (e.g. 1, 8, 20 and 22). A complete look on the average Q-sort for the team-oriented perspective is shown in Figure 0-3.

5.2.3 Perspective 3, Task-oriented

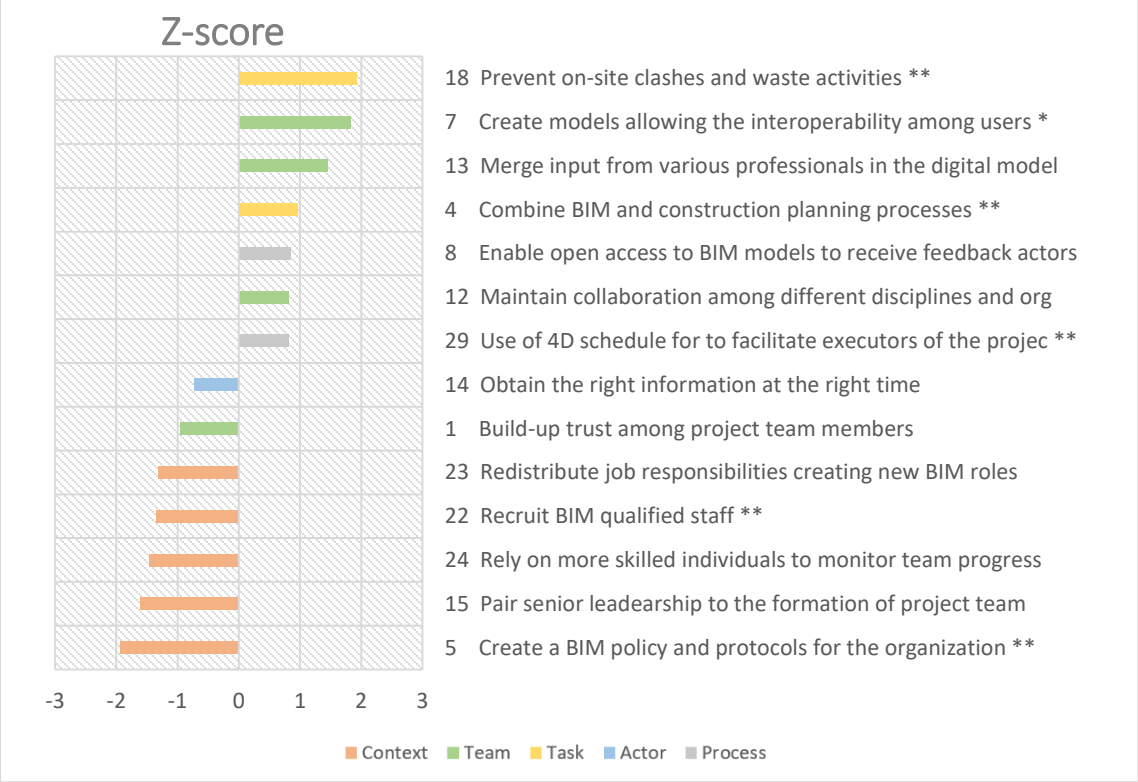

Figure 5-4 Z-scores of the most and least important statements for Factor 3

Finally, the last identified perspective is supported by the lowest number of respondents, composed by 2 Project Managers and 1 Information Manager. Furthermore, an important characteristic of this perspective is that includes the only 2 representatives of an owner organization, which is important to consider regarding their choices. Regarding their experiences, it is also balanced with working experience ranging from 2 to 35 years and BIM experience from 0 to 7 years.

Members with this perspective show a perceived high importance for more practical aspects during the execution of the construction project. For example, the highest ranked statement of this factor is the prevention of on-site clashes and waste tasks (St 18; Z-scr+1.93) as shown in Figure 5-4. Therefore, the focus of this perspective is put on the smooth execution of projects, where the plans accurately predict reality, with the help of BIM models (St 4; Z-scr=0.96) to prevent cost overruns or time delays. Another relevant characteristic of this perspective, is the perceived importance shown to the creation of models that allow interoperability among users (St 7; Z-scr=1.83), making sure that all involved actors can make use of the information when needed. Therefore, based on the previously mentioned high-ranked statements, which also belong to the more distinguishing statements (Table 5-5), this identified perspective has been labeled as "task-oriented". The most relevant comments made by members of this perspective are presented below:

"When you don't use a tool like BIM, most of the times it happens that you realize that some supplies don't match with what it was planned, already at site. That costs a lot of time, a lot of frustration and a lot of money." Participant #14

"*I think that interoperability is one of the main causes for design errors and communication problems within different disciplines*" Participant #1

"BIM is a good tool to visualize the construction process as a project manager, and to interact with the contractor" Participant #5

One of the most interesting aspects of this identified perspective is the radical different opinion regarding the topics that respondents with the other two perspectives ranked as quite high in importance to facilitate effective management. For example, they considered the creation of BIM protocols and policies (St 5; Z-scr=-1.93) as of little help. This ranking largely contrasts with the one assigned by the "Protocol Sticklers" perspective, which assumes to be the most important contributor. Another relevant difference can be seen regarding the trust that should be built-up among team members, contrasting the most relevant characteristic of the "team-oriented" perspective. The following comment exposes the different ways of thinking.

"*I cannot think of the usefulness of a protocol for a small construction company, maybe for an engineering or architecture organization this will be necessary*" Participant #14

Table 5-5 Distinguishing statements for factor 3

	Factor 1		Factor 2		Factor 3	
No. Statement	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**
18 Prevent on-site clashes and waste activities	-1	-0.63	1	0.63	3	1.93**
7 Create models allowing the interoperability among users	1	0.61	1	1.03	2	1.83*
4 Combine BIM and construction planning processes	0	-0.57	-1	-0.65	2	0.96**
29 Use of 4D schedule for to facilitate executors of the project	-1	-0.71	-1	-0.8	1	0.82**
6 Create as-built renders contribution involved parties	-1	-0.93	-2	-1.92	1	0.76**
17 Perform constant monitoring through the use of BIM	1	1.18	-1	-0.72	0	0.38*
11 Have building materials delivered just in time by suppliers	-2	-1.30	-3	-2.17	-1	-0.49*
22 Recruit BIM qualified staff	2	1.25	0	-0.35	-2	-1.35**
5 Create a BIM policy and protocols for the organization	3	2.58	2	1.18	-3	-1.93**

The overall analysis of this identified perspective towards the importance of BIM based collaboration contribution to construction project management, is that the perspective has shown to be the one that differs the most when compared with the other two previously presented. Their focus is more directed towards the contribution that BIM collaboration brings in terms of proper predictions and compliance to the planned budget, schedule and quality. In other words, they consider most important to focus on the outcomes that collaboration through BIM brings. A complete look on the average Q-sort for the task-oriented perspective is shown in Figure 0-4Figure 0-3. The similarities that each perspective presents are explained in the following section.

5.3 Similarities between identified perspective

After presenting the characteristics of each perspective, some commonalities found in the identified perspectives are presented. A list of consensus statements obtained during the analysis performed with PQ Method 2.35, is analyzed. The list includes all the statements that do not distinguish between any pair of factors and is presented in Table 0-6, Appendix E. However, even though the list includes 10 statements, only those that are ranked positively or negatively high are considered as relevant in the following analysis, since the distribution selected for the Q-study was designed to focus on the statements located in the edges of the sorting scheme.

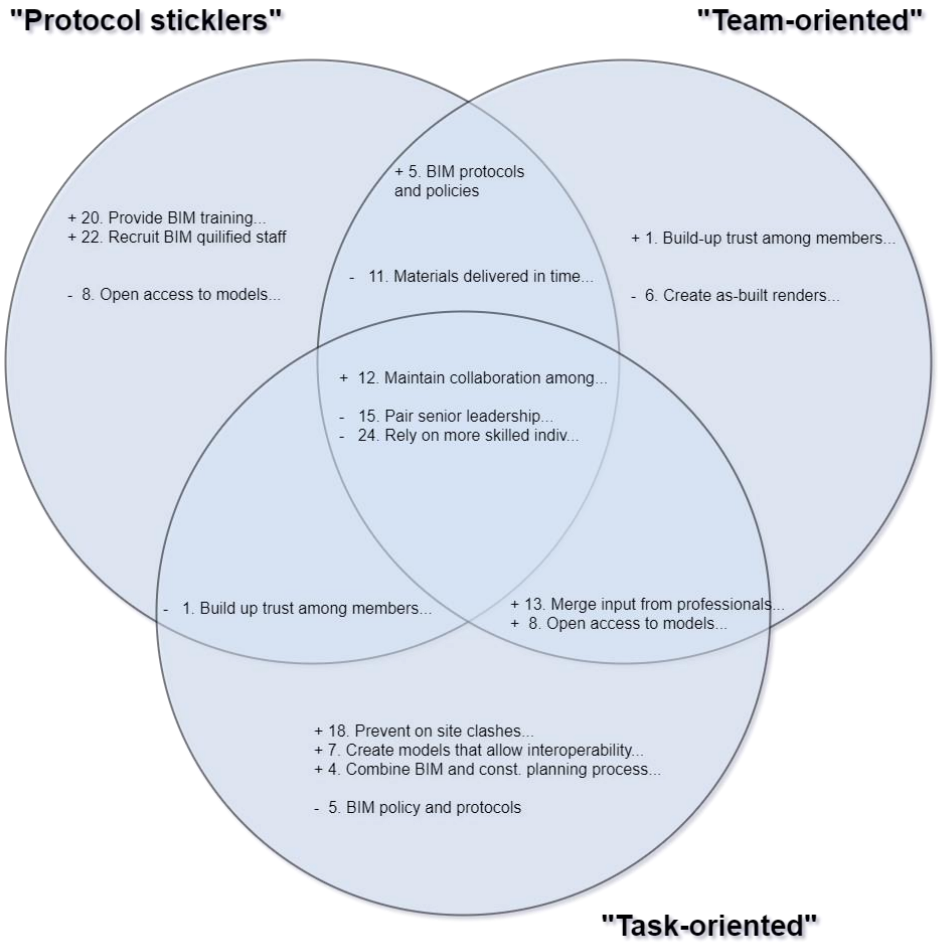

Figure 5-5 Similarities and differences between perspectives

Figure 5-5 shows the statements that characterize each of the identified perspectives, as well as the similarities between two or three of them. First, is shown in the center of the figure that every perspective has ranked relatively similar about the high importance of maintaining good collaboration practices among different disciplines (St 12). Another common point of view is the low importance shown to the inclusion of senior leadership in the formation of teams (St 15) and the reliance of more skilled individuals to monitor team progress (St 24). Therefore, these aspects have not been considered within the distinctive characteristics of neither of the perspectives, but they are important to consider as a common ground since they were ranked similarly high or low regardless of the perspective members present.

Furthermore, an important aspect is the similar ranking given to certain statements by two perspectives, while the other perspective significantly differs in the importance given to the same statement. These statements are those located in the connection between two perspectives as shown in Figure 5-5, and their differences are presented as follows:

- **Statement 1**.- While the importance of building-up trust among project team members is considered the most important for the "team-oriented" perspective, "protocol sticklers" and "tasks-oriented" rank it similarly as being of low importance.
- **Statement 8**.- The fact of enabling open access to the models for all involved actors in the project seems like an important contribution to good management practices for "teams and task-oriented" perspectives. However, according to "protocol sticklers", this could generate conflicts due to an unorganized way of communication and difficult to control, therefore they consider this contribution of low importance.
- **Statement 5**.- The importance of creating BIM protocols and policies is definitely the highest presented by "protocol sticklers", while the "team-oriented" perspective also ranks this statement relatively high, but the most interesting difference regarding this statement is the low importance given for this aspect by the "task-oriented" perspective.

To finalize this analysis, the statements situated in only one of the perspectives in Figure 5-5 are those that characterize each perspective and they have been thoroughly discussed in the previous section about the interpretation of perspectives. The rest of statements of the Q-set have been left out of the figure due to their neutral Z-score as shown in Table 0-5.

5.4 Wrap-up of identified perspectives

This chapter shows the performance of Q-study, which has identified three different perspectives between a group of 14 respondents from the AEC industry; The Q-sort from one participant has not been considered for further analysis due to its low loading factor. The selection of the perspectives is based on principal component analysis with a Varimax rotation. Then, a description of each one of the perspectives has been presented:

Protocols Sticklers (N=6). This perspective is represented by six respondents divided equally between PM and BIM managers. They show a perceived high importance to the creation of protocols and policies to follow during the project, supported by training personal and recruitment of qualified staff to meet the main objective of compliance to protocols to facilitate effective management.

Team-oriented (N=5). Five respondents with a similar perspective on the high importance of human relations and team-work mentality in order to achieve effective management of construction projects. This perspective is comprised of somewhat more experienced people than Protocols Sticklers, and balanced distribution between PM and BIM managers.

Task-oriented (N=3). The perspective with the smaller number of participants is comprised by 2 representatives from owner organizations, and 1 from an engineering organization, with experience ranging from 2 to 35 years. The main characteristic of this perspective is their focus on the BIM activities that will enhance collaboration among project team members, and therefore improving the results obtained throughout the execution of projects, like the prevention of clashes, waste of time, materials among others. Another relevant aspect is their low belief in the importance of policies and protocols, which clearly differentiates them from Protocol Sticklers.

The characteristics of each perspective present several differences. However, they all agree on the high importance of maintaining good collaboration practices among different disciplines and organizations (St.12) as represented in the center of Figure 5-5. This is important, because it shows that even though project team members differ in their preferences about what is more important to achieve effective management practices, they might be open to implement other aspects to promote collaboration if the overall result will help to achieve their project goals.

6. Discussion

This section starts by presenting a comparison between the perspectives shown by project team members with respect to the importance of BIM collaboration to enhance Management of Project practices, and what is already addressed about this topic by the Construction Extension to the PMBOK Guide. Then, an analysis of this comparison is presented, in which, a proposal for the inclusion of team member's viewpoint in the guide is suggested. Finally, this chapter ends with a discussion held with experts on the field of management of construction projects, where the aforementioned proposal was discussed to have their opinion about the validity as well as obtain suggestions on how to improve the proposal.

6.1 Comparison of Perspectives vs PMI Construction Guide

Once the different perspectives have been identified in the previous chapter, the most relevant aspects considered of high and low importance from members of each perspective, are compared to what is mentioned about it in the latest version of the Construction Extension to the PMBOK Guide issued by the PMI. The objective of doing this comparison is to address the aspects that are already stated in order to reinforce the concepts if necessary, or use them to promote collaboration in BIM-based projects, as well as to identify what aspects considered as important or less important according to project team members are missing in this guide. This comparison of the findings of the current research with the guide, will be the basis for proposing suggestions that should be included in a guide or standard in order to promote good collaboration practices in BIM-based construction projects.

In order to perform this comparison, first the *Construction Extension to the PMBOK Guide* was analyzed to identify which part of the book covers the aspect of collaboration with BIM. During this analysis, it was identified that not specific body of knowledge focusses on collaboration specifically, but instead, it is briefly mentioned in some sections of the guide. This lack of specific body of knowledge is also addressed in studies related to a global analysis of BIM (Zhao, 2017). Therefore, the words "collaboration", "collaborate", "collaborative" and "BIM" were used to identify what is mentioned about the topic in the guide. These words were spotted in different bodies of knowledge of the guide and then compared to the most relevant aspects according to each perspective. This comparison is presented as follows:

6.1.1 Protocol stickler in the PMBOK

The two highest ranked statements by members of the protocol stickler perspective are analyzed in the guide in order to verify its coverage (St.5 and St.20). Additionally, the lowest ranked statement is also considered for this analysis, however, since this statement (St.15) is considered as of low importance by the three identified perspectives (Table 0-6) it will be analyzed separately, and the following lowest ranked statement is considered within this perspective (St.11).

BIM policy and protocols. - First, in the Project Integration Management BOK it is mentioned that the reliance on contractual documents to perform inspection and reporting tasks, helps to create a collaborative environment. Subsequently, this helps to avoid conflicts in interpretations among different parties that could lead to improper performance or unresolved issues. However, this topic is briefly mentioned in the guide, and no mention it is made about the collaboration aspects that should drive the

creation of protocols to integrate the needs presented by the involved parties. Moreover, the Project Communication Management BOK suggests the use of communication protocols to be created during the planning phase of a project as an effective management practice. Furthermore, the use of technology is suggested as a good way to facilitate communication speed which could be very useful at the moment of making important decisions. BIM is mentioned as a helpful technology which could offer a common single platform where all the information is stored, but this aspect is not suggested in the guide to be included in the protocols. Additionally, no attention is paid to the integral creation of protocols in order to facilitate further collaboration between the people who is going to make use of them.

BIM training for personnel. - Regarding the aspect of considering trainings to existing personnel, the Project Integration Management body of knowledge highlights the importance of having a clear project strategy which includes the proper provision for human resources to allow the required performance by project team members. This suggestion could be interpreted as educational resources to train the personnel and keep them updated with the advances of technology, nevertheless this is not specifically mentioned in this section of the guide. Moreover, the Stakeholder Management section suggests the performance of continuous workshops to understand and resolve views and opinions among stakeholders. This suggestion could be a contribution to trainings for team members, to include more opinions in order to resolve issues.

Delivery of materials in time. - The Project Resource Management body of knowledge cover this topic by suggesting coordination for delivery of materials and general resources. However, the guide suggests that the coordination should start at the moment when the resources are delivered to the project job site, which disagrees with the statement that suggests that the coordination should start in an earlier stage, together with the supplier based on the execution plans created with the help of BIM.

6.1.2 Team-Oriented in the PMBOK

From the Team-Oriented perspective, the top two highest ranked statements as important enablers of effective management practices are considered for the analysis in the PMBOK Guide, since statement #12 is considered of high importance by all the perspectives, its analysis is performed separately and the following ranked statement is included in this section (St.1 and St.8). Additionally, the lowest ranked statement in this perspective was analyzed in the previous sub-section, therefore the following lowest ranked statement is analyzed (St.6).

Build-up trust. - The highest ranked statement in this perspective is to build-up trust among project team members, and this topic is covered by the Integration Management section of the guide, suggesting a technique known as “Partnering, which strives to create an environment of trust, respect, accountability and commitment among project team members, through the performance of follow-up meetings to avoid confrontational environment. The Communication Management section also refers to this aspect, highlighting the potential adversarial relationship that could be encountered in construction projects, and therefore, suggests the creation of an open communication culture along the execution of a project to avoid conflicts. On the other hand, the Stakeholder Management section suggests the promotion of personal connections to enhance collaboration among team members. In general, the topic of building up trust is well covered along the guide in different sections.

Open access to models. - Another aspect considered as important for this perspective is allowing open access to the models among the team members. This topic is covered by the guide in the Project Stakeholder Management body of knowledge by the suggestion of a list of actions to manage the engagement of different stakeholders, which includes the consultation of all the stakeholders whom should be heard during the process.

Create as-built renders collaboratively. – This topic is addressed by the Project Integration Management body of knowledge which mentions the elimination of tedious methods of as-built creation by a constant update of the BIM model in a collaborative way, with the contribution from actors from every discipline involved in the project.

6.1.3 Task-Oriented in the PMBOK

The two highest ranked statements by members of the task-oriented perspective are analyzed in the PMBOK Guide (St.18 and St.7). Additionally, the lowest ranked statement that has not yet been analyzed in the previous subsections, is also considered for the analysis (St.24). The coverage of the mentioned statements is presented next.

Prevention of clashes and waste activities. – The highest ranked statement within the task-oriented perspective is covered briefly in the Project Communication Management body of knowledge of the PMBOK Guide. The importance of using BIM as a single repository of project data is addressed as an enabler to obtain better communication and collaboration among project team members by the early identification of conflicts, this would lead to minimize errors on site.

Interoperability in models. - In addition to the benefits that the use of BIM presents for construction projects, the communication management section of the guide, highlights the importance of having compatible software and interconnected platforms to allow the easy use of models from members from different teams, so in that way the information will flow from one to another very smoothly. This will facilitate the normal collaboration among different parties in a BIM-based construction project.

Skilled individuals to monitor progress. - The Integration Management section covers this topic by suggesting intermittent checks on tasks or activities to verify if the facility is working as planned and by solving minor issues before the final completion of the project. To achieve these purposes, the integration of BIM technology is addressed to help visualizing the comparison between actual project progress and 4D time schedules.

In general, the aspects highlighted by the task-oriented perspective are the least mentioned in the PMBOK Guide, and therefore, it represents a topic that could be further developed in future versions of the guide.

6.1.4 Consensus statements in the PMBOK

After analyzing the most relevant statements from each of the identified perspectives in the PMBOK Guide, it has been considered relevant to analyze those statements that have been considered of high and low importance by most of the respondents, regardless of the perspective shown. In this case, statement #12 has shown the highest rank overall, and statement #15 the lowest (see Table 0-5). Due to this reason, they have not been considered as a characteristic of any of the perspectives, and therefore, they have been analyzed separately as a common ground between the identified perspectives.

Maintain collaboration among different disciplines and organizations. – This topic is widely mentioned in the PMBOK Guide, even though no specific section is dedicated to it. First, the advancement of technology is mentioned as an opportunity to improve the communication and information workflow in construction projects between the involved parties, highlighting the influence that BIM can have in this aspect. Then, the Integration Management section suggests regular follow-up meetings to maintain a team working environment. Additionally, the Communication Management section suggests the encouragement of intergroup communication in construction projects, and even suggests the use of external services to perform this promotion if those skills are not encountered within the management team. Moreover, the Stakeholder Management section highlights the importance of maintaining good relationships between team members of any of the involved parties, as well as ensuring full involvement of key stakeholders in complex projects to work together in finding common solutions to issues presented during the planning and execution phase of a project.

Pair senior leadership to the formation of project team. – The guide suggests to pair senior leadership in early stages in the Project Procurement Management section to guide how and when procurements should be carried out. Furthermore, the topic is also mentioned in the section about management of claims. However, the focus is put on the consistent engagement of senior leadership during the project execution, allocating them the responsibility for dispute resolution and the overall team working relationships. Not specific mention is given to the inclusion of senior leadership in the formation of the team.

The coverage of the aforementioned statements in the PMBOK guide have been presented with the objective of understanding the actual state of collaborative aspects in literature regarding the management of construction projects. These findings are considered the basis to create a proposal on how to promote collaboration in BIM-based construction projects by improving existing literature.

6.2 Analysis of Comparison

As shown in the previous section, the Construction Extension of the PMBOK Guide covers some of the aspects considered by project team members as important contributors to have effective collaboration in BIM-based construction projects. Nevertheless, collaboration is intermittently addressed throughout the different bodies of knowledge. In this research, the concept suggested by several researchers to provide the necessary antecedents of collaboration, and specifically those proposed by Oraee et al. (2017) has been chosen as the method on how to promote collaboration, based on its focus on BIM-based projects. Moreover, this research has discovered based on the responses from project team members, that the viewpoints in respect to what is important to consider to obtain effective collaboration have important

differences among perspectives. These identified perspectives have been linked to the aforementioned antecedents, to have a clear idea either on what do project team members already consider important so those aspects could be exploited, or what they consider to be less important, so these aspects would need more support to have the acceptance of project members, and consequently being effectively applied in construction projects.

Therefore, before the proposal on how to engage people with different perspectives is discussed, it is recommended to perform a thorough analysis of the project team members. This analysis should be performed by the entity in charge of creating the team, and could make use the perspectives identified in this research to determine to which of them each member feels more identified to. Nevertheless, due to the complex nature of construction projects, in case this analysis is not possible to be performed prior to creation of the team, it is still recommended to analyze the perspectives shown by members of the already assembled team. The aim of this analysis, is to identify the different perspectives shown by team members to have a global picture of how the project team is composed. In this research, Q-methodology has been used in order to discover the perspectives, but after they have been discovered, a different methodology should be used in practice to identify the perspective shown by each team member. Consequently, after understanding the perspectives shown by team members, apply the proper strategy targeting to engage those members into a collaborative environment, depending on which perspective they present.

Suggestions on how to engage team members from different perspectives.

The framework suggested to engage team members is built-up based on the commonly high perceived importance showed by the respondents to statement #12, represented by the highest average Z-score (1.38) as shown in Table 0-5 and portrayed in the center of Figure 5-5. The high importance given by respondents to maintain collaboration among different disciplines and organizations shows that participants are aware of the importance of the efforts needed to improve collaboration in BIM-based projects, and subsequently, achieve better management practices. Additionally, as detailed in the previous subsection this topic is well covered in the PMBOK Guide. Therefore, it is suggested to maintain these principles to highlight the importance of collaboration, especially in a complex industry like construction.

The next step of the framework is based on the five required antecedents for collaboration presented in chapter 3. With the objective of providing the proper environment for effective collaboration in BIM-based projects, five actions related to each antecedent are proposed, see Figure 6-1. These actions are based on the selection of statements (Q-set) that were presented to respondents, in combination with the ranking given to them by each perspective. This framework will facilitate effective collaboration and could be used in order to support a new body of knowledge in the *Construction Extension to the PMBOK Guide* related to collaboration.

Furthermore, the framework serves as a basis to guide the engagement of project team members into a collaborative environment. The use of the framework will depend on the perspective that each member has, trying to make use of their perceived importance of a certain aspect of collaboration to share with the rest of the team, as well as working on the aspects they believe to be of less importance, in order to highlight the benefits of its implementation and engage them to promote a collaborative environment.

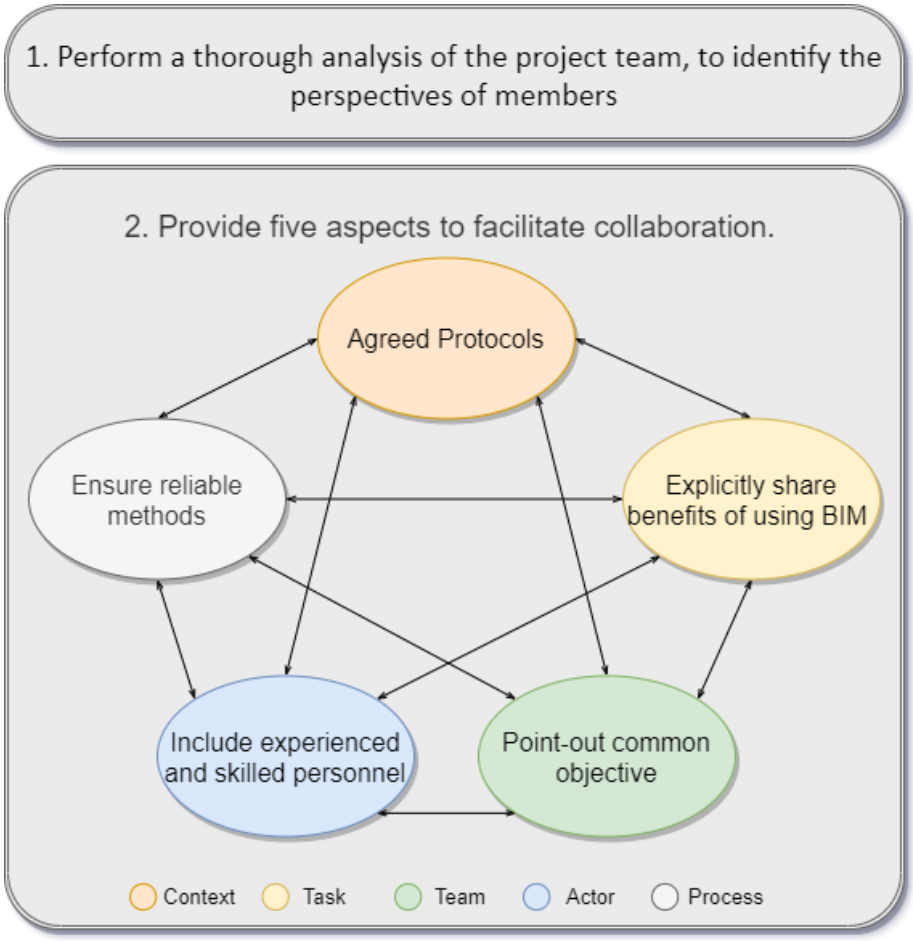

Figure 6-1 Overview of proposed framework to enhance collaboration in BIM-based projects

However, since no perspective showed a predominant preference to the importance of *actor* and *process* aspects, suggestions on how to engage team members into these aspects will be addressed generally, regardless of the perspective of project team members.

Actor antecedent. - The importance of the role of individual team members should be highlighted within a project team. This aspect is considered as an important antecedent for having effective collaboration in BIM-based construction projects because of the influence that skilled and experienced staff could have on the rest of the team, to feel confident that the use of the new technology is indeed of help when support is given from the right people. Therefore, regardless of the perspective shown by members, it is suggested to promote the inclusion of high experienced and skilled personnel to give support and confidence to the rest of the team. By implementing experienced people with high level of knowledge in specific points, and specifically regarding the use of tools and outcomes of BIM is considered an important contribution to enhance collaboration since less experienced people will rely on others in order to obtain the expected results. For example, the protocol sticklers pointed out the importance of recruiting qualified staff in the team to facilitate effective collaboration practices.

Process antecedent. - Moreover, another important aspect to facilitate collaboration in BIM-based projects is the use of the proper processes in order to perform the activities needed to achieve the project goal. Therefore, it is suggested to make sure that reliable systems and methods are provided to team members, and they should have been accepted by involved parties. Thus, all the other suggested actions can successfully be implemented during the execution of projects.

After the general suggestions presented to engage team members into a collaborative environment, the specific suggestions to engage members with certain perspectives are presented next.

6.2.1 Engaging Protocol Stickler members to a collaborative environment

The protocol sticklers are characterized for their willingness to follow protocols and contribute to persuade the rest of the team to do the same. Another characteristic is the believe that management should support constant trainings to personnel or the recruitment of high qualified staff to facilitate compliance to protocols. In accordance with this aspect, the current *PMBOK Guide* highlights the importance of clear contracts between involved parties, which should be the guide where the protocols are established. Additionally, the collaborative terms should also be included in order to prevent derailment from certain actors along the duration of the project. However, it is recommended to put more emphasis on the creation of such protocols, in order to make sure members with different preferences also comply to them satisfactorily. Therefore, the contribution from members with different perspectives in the creation of protocols should be encouraged by protocol sticklers, in order to give them a word in the protocols that would guide the rest of the project, and by doing so, ensuring their willingness to comply to the protocols and promoting the collaborative environment. Moreover, the resulting agreed-upon protocols should then be shared among all members of the project team, showing the common benefits of its use and compliance.

However, it is also important to show members with this perspective the importance of team and task aspects. Specifically, this group has shown to give little importance to the promotion of team working mentality, or to focus on building-up trust among project team members. These are considered as essential actions to ensure that members keep collaborating during the execution of the project, and therefore, strong emphasis should be put on making team members with this perspective realize of the importance of these aspects. One possible way to do so, is by showing that the compliance of protocols or contract terms, is more likely to happen if members feel confident with the rest of the team. Additionally, members with this perspective did not consider the aspects related to the BIM activities as enabler of collaboration to be of big importance, so it is accurate to acknowledge that the use of protocols are important, but its purpose is to guide the project team members to collaborate more effectively throughout the use of the agreed tools and methodologies, and therefore, the use of BIM as a support to achieve the common objectives should be encouraged within the entire team.

6.2.2 Engaging Team-Oriented members to a collaborative environment

As for the Team-Oriented members, they are more inclined to support good relationships between members built on mutual trust and respect. These topics are frequently addressed within the different bodies of knowledge of the PMBOK Guide, fostering personal connections, suggesting regular meetings or promoting open communication culture. Therefore, the guidelines are very helpful for

users to remind about good practices that will enhance collaboration among the project team. Furthermore, based on the aspects considered as important contributors to effective collaboration in BIM-based projects, it would be important to promote the trust between members by constantly pointing out the common objectives to promote a team-working mentality. Where small conflicts between members occur, especially from different organizations, can be solved more easily if members know that coming to a common agreement will contribute to help themselves and the others to achieve their individual goals. Since these members believe on the importance of these aspects, they should help to create the environment of trust and respect in the team by sharing the results they have had in previous experiences, encouraging the rest of the team to imitate them.

Additionally, one of the aspects that should be reminded to members with this perspective is the importance of setting-up the proper environment to facilitate collaboration throughout the constant training of personnel, this will help to ensure the protocols are being followed during the entire duration of the project. Even though an environment of trust is wanted, these members should be aware that the right context within the project enables a collaborative environment. Another aspect that should be treated with members of this perspective is highlighting the importance of the use of BIM as a support for activities such as planning or monitoring, because the proper use of technology aids could facilitate the communication between trusted parties.

6.2.3 Engaging Task-Oriented members to a collaborative environment

The task-oriented members give more importance to the activities performed with the help of BIM methods as a contributor to promote effective collaboration in construction projects. This topic is briefly addressed in the PMBOK Guide, for example by suggesting the use of BIM to facilitate the monitoring process of the schedule to check if the real progress is in line with the plans, or highlighting the importance of using models that allow the access of the rest of the teams to facilitate collaboration. Additionally, it is suggested to put more emphasis on highlighting the important characteristics of BIM activities that facilitate effective collaboration among all members of the team, along the different stages of a project. Members with this perspective should be put in charge of this task, since they are more confident about the usefulness of the technology as a contributor to perform better, this will show the benefits provided by the application of BIM processes, and subsequently, the rest of the team will present more willingness to collaborate with other members through the use of BIM outcomes.

However, one of the most important actions needed to engage members with this perspective is to make them aware of the importance of having clear protocols for the execution of the project. Members from this group showed reluctance to follow protocols and most of the aspects related to create a proper context that will enable collaboration. Therefore, it is suggested that these members should be involved in the elaboration of the protocols from the beginning stage, to give them a feeling of belonging to the project, and let them be part of the entire process. This will help them to realize of the importance of having a clear context to make collaboration among members more simple.

The suggested framework will help to facilitate collaboration in BIM-based construction projects, and the emphasis needed on the different points will vary, depending on the previous analysis of the perspectives shown by team members. Furthermore, the PMI after analyzing their previous works, are currently

developing some changes in their literature, due to the difficulty to read and to make the guide easier to use in real life by project managers. The main change in their document is moving from a prescriptive methodology suggesting how to do things, towards a principle-based methodology where the behavior of readers is guided by setting the parameters within which to operate. This change is considered to be aligned with the findings of this research where the collaborative principle is suggested to be included in current guides for construction project management. However, even though the draft exposed by the institution (PMI, 2020) mentions some collaborative practices among their suggested principles, no specific principle is mainly focused on this topic.

6.3 Expert Opinion

In this section, the findings of the research are discussed with experts on the field of management of construction projects. The objective is to obtain feedback about the topic under research, and the suggestions proposed in the previous subsection. Firstly, the set-up for this discussion is presented, followed by the outcomes of the discussion with experts.

6.3.1 Experts interview set-up

The opinion of experts in the field of management of construction projects is considered a relevant input to verify the validity of the proposed framework. Furthermore, the selection of professionals to be interviewed, intended to count on the opinion from a representative of construction project managers and another representative from digital managers of construction projects. Another characteristic presented by the interviewees is that they should have been performing in the industry for several years, however, in the case of the digital manager representative, since the role is quite new in the industry the required experience is set to be at least of 10 years.

The interview consists of two parts. The first part starts with a small personal introduction of the interviewee to discuss about the projects they have been involved in, as well as their educational background. After this introduction, a brief description of the objectives and methodology of the research is presented, followed by some general questions regarding collaboration aspects in the construction industry as well as the contribution of a management guide or standard to collaboration in a project. The second part of the interview starts with the presentation of the proposed framework based on the findings of the research, see Figure 6-1, followed by questions to obtain their opinion about its validity and usefulness. Finally, the interview finishes discussing general opinions regarding the research and its utility. The questions presented to interviewees are the following:

Part 1.

1) How important do you consider collaboration in the management of construction projects, and how much would you focus on improving collaboration in a manager position?
2) What would you do in order to promote collaboration in a BIM-based project, and how would you engage people in the team to collaborate?
3) Do you think that the use of a guide or standard is important to promote collaboration, i.e. Would these standards be a good tool to promote collaboration?

Part 2.

4) How effective do you consider the proposed action points to promote and obtain effective collaboration?
5) Can you think of any other aspect that is missing in the action points previously presented?
6) Regarding the suggestion to consider people's perspectives prior the creation of project teams, would you consider this as an effective method to obtain effective collaboration in BIM based projects? Why?
7) Do you have any other comments regarding this research?

The interviews were performed with two experienced managers from construction companies in The Netherlands. The results are presented in the following subsections and the entire responses to the presented questions can be found in Appendix F.

6.3.2 Interview with PM expert

The first interview presents the opinion of someone who has worked in the construction industry for more than 35 years, in different construction companies in The Netherlands. Throughout his career, he has been involved in several type of engineering projects, and at his current position, has helped the company to obtain a BIM level 2 certification.

The interviewee started pointing out the importance of having good collaboration between members of a construction project. The experience from previous works has shown that without collaboration, it is the overall project which suffers the consequences. According to his opinion, the most important aspects to consider in order to promote collaboration in BIM based projects is making people aware of the benefits of having a shared platform throughout the use of BIM. This is the case, especially for people who do not necessarily need to know how to perform, but only need the outcomes of BIM processes to make important decisions, and therefore should collaborate effectively with the rest of the team. Moreover, the expert showed a strong agreement on the use of a guide or standard, as a helpful tool to promote collaboration in construction projects. In fact, a BIM execution plan has been elaborated internally within the company, and it has shown to be a strong tool to raise the willingness to collaborate between project team members.

Regarding the proposed suggestions in this research, first, the expert agrees on the evaluation of perspectives presented by project team members, highlighting the importance of understanding the team internally in order to obtain the expected outcome, which in this case is effective collaboration. For example, in the company he is currently working for, a personality test is performed to the employees throughout the use of a system called "Insights Discovery". The system categorizes each employee according to their capabilities after analyzing the answers to a set of questions. Therefore, it is mentioned that a similar test could be performed among team members or potential team members, but more focused on the perspectives shown in respect to collaboration, which could be a useful indicator of how to engage members on a collaborative environment. Furthermore, the five proposed action points were openly agreed by the interviewee, especially the creation of agreed upon protocols and the inclusion of experienced and skilled personnel. It was remarked that these practices will not only improve the collaboration, but also would have a positive impact in the confidence the team has, towards the

achievement of the general project objectives. Nevertheless, in order to maintain collaborative practices along the duration of the project, it was suggested to implement workshops on a regular basis, to verify if the communication methods are being indeed effective. This practice will highlight the importance of collaboration in a construction project team.

6.3.3 Interview with Digital PM expert

The second interview was performed with a digital PM expert and co-owner of a prestigious consultancy firm, specialized in project and process management of complex construction projects. The involvement in his current position starts after working in important project in The Netherlands and the Middle East. Furthermore, in his current position works in the integration of digital technologies like BIM, GIS and document management, to facilitate the successful management and execution of complex construction projects.

The perception of this expert in respect to the importance of collaboration in BIM based construction projects was somewhat ambiguous. On the one hand, collaboration between different disciplines is highlighted as a key factor in order to achieve the objectives of a complex project. But on the other hand, it was also mentioned that a balance should be achieved in order to not overspend time and resources trying to satisfy everyone, if it compromises the progress of a project. In addition, a positive personal experience was shared, where he managed to engage a big diverse team, comprised from different disciplines to work in a collaborative environment, where the issues for one discipline were shared among the team members to solve them together with the main project objective in mind. Moreover, positive feeling was shown towards the help that guides or standards provide, as a baseline for collaboration in BIM-based projects.

Another comment by the expert was the support to perform an analysis of the perspectives shown by the members of the project team. At his company they also perform a personality test, but many times this aspect is forgotten at the moment of start a new project, and it could be really helpful to promote collaboration within the project team. In respect to the proposed points of action, most of them were supported by the expert, especially the provision of reliable methods that enable effective collaboration, because if the methods fail, then everyone will step behind and get back to the traditional ways of performing. However, one action point that was supported with less enthusiasm was building-up the trust by pointing out the common objectives; the reason for this thought was that “even though it is important to talk about outputs, is more important to show the real outputs and work to obtain them”. Furthermore, an additional suggestion to focus on the content of contracts to include collaboration terms is considered to be of high importance, due to the legal importance of this document, and if it is not properly prepared, can be even considered as a “collaboration killer”.

6.4 Theoretical contribution and practical implication

The results of this research have identified the existence of different perspectives presented by project team members in the AEC industry in respect to the importance of BIM collaboration in effective project management. Hence, this study contributes to the existing literature regarding the implementation and benefits of using BIM technologies in construction projects, by enriching the focus put on collaboration aspects of BIM. As stated in the beginning of the research, is not sufficiently addressed in previous studies, which showed to have predominant focus on the technical aspects of the technology. The results of this research could be further used as a base to understand better the importance of the identification of different perspectives among a team, in order to elaborate more accurate theories on how to engage different type of members to collaborate and therefore contribute to improve the management of projects.

The practical implication of this research includes the possibility to use the suggested framework in order to improve collaboration practices in BIM based projects by different types of organizations, especially due to the lack of instructions in existing guides for the management of construction projects. By following the suggested framework, first an organization should verify the existence of certain perspectives within the team in order to elaborate an appropriate strategy to engage the entire team in a collaborative environment. The acknowledgement of the composition of the team in respect to which perspective each team member presents in respect to the importance given by them to certain aspects of collaboration, can influence the optimization of resources in order to obtain their expected results for the project. Additionally, as suggested in the discussion held with experts, the verification of collaboration terms in the contract could simplify further attempts to provide a collaborative environment along the development of the project, as well as the constant monitoring of the collaboration results throughout regular workshops, would help to verify that the planned collaboration is indeed effective, or on the contrary, allocate necessary resources to re-engage the team into a collaborative environment.

7. Conclusion and Recommendations

In this section, the results of the research are presented. The objectives consisted in 1) Discover the features of BIM collaboration relevant to contribute to enhance management of projects. 2) Evaluate existing guides for management of construction projects to include team member's viewpoint in respect to important contributors to effective collaboration, and 3) Contribute to existing literature about collaboration in BIM-based construction projects. First, an answer is given to the proposed sub-questions, which will subsequently lead to solve the main research question of the research "*In what way can collaboration be promoted in BIM-based construction projects to improve management practices?"* Then, the theoretical contribution as well as practical implication is presented based on the research results. Following this, recommendations for future research and limitations of the current research are exposed.

7.1 Answer to research questions

The first aim of the report is to set a strong contextual base about the topic under research. For this reason, an extensive literature review was performed to give answer to the first research question, which aims to introduce what does the term collaboration mean in the AEC industry: "*What does collaboration in Construction Project Management entail?"* The concept of collaboration seems extensively researched, and proven to be an effective practice for the success of many industries, no exception regarding the AEC industry (Bosch-Rekveldt, 2011; Shen et al., 2010; Tapscott & Williams, 2007). However, even though the definition could vary depending on the field of application, the definition suggested by Hughes et al. (2012) is considered as appropriate, because it combines the perspective from different roles in the industry. In this work, collaboration is defined as:

> "A non-adversarial team-based environment, where through the early involvement of key members and the use of the correct contract, everyone understands and respects the input of others and their role and responsibilities".

Therefore, in a construction project context, the term collaboration entails the action of sharing relevant information among the key members of the project, in the correct time. This practice will facilitate the management performance, which aims for achieving the main goals of a project in time, at the expected cost and with the pretended quality. One important enabler to facilitate collaboration practices in the AEC industry is the use of BIM processes.

Furthermore, the second sub-question is aimed to provide insight about what previous studies consider to be important contributors of the use of BIM in order to be later presented to respondents. The answer to this question "*What are the features of collaboration through the use of BIM in AEC industry*?" is the result of a thorough selection of recent articles from relevant journals regarding the contribution of BIM collaboration to the management of construction projects. Then, the most relevant statements from this list of 11 articles were extracted. The final result was a list of 29 statements remarking the most important features of using BIM as a collaboration process to facilitate effective management practices, see Table 4-3 Final Q-set. Moreover, all the statements were categorized according to the feature to which it relates. A total list of 12 features were identified and grouped according to the five most important antecedents

suggested to be considered in order to allow effective collaboration in BIM-based projects (Oraee et al., 2017). The features of collaboration through the use of BIM processes are summarized in Figure 7-1.

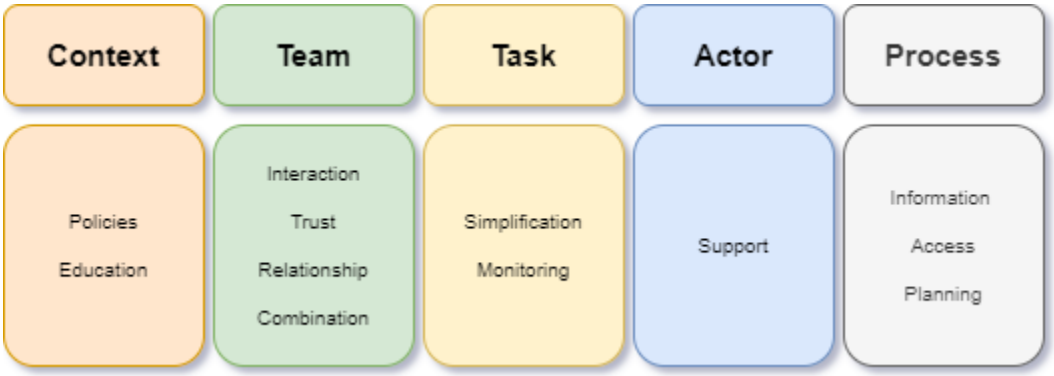

Figure 7-1 Overview of features of collaboration through the use of BIM

After the identification of the aforementioned features, they were presented and discussed with project team members currently working in the AEC industry throughout the use of Q-methodology, which aims to identify different perspectives from a target group of people. The analysis of these Q-interviews led to solve the third sub question of this research: "*What perspectives do project team members have in respect to the importance of collaboration though the use of BIM, in the management of construction projects?*". The aim of this question is to understand what are most important features of BIM collaboration according to the project team members. Consequently, the Q-study identified 3 different perspectives among the 15 respondents, each one with a similar viewpoint in respect to the most important features of BIM collaboration, but different to the choices made by the other two. The main distinction and characteristics of the identified perspectives are:

Protocols Sticklers (N=6). This perspective is composed of 6 respondents divided equally between PM and BIM managers. They show a perceived high importance to the creation of protocols and policies to follow during the project, supported by training personal and recruitment of qualified staff to meet the main objective of compliance to protocols to facilitate effective management.

Team-oriented (N=5). Other 5 respondents showed a similar perspective on the high importance of human relations and team-work mentality in order to achieve effective management of construction projects. This perspective is comprised of somewhat more experienced people than Protocols Sticklers, and it presents a balanced distribution between PM and BIM managers.

Task-oriented (N=3). The last perspective is represented by 2 representatives from owner type of organizations, and 1 from an engineering organization, with experience ranging from 2 to 35 years. The main characteristic of this perspective is their focus on the BIM activities that will enhance collaboration among project team members, and therefore improving the results obtained throughout the execution of projects, like the prevention of clashes, waste of time or materials among others. Another relevant aspect is their low belief in the importance of policies and protocols, which clearly differentiates them from Protocol Sticklers.

After identifying the different perspectives, their viewpoints about the most important collaboration aspects to contribute to effective management practices are analyzed in existing management guides, this research focused particularly in the guide provided by the PMI due to the wide acceptance shown internationally. The comparison between the high ranked features and the what is addressed about them gives answer to the fourth sub question: "*How are the most relevant features according to each perspective addressed in existing guides for the management of construction project?*". The result of this comparison showed that even though some of the analyzed features are briefly covered by the bodies of knowledge, more emphasis should be put on the collaboration aspects itself. Especially because some of the aspects considered of high importance by the project team members, are not mentioned in the guide. Moreover, it is considered important to highlight that the features considered as important by the Task-oriented perspective are the least covered by the guide, and therefore, they need extra attention in order to facilitate effective collaboration.

Finally, based on the results obtained throughout the development of the research, the answer to the sub questions build up the solution to the main research question:

In what way can collaboration be promoted in BIM-based construction projects to improve management of projects?

In order to answer this question, the first relevant aspect identified is the diversity that project team members present in regard to the importance of the influence of different features of collaboration to affect the effectiveness of management practices. Thus, the three perspectives identified in this research represent the focus that each member would put in the development of a project, in order to promote collaboration. However, focusing only on what is considered as important to them, might conflict with the rest of the team members and endanger collaboration. Therefore, it is concluded that a thorough analysis of the project team should be performed, in order to understand how the team is composed, and by doing so, preparing the proper strategy that will attend the needs presented by the team, as well as exploiting the opportunities to take advantage of counting on members with certain perspective.

Furthermore, it is concluded that the strategy adopted to engage team members in a collaborative environment, should consider five interrelated aspects. These main aspects are: Creation of agreed-upon protocols, explicitly share benefits of BIM use, point-out common objectives, include experienced and skilled personnel in the team and ensure reliable methods to communicate. However, the composition of the team in terms of the perspectives shown by team members, will guide the emphasis that should be put in each aspect in order to engage members with different perspectives into a collaborative environment.

In addition, after the discussion held with two experts in the management of construction projects about the proposed framework, it is confirmed that the inclusion of such a framework in a guide or standard could be of big help as a tool for project managers to focus on the promotion of collaboration among the team members, which subsequently will help them to achieve the objectives of the project. However, two important recommendations were given to improve the proposed framework. Thus, they should be implemented along with the proposed framework, as a contributor to promote collaborative practices.

The two suggested aspects by the experts are considered to improve the framework, and therefore are implemented as a following step. These recommendations states as follows:

- Implement collaboration workshops on a regular basis
- Include collaboration terms in contract documents.

7.2 Recommendations

After analyzing the results obtained in this research, the following recommendations are given for future research as well as for professionals in the field of construction management.

- After analyzing the current guide for the management of construction projects by the PMI, it is recommended that more explicit knowledge about the importance of BIM collaboration should be addressed. The development of a specific body of knowledge focused on this topic could be a useful guide that serves professionals involved the field, to know what aspects should be considered in order to promote collaboration among their projects, as well as to know how to achieve the expected level of collaboration.
- An important recommendation for future research in the topic, is to analyze the interaction between members with different perspectives within a team, in order to verify certain compatibility or incompatibility among members. This could improve the strategy executed by managers to engage team members in a collaborative environment.
- Another recommendation for future research is the further analysis of each perspective identified in this study. A deeper understanding of the way that a member of a project team with a defined perspective collaborates, could build a strong basis on how to promote collaboration among members with different perspectives.
- The results of this research did not find a perspective that believes that the influence of process and actor aspects are the most important contributors to obtain effective results in the management of construction projects. Therefore, further analysis could be performed to either confirm or contradict the findings of this research.
- The importance of collaboration aspects in the development of construction projects is proven to be of high influence on the achievement of the project goals. Therefore, it is recommended for professionals in the AEC industry to read the most updated literature regarding this topic, even if it is not specifically included in management guides, in order to facilitate collaboration among project team members

7.3 Limitations

It is also important to mention the limitations which have restricted this research. The main limitations are: The amount of participants to perform the Q-study, the focus on the guide provided by PMI and not in other international guides, and the location where the research was conducted.

The amount of participants (N=15) in the Q-study, complies with the number suggested by experts in the use of this methodology. However, a bigger number of participants could have led to a more accurate definition and description of the identified perspectives. Moreover, some of the characteristics presented

by the respondents could have be attributed to certain perspective. However, due to the limited amount of participants, no assumptions or generalization can be made out of the respondent's characteristics.

Another limitation of this research, is the consideration of a unique guide (PMI) to analyze the inclusion of BIM collaboration aspects considered as important by team members. The selection of this guide above others in the market was based on the international relevance of the institution. However, the analysis of different guides is not considered of less importance, and therefore, it could enrich the knowledge on what aspects should be considered to ensure collaborative practices in construction projects.

Furthermore, the research has been performed in The Netherlands, which according to the comment of one interviewee is a very collaboration supportive country. Thus, all the responses might be biased by a very collaborative environment, where the respondents interact in their regular operations. Perhaps, realizing this study in different locations, where collaboration is not a supported practice among project team members, could result in different conclusions.

Reflection

During the last few months, I have dedicated myself to the execution of this graduation research project with the help from my graduation committee, friends and family. After finalizing this stage, I feel satisfied with the results obtained, and mainly with the knowledge obtained throughout all the articles read, interviews performed and feedback obtained.

The process started by looking for topics related to what would I like to do in my future career, and there is where Information technology, and specifically BIM came into play. I strongly believe in the help of technology and in the constant update needed by professionals to keep improving the performance of daily activities. In my particular case, I related all this help of technology to the usefulness that could have had during my five years of construction experience after obtaining my Civil Engineering title. It was exactly what I expected to feel when I decided to pause my professional career to give a step forward into the academic world, and get familiar with the latest updates in the construction industry. I am sure that this research project has clearly showed me the importance of linking academic findings with my future professional career.

After of months dedicated to this research, I am more aware about the importance of collaborating in the AEC industry, and I think it is important that every project should ensure the necessary means to allow effective collaboration. I was positively surprised by the wide acceptance to participate in this research from people in the industry, and during the interviews I realized that the reason was because of their interest on this topic. It was very satisfactory to have the input from various professionals and confirm the relevance of the research.

One of the toughest part of the process was the development of a framework to suggest how to engage people with different perspectives into a collaborative environment. However, after analyzing the results of my research and discussing with different people, I feel proud and satisfied with the outcome presented in this research. I recognize that my personal time restriction was a limitation to perform a deeper analysis of the results, and sometimes I was too critical to myself, but on the other hand, it has been a difficult time with social distancing and adapting to a new way of working.

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Appendices

Appendix A: Participants of the Q-interviews

Table 0-1 List of Participants

#	Code	Organization	Type of organization	Position	Working Experience	BIM experience
1	ENG2PI3	Witteveen+Bos	Engineering / Consultant	Project Information Manager	2	3
2	ENG7PI1	Witteveen+Bos	Engineering / Consultant	Project Information Manager	7	1
3	CON10BM9	BAM International	Contractor	BIM Manager	10	9
4	DEV2PM2	EDGE (former OVG Real Estate)	Developer	Project Manager	2	2
5	OWN5PM7	NewCold	Developer	Project Manager	5	7
6	ENG6PM6	NACO - Royal Haskoning	Designer / Engineer	Project Manager	6	6
7	ENG4PM3	Stadium Consultancy	Designer / Engineer	Project Manager	4	3
8	ENG10PI7	Witteveen+Bos	Engineering / Consultant	Project Information Manager	10	7
9	ENG10BM6	Witteveen+Bos	Engineering / Consultant	BIM Manager	10	6
10	ENG6BM6	Sweco	Designer / Engineer	BIM Manager	6	6
11	CON11BM7	BAM contractors	Contractor	BIM Manager	11	7
12	CON7BM5	Besix Nederland	Contractor	BIM Manager	7	5
13	CON9BM7	BAM International	Contractor	BIM Manager	9	7
14	OWN35PM0	NewCold	Owner	Project Manager	35	0
15	CON7PM2	Royal Haskoning	Designer / Engineer	Project Manager	7	2

Appendix B: Q-concourse

Table 0-2 Q-Concourse (Draft list of statements)

	Statements regarding collaboration through BIM	Becerik-Gerber (2012)	Du (2020)	Ghaffarianhoseini (2017)	Heigermoser (2019)	Liu (2017)	Oraee (2017)	Oraee (2019)	Ozohorn (2016)	Singh (2011)	Wang (2017)	Zou (2017)
1	BIM allows input from various professionals to come together in the model			x								
2	BIM allows joint risk management											x
3	BIM enables accurate comparison of different design options			x								
4	BIM eradicates unforeseen modifications			x								
5	BIM facilitates collaboration among geographically dispersed teams	x										
6	BIM helps to coordinate activities, which help to prevent delays on the project			x								
7	BIM helps to prevent high costs overruns			x								
8	BIM increase the chances of getting quality right at the first time				x							
9	BIM is used for executing tasks more efficiently					x						
10	BIM offers the right information at the right time							x				
11	BIM prevents on site clashes			x								
12	BIM professionals need operation objectives to guardiancy their BIM utility										x	
13	BIM should be considered as a collaborative platform for different disciplines					x						
14	BIM technologies provide optimized platforms for effective project management			x								
15	BIM tools should be simple to use							x				
16	BIM tools should be used to in-depth communication instead of only for information exchange					x						
17	BIM use promotes team integration	x										
18	BIM utilization requires work process reform and redistribution of job responsibilities										x	
19	Building materials can be delivered by providers just in time			x								
20	Communication of planned work to a variety of audiences			x								
21	Constantly check on digital models to facilitate construction of complex design concepts			x								
22	Coordination and cooperation among project parties to avoid misunderstandings								x			

23	Creation of as-built renders with contribution of all of the involved parties in construction			x								
24	Creation of execution focused teams									x		
25	Creation of new BIM related roles							x				
26	Day to day management of processes			x								
27	Ease of information exchange outside closer group		x									
28	Educate more experienced professionals on BIM					x						
29	Education on BIM collaboration							x				
30	Elaborate a BIM policy for the company								x			
31	Encourage digital representation of models to transfer information easier			x								
32	Establish modeling protocols that eases remote collaboration	x										
33	Fast and effective communication of information		x									
34	Good relationship between roles of PM and BIM manager							x				
35	Integration of tasks like estimating, scheduling and spatial coordination	x										
36	Maintain collaboration among different disciplines						x					
37	Maintain collaboration among different organizations						x					
38	Maintain collaboration remotely						x					
39	Management by objective coming from common goals and responsibilities of team members										x	
40	Management focused on minimizing waste activities thorough the help of BIM				x							
41	Management of collaboration through different methods than BIM							x				
42	Model creation and sharing management to ease the interoperability among users					x						
43	Monitoring and assessment through the use of BIM			x								
44	More effort should be allocated to BIM education	x										
45	Multiple parties contribute to a centralized model									x		
46	Multi-user viewing of merged or separate multi-discipline models				x							
47	Necessity of coupling BIM planning and construction planning process.				x							
48	New roles and relationships emerge to manage collaboration between team members									x		
49	Online communication of product and process information				x							
50	Open access to BIM models, to obtain more feedback from project participants					x						
51	Open and honest communication					x						
52	Perform quality control of separate areas of the construction			x								

53	Physical meetings between personnel from different parties to increase trust					x						
54	Project data is shared across involved organizations							x				
55	Promote share team responsibility										x	
56	Promotion of team-working mentality							x				
57	Rely on more skilled individuals to monitor the team progress	x										
58	Retrofit planning including learnings from past experiences			x								
59	Senior leadership pair to the formation of project team								x			
60	Share BIM models with resource providers to facilitate pre-fabricated elements.			x								
61	Skills and abilities to use BIM							x				
62	Standard processes and agreed protocols are required to passing responsibilities									x		
63	Support from senior management to implement BIM								x			
64	Task allocation should consider individual's skills	x										
65	Technological support for collaboration							x				
66	The administration team and project teams are trained									x		
67	The use of BIM bring places together, reducing time waste.		x									
68	The use of BIM creates a more efficient process of construction projects				x							
69	Third party as a leader to better deal with conflicts					x						
70	Top management should be careful in recruiting qualified staff								x			
71	Top management support by providing necessary resources										x	
72	Training employees on BIM implementation								x			
73	Trainings to existing personnel to enhance BIM knowledge					x						
74	Trust should be developed among project team members					x						
75	Use BIM to coordinate procurement processes during design and construction			x								
76	Use learnings of previous experiences with BIM								x			
77	Use of 4D schedule for simplified comprehension of executors of the project			x								
78	Use of guidelines and standards for BIM collaboration							x				

Appendix C: Shared platform for Q-interview

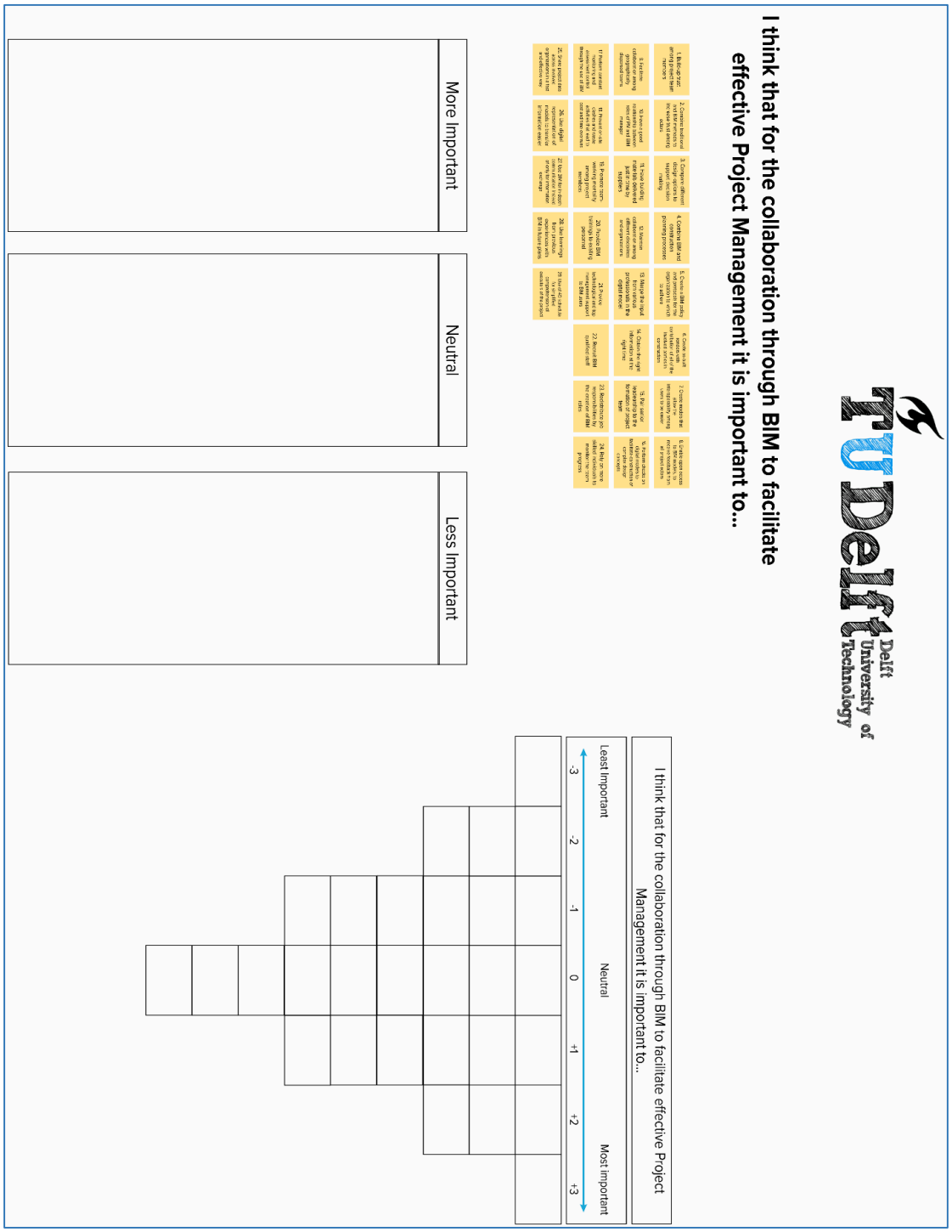

Figure 0-1 Q-interview workspace

Appendix D: Q-Interview Form

Thank you for your contribution to this research about the perspectives of project team members towards the importance of collaboration through BIM in the construction industry. In order to get a better picture of what the directly involved actors consider relevant about the influence of BIM on the management of construction projects, Q methodology is applied. This methodology is designed to obtain personal viewpoints by prioritizing and distributing certain factors in a predefined sorting format. The collected data will be treated anonymously, and no further contact will be linked to participants of this interview.

Before the beginning of the Q study, please fill in some general information regarding your current work and background:

- Organization: _____
- Type of organization: (Contractor / Owner/ Designer / Engineer / Other) _____
- Your position: _____
- Years of experience: _____
- Degree of education: _____
- Experience with BIM (years): _____
- Feeling towards use of BIM: (Positive / Negative) _____

Q-sorting instructions:

In order to start with the sorting procedure, please follow the next steps:

1. Click on the link provided at the beginning of the interview.
2. You will find a shared digital board; in which you can identify 29 sticky notes including statements regarding the use of BIM on construction projects. You can zoom in and out to facilitate reading.
3. Then, proceed to read the statements as a continuation of the following sentence: "I think that for the collaboration through BIM to facilitate effective Project Management it is important to…".
4. While reading these statements, you will distribute them by click and drag them into 3 stacks depending on your opinion: 1) More important, 2) Less important or 3) Neutral.
5. Once all the sticky notes have been sorted in the correspondent stacks, you should start with the list of "More important" statements. Pick the statement that in your opinion is the most important among this stack, click and drag it to the sorting scheme (Figure 1) in the box underneath the "+3" column on your right.
6. Then, choose the second most important statement and place it underneath the "+2" column. Do the same with all of the statements of the stack (the order in the column does not matter).
7. Repeat steps 5 and 6 for the "Less important" stack, starting from the "Least important" (-3) and finally the same with the "Neutral" stack until the sorting scheme is full.

Note: The sorting process will be performed during a videoconference with the interviewer, who is going to be there to attend any questions you might have.

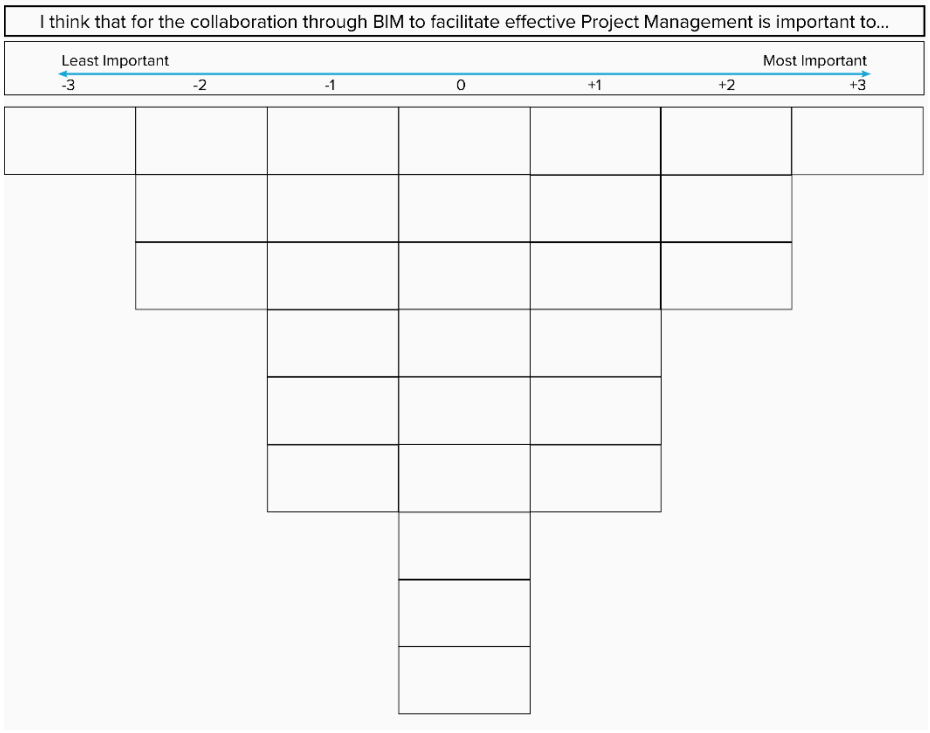

Figure 1 Sorting Scheme

After the sorting procedure, the following questions will be asked:

- Can you elaborate on why did you choose the statements in '+3', '+2' and '-3' boxes?
- How satisfied are you in your day to day experience, regarding the statement positioned in '+3' box?
- Besides the statements presented, can you think of any other collaborative action that enhances management of construction projects?
- If so, where would you have placed it in the previous sorting scheme?

Thank you for your time and cooperation. It is important to state that the interviews will be recorded only for collection of data purposes. After the interview, transcripts will be extracted into a text file to be used anonymously in the research, and then the recordings will be deleted.

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Appendix E: Data of Q-methodology analysis

Table 0-3 Statement Correlation Matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	100	7	-26	-4	33	37	0	41	-6	7	30	-22	-6	**67**	31
2	7	100	28	13	6	35	-15	2	-6	2	15	6	28	20	-6
3	-26	28	100	37	7	**43**	20	6	**43**	**44**	35	**46**	37	-24	22
4	-4	13	37	100	-7	28	31	17	39	30	19	13	22	-13	28
5	33	6	7	-7	100	22	22	11	4	9	7	2	15	39	22
6	37	35	**43**	28	22	100	13	**43**	39	**59**	**54**	39	26	37	**43**
7	0	-15	20	31	22	13	100	13	37	24	2	15	39	-15	**43**
8	41	2	6	17	11	**43**	13	100	28	33	**50**	**46**	-7	22	31
9	-6	-6	**43**	39	4	39	37	28	100	31	15	33	**52**	-19	26
10	7	2	**44**	30	9	**59**	24	33	31	100	39	**59**	31	17	**50**
11	30	15	35	19	7	54	2	**50**	15	39	100	**48**	-4	20	31
12	-22	6	**46**	13	2	39	15	**46**	33	**59**	**48**	100	7	-15	33
13	-6	28	37	22	15	26	39	-7	**52**	31	-4	7	100	-4	30
14	**67**	20	-24	-13	39	37	-15	22	-19	17	20	-15	-4	100	30
15	31	-6	22	28	22	**43**	**43**	31	26	**50**	31	33	30	30	100

Table 0-4 Factor loading per potential solution

	2-FACTOR SOLUTION		**3-FACTOR SOLUTION**			**4FACTOR SOLUTION**				**5-FACTOR SOLUTION**				
Q-SORT	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	-0.30	**0.80**	-0.14	0.20	**0.85**	-0.13	0.18	**0.86**	-0.04	0.01	0.06	**0.92**	-0.01	0.04
2	0.11	0.22	0.05	0.21	0.11	0.00	0.03	0.12	**0.88**	-0.07	0.04	0.11	**0.89**	-0.03
3	**0.77**	0.00	**0.52**	0.47	-0.33	**0.51**	0.39	-0.31	0.46	0.37	**0.49**	-0.38	0.46	0.02
4	**0.57**	0.04	**0.51**	0.25	-0.12	**0.52**	0.23	-0.10	0.11	**0.56**	0.15	0.05	0.18	-0.58
5	-0.03	0.47	0.24	0.00	**0.60**	0.23	-0.04	**0.60**	0.03	0.22	0.06	0.35	0.06	**0.70**
6	**0.48**	**0.68**	0.30	**0.71**	0.34	0.30	**0.61**	0.37	0.40	0.27	**0.61**	0.37	0.42	0.01
7	**0.51**	0.04	**0.73**	-0.04	0.11	**0.75**	0.00	0.11	-0.34	**0.78**	0.05	-0.01	-0.26	0.11
8	0.25	**0.61**	-0.03	**0.69**	0.24	0.01	**0.73**	0.27	-0.19	0.06	**0.64**	0.43	-0.19	-0.23
9	**0.72**	0.04	**0.69**	0.27	-0.12	**0.70**	0.26	-0.11	-0.01	**0.69**	0.28	-0.11	0.06	-0.20
10	**0.63**	0.42	0.40	**0.66**	0.06	0.43	**0.64**	0.09	0.08	0.35	**0.70**	0.03	0.09	0.14
11	0.34	**0.58**	-0.06	**0.81**	0.11	-0.03	**0.79**	0.15	0.16	-0.06	**0.75**	0.26	0.13	-0.14
12	**0.65**	0.20	0.18	**0.76**	-0.32	0.22	**0.78**	-0.28	0.01	0.09	**0.87**	-0.30	-0.03	0.08
13	**0.56**	0.01	**0.80**	-0.05	0.08	**0.77**	-0.15	0.09	0.35	**0.72**	-0.05	-0.10	0.42	0.20
14	-0.35	**0.79**	-0.19	0.18	**0.84**	-0.20	0.12	**0.85**	0.17	-0.13	0.08	**0.81**	0.18	0.31
15	0.43	**0.54**	**0.48**	0.39	0.40	**0.50**	0.40	0.42	-0.18	**0.53**	0.42	0.35	-0.13	0.17

Table 0-5 Statements score and ranking per factor

NO.	STATEMENT	FACTOR 1		FACTOR 2		FACTOR 3		AVERAGE	
		Z-scr	Rank	Z-scr	Rank	Z-scr	Rank	Z-scr	Rank
1	Build-up trust among project team members	-0.72	23	1.91	1	-0.96	24	0.17	12
2	Combine traditional and BIM methods to increase trust	-0.87	24	0.17	13	-0.47	21	-0.41	23
3	Compare design options to support decision making	-0.47	17	-0.05	15	-0.15	17	-0.25	21
4	Combine BIM and construction planning processes	-0.57	18	-0.65	22	0.96	4	-0.27	22
5	Create a BIM policy and protocols for the organization	2.58	1	1.18	4	-1.93	29	1.11	2
6	Create as-built renders contribution involved parties	-0.93	25	-1.92	28	0.76	8	-0.92	26
7	Create models allowing the interoperability among user	0.61	8	1.03	5	1.83	2	1.02	3
8	Enable open access to BIM models to receive feedback a	-1.08	26	1.32	3	0.85	5	0.19	10
9	Facilitate collaboration geographically dispersed team	-0.14	15	-0.35	20	0.12	14	-0.16	20
10	Have good relationship between roles of PM and BIM man	-0.59	19	0.64	8	-0.47	21	-0.13	19
11	Have building materials delivered just in time by sup	-1.30	28	-2.17	29	-0.49	22	-1.44	28
12	Maintain collaboration among different disciplines and	1.40	3	1.70	2	0.82	7	1.38	1
13	Merge input from various professionals in the digital	0.43	10	0.86	6	1.46	3	0.80	4
14	Obtain the right information at the right time	0.82	6	-0.13	16	-0.73	23	0.15	13
15	Pair senior leadership to the formation of project team	-1.63	29	-1.40	27	-1.60	28	-1.54	29
16	Perform checks digital models to ease complex construct	0.28	11	0.55	10	0.61	9	0.45	7
17	Perform constant monitoring through the use of BIM	1.18	5	-0.72	23	0.38	11	0.33	9
18	Prevent on-site clashes and waste activities	-0.63	21	0.63	9	1.93	1	0.37	8
19	Promote team-working mentality among project members	-0.59	20	0.67	7	0.03	15	-0.01	16
20	Provide BIM trainings to existing personnel	1.66	2	0.05	14	-0.26	18	0.67	5
21	Give technological and top management support to BIM u	0.10	12	-0.14	17	-0.35	19	-0.08	18
22	Recruit BIM qualified staff	1.25	4	-0.35	19	-1.35	26	0.12	15
23	Redistribute job responsibilities creating new BIM roles	0.00	14	-1.32	26	-1.31	25	-0.75	25
24	Rely on more skilled individuals to monitor team progr.	-1.27	27	-0.75	24	-1.46	27	-1.13	27
25	Share project data across involved organizations fast	0.60	9	0.40	11	0.35	13	0.48	6
26	Use digital models to transfer information easier	-0.22	16	-0.14	18	0.38	11	-0.06	17
27	Use BIM for in-depth communication	0.07	13	0.22	12	0.35	13	0.18	11
28	Use learnings from previous experiences with BIM	0.74	7	-0.44	21	-0.12	16	0.13	14
29	Use of 4D schedule for to facilitate executors of the	-0.71	22	-0.80	25	0.82	7	-0.41	24

Table 0-6 Consensus Statements

No. Statement	Factor 1		Factor 2		Factor 3	
	Q-SV	**Z-SCR**	**Q-SV**	**Z-SCR**	**Q-SV**	**Z-SCR**
3 Compare design options to support decision making*	0	-0.47	0	-0.05	0	-0.15
9 Facilitate collaboration geographically dispersed teams*	0	-0.14	-1	-0.35	0	0.12
12 Maintain collaboration among different disciplines and org	**2**	**1.40**	**2**	**1.70**	**1**	**0.82**
15* Pair senior leadership to the formation of project team	**-3**	**-1.63**	**-2**	**-1.40**	**-2**	**-1.60**
16 Perform checks digital models to ease complex construction*	0	0.28	1	0.55	1	0.61
21 Give technological and top management support to BIM users*	0	0.10	0	-0.14	0	-0.35
24 Rely on more skilled individuals to monitor team progress	**-2**	**-1.27**	**-1**	**-0.75**	**-2**	**-1.46**
25 Share project data across involved organizations fast*	1	0.60	0	0.40	0	0.35
26 Use digital models to transfer information easier*	0	-0.22	0	-0.14	0	0.38
27 Use BIM for in-depth communication*	0	0.07	0	0.22	0	0.35

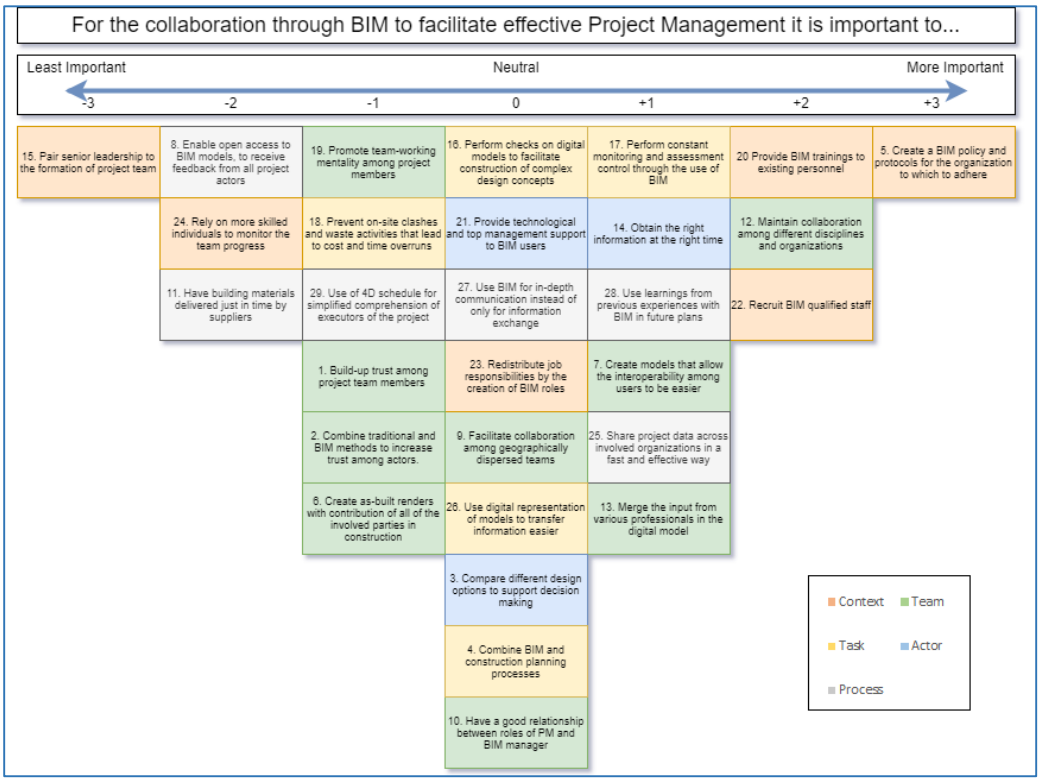

Figure 0-2 Average Q-sort, Protocol Stickler perspective

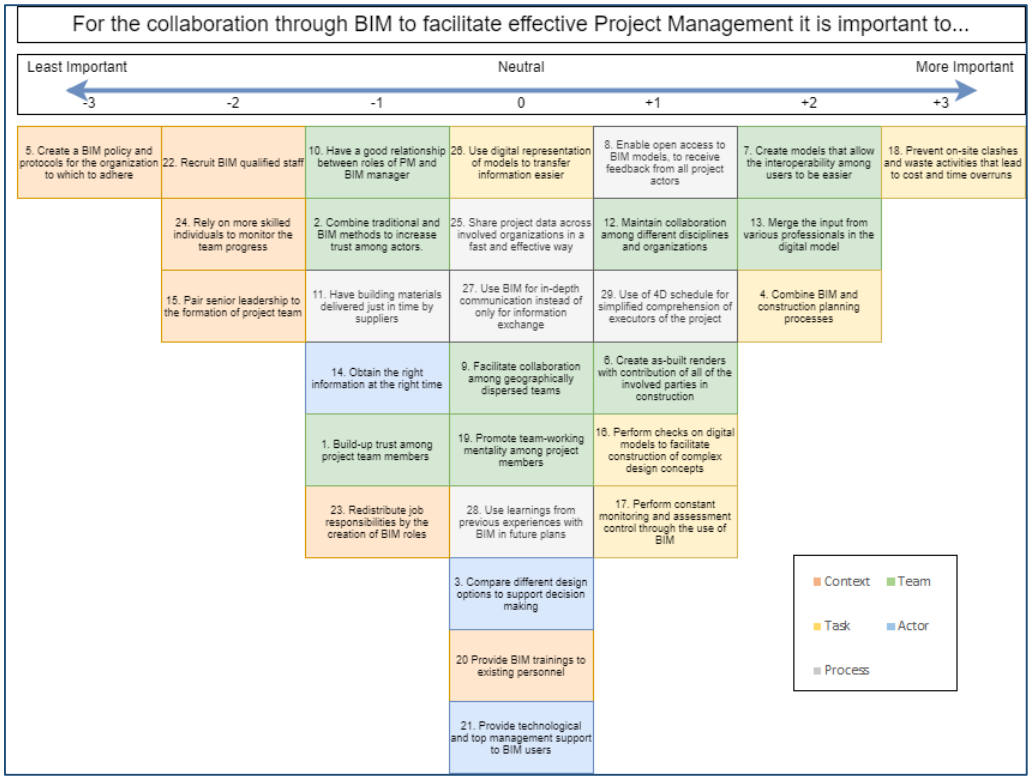

Figure 0-3 Average Q-sort, Task-oriented perspective

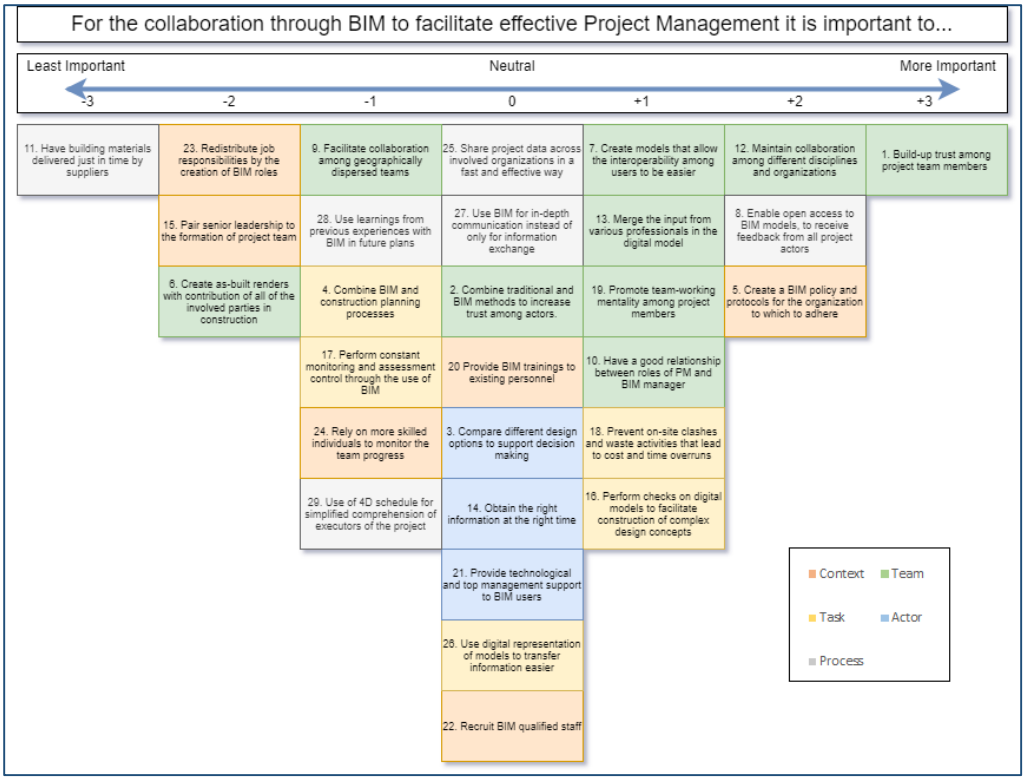

Figure 0-4 Average Q-sort, Task-oriented perspective

Appendix F: Transcript of expert interviews

Expert Interview #1

Education: Graduated 1983, Civil Engineer, TU Delft.

Position: Manager design & engineering

Experience: Worked in several companies, public and private. First with an engineering consultant, 16 years Hollandsche Beton Groep (HBG). 17 years at Shell, on worldwide projects; in technical insurance and engineering management for the earthquake issues in the north of Holland. Currently working in BAM International. In total more than 35 years of experience in civil engineering projects. And in his current work the company managed to get a BIM level 2 certification.

1. **How important do you consider collaboration in the management of construction projects, and how much would you focus on improving collaboration in a manager position?**

Is one of the more important things in my opinion the collaboration among different people and different disciplines, because you work together in the project. I have seen organizations where there was a lot of collaboration, and on the other hand I have also seen projects where there were a lot of people working in silos with little collaboration. Therefore, I think collaboration is a key for the performance of the project, and not only between technical people but also with commercial and other people, because they contribute with knowledge about what is important and what should be considered along the project, and that will help to achieve the common objectives. That will allow not only to focus in making money in a project but also success in terms of safety, taking care of the environment. Working together with team members with effective collaboration is essential, otherwise the project will suffer. If you have collaboration is a very important starting point for a good performance.

2. **What would you do in order to promote collaboration in a BIM-based project, and how would you engage people in the team to collaborate?**

One of the most important things there is to have good awareness of all the people in the project, what it really means to work with BIM, and show them what it really means to have one common platform where everything is connected and storage, and what the benefits are of having this platform and also how people can have access to the models. It is important and we have seen in our own company, that especially for people who have not been educated with BIM and especially Project Managers who are more experienced people but not aware of what does BIM means and the benefits of using BIM, that is also important not only to communicate in a digital way, but also to have conversations looking at the model together. Especially in the industry is quite traditional, where people have been doing this job without the use of BIM, so you have to make clear to them that the use of BIM is an extra tool that can be used to avoid a lot of problems during construction. In resume, awareness and good examples of the benefits of BIM is key aspect to promote collaboration, then they will see that it is important that everybody has the same view on the model and pushes them to collaborate more.

3. **Do you think that the use of a Guide or standard is important to promote collaboration, i.e. Would these standards be a good tool to promote collaboration?**

Yes, certainly. A BIM execution plan will show to all the people involved how BIM will be executed in the project and that will not only help them to collaborate but also help them to improve their awareness and what the role of BIM is on the project. Certainly a guideline, a document which tell them how BIM is used along the project, will help them to collaborate even more. In our company, we have to have a BIM execution plan for a project in order to be ISO certified. This execution plan in principle tells all people in the project how BIM is used, so it is kind of a plan to tell everybody what to do, sort of a manual that assign tasks and responsibilities to all actors. Consequently, this plan indeed promotes collaboration because it makes everyone be focused on the same end result. So it is not necessary an enabler to promote collaboration but it is definitely a supporter of collaboration since it makes everybody understand easier through the use of same language, same model, the level of detail you want you achieve. So it will definitely support collaboration.

4. **How effective do you consider the proposed action points to promote and obtain effective collaboration?**

All of the 5 suggestions are in fact good project management practices. If you would like to work together using BIM then of course is really important that everyone in the team talk in the same language, which is based in agreed protocols among the involved people. The other aspect of course is that if you have dedicated people, who knows a lot about a certain subject, that will give a lot of confidence and that will also increase collaboration, allowing people who have questions or doubts to speak up to experts and rely on their expertise. As I said, I think all of the suggested aspects will not only improve collaboration, but also the confidence that you will achieve the general project objectives. That is really important, because when you are in a project, you will like to have a good project performance in terms of earn some money, complete it in time among others. The more collaboration you have among the team members, the better the chances you have to achieve your objectives. I think that the suggestions presented will effectively contribute to have better collaboration in a project team, but I also think that next to them, it is important to keep the communication going, in order to check all the time if people is aligned to the common objectives. For example, people who is working daily with BIM models have no issues, but others like the project, designer or construction manager, only need to know what is important for them out of the information provided by BIM, so you have to check that they are making in fact good use of the outcomes of the technology.

5. **Can you think of any other aspect that is missing in the action points previously presented?**

Well I think it is covering most of the aspects. However, perhaps the performance of workshops in a regular basis between managers and people working constantly in the BIM models. In there, all the people working on BIM can talk about their work, but also the managers can talk about what kind of questions or issues they have. Perhaps is good to suggest to have these good communication sessions through 1 or 2 hour workshops perhaps once a month. Overall the presented suggestions have all the necessary ingredients to enhance collaboration practices, and if you add workshops, you will contribute to the awareness and keeping track of the effective collaboration practices along the duration of the project.

6. **Regarding the suggestion to consider people's perspectives prior the creation of project teams, would you consider this as an effective method to obtain effective collaboration in BIM based projects? Why?**

I think is a good solution. There is a system that classify personalities assigning them colors of red, yellow, blue and green. Blue is very technical, red is very stirring people who like to give directions, green people would like to get instructions, and yellow would like to discuss about issues and come up with all kind of new ideas. Is always good to have a mix of characters in a team. I think is quite ideal to have a wide variety of people, for example in a technical company, you would see that a lot of people is blue and red, but you would also like to include curious people that asks many questions with different backgrounds, and that will benefit the team with new ideas. The manager should always be someone capable of taking decisions and asking the right questions to the people to find out if the common decision is indeed the best one for the project.

Within our company we use a system called Insights Discovery, which is a system where you discover through several questions how your personal profile is build up. It is a very good tool, and when you use it with a lot of people, you can see how can you contribute to each other to improve collaboration. For example, when you do this analysis with a team, you can see how can you match the team such that you have in each of the direction some people, because if you only have directors type personality, that will raise conflicts, but if in the other hand you have a balanced team, members can contribute to, and learn from each other.

7. **Do you have any other comments regarding this research?**

I think that collaboration is a very important topic, and especially on how can project managers can collaborate with the use of BIM. In projects there is a lot of team work, and BIM can improve that. What we have seen in our company is that when you introduce BIM practices, you improve collaboration because you have only one platform where the models are stored and people start discussing with each other while using the same model more easily than without BIM. Especially now that we have to work from home, it is good to have one central part in the project where all the people are connected.

Expert Interview #2

Education: Civil Engineer and Bachelor in Business Administration.

Position: Digital Project Manager / Co-owner

Experience: 12 years of experience, currently working in integrating digital technologies of BIM, GIS and document management in construction projects, both responsible of the organizational level and the application of it in current projects. Most of his work have been in different roles of construction firms internationally, working for a few years in the Middle East and then worked for one of the largest contractor firms of The Netherlands, before joining Count & Cooper for his current position.

1. **How important do you consider collaboration in the management of construction projects, and how much would you focus on improving collaboration in a manager position?**

I would say collaboration is a key factor to consider, without it I think it would be very hard to realize your objectives in a complex task like construction project. The focus on collaboration however, is quite hard to find the proper balance in terms of when are we focusing on collaboration and when are we focusing in actually progressing ahead. In Holland usually collaboration is considered as super important, but

sometimes goes a bit far in terms that everybody should know about everything and everybody should be happy with everybody, and there is when collaboration might have the side effect of not being effective. So collaboration I would say is super important, but just don't make it the main driver in everything.

The fragmentation of the construction business in terms of roles and specialties and more is very broad, so you have many actors. For example, Manager of projects and structural are two different worlds, but they are very dependent on each other. And there is no somebody who knows about everything, so you need to collaborate to get the benefit of the expertise of the other without having to know everything yourself. And based on that common knowledge you can make better decisions

2. **What would you do in order to promote collaboration in a BIM-based project, and how would you engage people in the team to collaborate?**

I have a real life example for this in a project we did in Holland. There we had a lot of people who never worked with BIM before, or some others were very skeptical. And then what we did is that we put the team altogether in one floor, all the different disciplines, and I asked them in a process point of view to work individually in their design models and to build the best model they can, not in a global perspective but as they had no clashes with other disciplines. For the next two weeks they had time to improve their individual designs without speaking with other disciplines, and then we did the bonding together in a period time of 3 weeks where we solved every single issue there is. So that is the time for issue solving. That way the team was focusing together in the issues and they all have a better understanding of the impact of some things, instead of just saying "it doesn't fit, fix it", but sitting down and solving the issues together. After this design, a very few issues arose during the construction phase, so the collaboration was very effective and positively related to the success of the project

3. **Do you think that the use of a Guide or standard is important to promote collaboration, i.e. Would these standards be a good tool to promote collaboration?**

I think it definitely helps. In my experience, when I started using BIM for example, there were no guides and that time you will be receiving all the models separately where the naming was always different so you are not really making benefits out of the models. So having standards and protocols definitely gives you a good baseline for collaboration.

4. **How effective do you consider the proposed action points to promote and obtain effective collaboration?**

- I think that doing the development of protocols with all the involved parties is very helpful, but in the real world could be quite difficult to have the contribution of all the involved parties, one because not all parties are already on board on the project at this stage, and for example the contractor might appear later on with some different needs, so I think it has its pitfalls. And secondly, because some people might have no clue about what are you talking about when asking them for an opinion on the creation of protocols, but then at least they could be aware of the protocols from the beginning.
- I think that reliable methods are the only way to effectively deliver an output, because you need to have one way that is reliable to deal with it, because if it only comes from one way and some

organizations are not used to it, then collaboration will not happen. I would consider this aspect even more important the creation of protocols

- Important, but I would say is more important to show outputs, than it is to talk about the outputs.
- I would definitely agree with highlighting the important characteristics of using BIM, because even though the benefits of BIM itself might be obvious, but is not for everybody in the supply chain a process optimization. For example, sometimes it might seem a bit slower or more expensive for some specific areas, but you will get bigger benefits in return.
- Definitely I think that promoting the inclusion of high experienced and skilled personnel is very important, because on the route to successful BIM and collaboration people face a lot of up and downs. And I think that experienced people have learned especially form the downs, and they can guide the team to not commit the same mistakes.

5. **Can you think of any other aspect that is missing in the action points previously presented?**

Contracts are really important to enable collaboration, otherwise you can talk about collaboration whatever you want but if you have a type of contract that focus on the cheapest and fastest execution, people will just follow what the contract says. In other words, contract could be collaboration killers.

In my personal experience, another important suggestion would be to be cautious with your promises to your client and trying to be as realistic as possible. BIM cannot solve all of your issues on site, so it is better to be realistic with your expectations.

6. **Regarding the suggestion to consider people's perspectives prior the creation of project teams, would you consider this as an effective method to obtain effective collaboration in BIM based projects? Why?**

I would say this should be a must to be honest, because collaboration is about people and is good to be aware of which members are you going to put on the team if you have that luxury or at least analyze what people do you already have on your team and find the way to effectively collaborate. In projects this is something that is usually skipped. In our company we do an analysis of personalities before the selection of personnel and we really focus in creating balanced teams, and from there the project manager you should get the ability to manage accordingly.

7. **Do you have any other comments regarding this research?**

I think the topic is very important, since a lot of companies are struggling with these issues, and especially I like the approach of focusing on PMI guides, because you normally see that a lot of the people who build the protocols telling you how to use BIM and such, but it usually gets forgotten to consider at a management level. I often see in real life that successful implementation BIM methodology gets understood by the technical people, but when you move a few levels higher and the project manager does not really understand the process anymore and what is going on, they will switch back to what you are used to, like "when am I getting this drawings" or this type of traditional requests, and usually that is not in line with BIM process. A BIM process is up-front a little bit slower, because it is more integrate and more complete and afterwards, answering these questions is easier. But construction is always driven by

“I want it now” or actually “I want it for yesterday” and those two worlds conflict a lot. So in resume having guides that suggest managers to consider BIM processes and how to collaborate effectively with all parties involved could be a key to successful management practices and less conflicts.