DOCTOR OF PHILOSOPHY

Critical factors to BIM team development
applying innovation, knowledge and change management perspectives

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Award date:
2020

Awarding institution:
Coventry University

Critical factors to BIM team development: applying innovation, knowledge and change management perspectives

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For the award for PhD

September 2019

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A thesis submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy (PhD)

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Ethical Approval P73060.

Ethical Approval P53162 and Ethical Approval P48040 are presented in Appendix A.

Coventry University

Certificate of Ethical Approval

Applicant:

Nada Milivojevic

Project Title:

Renewal of applications P53162 and P48040 from 2017/2018 - data analysis and writing up

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

16 September 2018

Project Reference Number:

P73060

Turnitin Report Summary

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Abstract

This study investigates the issues of team development and limited skilled human capital for the adoption of BIM technology and processes. This study explores what measures can AEC project teams adopt to achieve better use of this technology and embrace benefits. A few recent studies mention a need for change in the managerial approach or style of training, but there is little guidance that AEC organisations can adopt. The approach this study takes to investigate those issues is a combined use of principles of Innovation Management (IM), Change Management (CM) and Knowledge Management (KM). As a result, this study identifies twenty-one theoretical factors that come from these theories. As a final result of expert-elite interviews and a case study in the UK, this study identifies and discusses mechanisms to achieve those critical factors and the final list of seventeen factors that managers of AEC organisations can apply to achieve more efficient BIM team development. While the qualitative inquiry - expert interviews - findings show why some factors are essential and also show measures of achieving the critical factors; an exploratory case study further shows details of a change in one of the largest AEC organisations in the UK. This is the first study that applies principles of CM, IM and KM, shows interconnectivities between the factors as well as interconnectivities between CM, IM and KM theories. Additionally, this study shows why these principles need to be applied together to maximise the benefits. The results highlight that the best results are achieved by providing the management support, improving communication, by having social learning and experiential learning, reflection opportunities, planning as a team, clear vision and collaborative team internally and externally. The results also show the importance of engaging people to achieve BIM team development and help AEC managers to manage people's perceptions about BIM tools. Another contribution of the study is in establishing sustainable mechanisms that are not resource consuming and expensive to implement. The methodological contribution of this study is the application of Framework Analysis, that has mostly been used by other disciplines to achieve an in-depth analysis of the qualitative data. The qualitative data enabled obtaining detailed answers, explanations from experts in the field and comparing results with established theories.

Acknowledgements

I would like to express my sincere gratitude to my supervisory team at Coventry University. I would like to thank my Director of Studies Dr Abdullahi Ahmed for his support and guidance throughout the study. I would like to thank him for the excellent collaboration and all research and teaching opportunities during my study. I would also like to thank my other supervisors, Stephen Austin, Danny McGough and Dr Messaoud Saidani for the support to complete the thesis and lecturing opportunities. I would like to thank further The School of Energy, Construction and Environment and Coventry University for providing me with the full scholarship to complete the studies.

I would also like to thank my colleagues and academic staff for their further guidance, in particular Dr Andrew O. Arewa. I would like to extend my gratitude to company managers and my interview participants who provided immense support. I would like to thank them for their support, opportunity to conduct my research and for their openness and willingness to share the knowledge.

Finally, I would like to thank my family and close friends in Serbia, Italy and the UK. Their support and understanding greatly allowed me to conduct and complete the research and achieve the contributions of this thesis.

Table of contents

List of tables

List of figures

List of abbreviations

AEC - Architectural, Engineering and Construction

BIM – Building Information Modelling

CA – Content Analysis

CDE – Common Data Environment

CIMO - Context, Intervention, Mechanisms, Outcome

CM - Change Management

CMO – Context, Mechanisms, Outcome

CR – Critical Realism

DQA - Deductive Qualitative Analysis

FA – Framework Analysis

FM – Facility Management

Fn (n=1-27) – Factor n (n=1-27) (e.g. F1 – Factor 1)

GT – Grounded Theory

ICT – Information and Communication Technology

IM – Innovation Management

IPD – Integrated Project Delivery

IT – Information Technology

KM – Knowledge Management

NBS - National Building Specification

SECI - Socialisation, Externalisation, Combination, and Internalisation, four knowledge dimensions by Nonaka

SME – Small and Medium-sized Enterprises

SR – Systematic Review

TAM - Technology Acceptance Models

Chapter 1. Introduction

1.1 Research background and relevance to professional and academic field

Building Information Modelling (BIM) is a concept of enhancing cooperation and efficiency in the Architectural, Engineering and Construction (AEC) industry. Seen as a process, BIM integrates different professionals into multidisciplinary teams which creates opportunities to record, check, analyse and coordinate the knowledge of the entire team. As a concept, it has existed for the last twenty years (Arayici et al. 2011a), however, in the last few years, awareness, acceptance and research regarding BIM have rapidly increased (NBS 2016, NBS 2018, Yalcinkaya and Singh 2015). In the UK this is due to the UK government mandate for BIM Level 2 (Cabinet Office 2011), while internationally the increase has been down to similar government mandates, for example in the United States, Denmark, Korea, Singapore and other countries (Son et al. 2015, Liao and Teo 2018, Zakaria et al. 2013). The idea is that BIM can achieve a higher level of information quality and resource control for the AEC project teams, yet to achieve these benefits, there is a need to develop organisational and individual BIM skills within the AEC organisations.

Academic studies in the last couple of years have recognised many challenges that inhibit BIM adoption and BIM team development, with the strong emphasis on challenges in relation to lack of skilled professionals and practice, and inability of practice and people to adapt. According to Arayici et al. (2011a, 2011b), Azhar (2011), Azhar et al. (2015), Bataw (2013), Codinhoto et al. (2013), Zakaria et al. (2013), Ghosh et al. (2015), Ku and Taiebat (2011), Stanley and Thurnell (2014), Succar et al. (2013), Elmualim and Gilder (2014), Puolitaival and Forsythe (2016) these are:

- Lack of team integration and collaboration;
- Lack of communication;
- Industry fragmentation;
- Resistance to change and the lack of enthusiasm;
- Adapting to a learning-oriented practice; this means that people should have the ability to adapt and to be prepared for continuous learning with BIM technology;
- Lack of training and education, which includes training on processes and technology;
- Lack of skilled professionals in terms of knowledge and experience;
- Uncertainty in decision-making, such as choosing a software;
- The complexity of BIM tools which are to be learned;

- Challenges with data control,
- Lack of understanding of how to implement BIM and new practice;
- Lack of understanding regarding the value of BIM.

These challenges impact the effectiveness of BIM within the AEC projects, therefore, organisations that want to utilise BIM effectively need to find solutions for these challenges. This study investigates how to manage some of these critical challenges, particularly: building the individual and organisational knowledge – skilled human capital development, information sharing, communication, motivation and collaboration challenges to achieve BIM team development. Addressing the limited, skilled human capital, motivation, enthusiasm, information sharing, collaboration and communication is achieved in this study by implementing principles of Knowledge Management (KM), Innovation Management (IM) and Change Management (CM). KM is applied to address the lack of skilled professionals and issues with knowledge, as KM includes strategies for knowledge sharing and creation (Nonaka and Toyama 2003); while IM and CM are applied as theories that address motivation and the inability of people and practices to adapt (Goodman and Dingli 2017, Kotter 2012, Hughes 2006). This is further discussed in Sections 1.1.1, 1.1.2, 1.1.3, Chapter 2, Section 2.6 and Chapter 3, while Section 3.5 and the discussion in Chapter 7 show the impact of these theories and their interrelations.

There is a need for improvements, changes in the practice and project workflows. The change should include more communication on projects, interaction and collaboration across the AEC disciplines (Singh, Gu and Wang 2011: 135). There should also be changes in managerial styles, roles and responsibilities, team development and training to adopt BIM practice (Zakaria et al. 2013, Lindblad and Vass 2015). These suggestions have also been achieved by implementing principles of KM, IM and CM theories and this is discussed in the results of this study, Chapters 5 and 6, and compared to the existing body of literature in Chapters 7 and 8.

Further rationale for investigating BIM team development is found in the research on trends and recommendations in other academic studies. Firstly, the research of several databases by Yalcinkaya and Singh (2015) was used to understand BIM research trends and patterns. This study identifies seven studies on BIM application and adoption problems in the AEC organisations and five studies dedicated to opportunities and challenges with BIM implementation. Most of the studies are published after 2012, therefore, the field is relatively new. After an in-depth review of the mentioned papers, classified as ‘BIM implementation and adoption’ and ‘Academy and industry training’, it was found that there is a potential for improvement. There are limited studies that could be classified as literature that provide advice on BIM team development and management, such as the study by Won et al. (2013). Other studies identified by Yalcinkaya and Singh (2015) are mainly focused on technology adoption, technology requirements, cloud collaboration or topics such as Integrated Project Delivery (IPD) or lean construction. It can be observed that the number of studies dedicated to 'BIM development' in the industry is significantly lower than the number of studies dedicated to 'teaching at universities' - 46 studies, or 'analysis of adoption in industries' - 23 studies. Nevertheless, even with several studies dedicated to education and adoption, other authors such as Ghosh et al. (2015), Becerik-Gerber et al. (2011) and Lee and Dossick (2012), recognise the need for more research in the area of BIM adoption and development in general, which further justifies the direction of this study into educational and development issues of BIM.

In regard to other recommendations for the future research, the review of BIM management literature by He et al. (2017), suggests for studies related to BIM adoption to explore different styles of leadership, aspects of motivation and psychology, which this study has achieved as a result of implementing IM, KM and CM, as presented in Chapters 3, 5, 6 and 7. According to He et al. (2017), there is also a lack of studies that explore contextual factors and show how contextual factors impact BIM adoption. The value of such studies is in showing the real-life examples of management practice and mechanisms that are efficient to achieve BIM team development. Therefore, this research study investigates practical, managerial techniques that can support BIM team development.

1.1.1 Innovation Management application to address BIM team development

Innovations are significant for the development of the AEC industry (Egbu 2004) and the AEC teams need to continually grow and adapt to stay competitive (Kamara et al. 2002). BIM is an innovation that requires some changes in the current managerial practice of the AEC teams, as suggested in previous studies (Zakaria et al. 2013, Lindblad and Vass 2015, He et al. 2017). BIM also requires mechanisms to achieve greater adaptability of teams and people, which is also one of the challenges found in BIM adoption literature. While many studies already see BIM technology as an innovation, it is also Innovation Management that can provide guidance for teams to address issues of adaptability and guide the change in managerial practice. This connection and potential between BIM and Innovation Management are further explained in Chapter 3.

The current research on BIM and 'innovation', mostly explores BIM innovation diffusion in the AEC industry, such as studies by Linderoth (2010) and Singh (2014). While the main directions of these studies differ to this research study, some of the key findings were found beneficial to support this study. For example, Singh (2014) investigates the needs of actors to support BIM innovation diffusion. The other study, Linderoth (2010), provides useful insights for BIM team development. These have been incorporated in the systematic review (Chapter 2) and discussion (Chapter 7). Linderoth (2010) also makes a connection with ICT adoption literature and knowledge transfer, as this research study does. However, the main direction of Linderoth (2010) differs, as that study explores innovation diffusion, networks and the change of roles within the AEC project networks.

There are also a few other studies that contain the words 'innovation' and 'BIM' within their keywords and titles, such as Elmualim and Gilder (2014), Poirier et al. (2015c) and Murphy (2014). These studies recognise that innovation is poorly explored in the construction industry and that more research is needed to connect Innovation Management and BIM implementation. It is recommended that future research needs to deliver more empirical results (Murphy 2014 and Poirier et al. 2015a, 2015b, 2015c). It is also found that future research on BIM and IM needs to be more experiential and that there should be more case studies (Murphy 2014). It is further recommended for the future research to achieve the development of stakeholder competencies (Murphy 2014), which this research study has also achieved as one of the results.

Elmualim and Gilder (2014) explore who has an influence on BIM innovation in the team and explain that innovation is about improving the value for the client. However, this study does not consider the 'process of integrating BIM' and 'developing BIM skills' as an innovation that requires Innovation Management. Elmualim and Gilder (2014) and previous studies also do not identify the need to build a more innovative team. Instead, they treat the results of BIM technology and processes as an innovation.

Closer to the idea of this study is the study by Murphy (2014), which provides insights that BIM implementation is an Innovation Management process. However, Murphy (2014) explores different directions. This study seeks to understand the type of BIM innovation on the organisational level. It also investigates required stakeholder competencies for BIM implementation, which includes cost and programme elements, concluding that the BIM innovation "must be implemented as a stakeholder competency" (2014: 447). There are also other points that differ from this study's direction and conclusions. For example, Murphy (2014) has a perspective that BIM needs to be a radical change, while this research study, through both systematic review and study findings, explains why and how to create a gradual development of a BIM team.

Among the studies that also discuss concepts of 'innovation' and BIM is Poirier et al. (2015c). This interpretive case study of mechanical contracting Small and Medium-sized Enterprise (SME) adopting BIM, suggests future studies to investigate and explain more contextual factors that impact BIM adoption, particularly on the project and organisational levels. Poirier et al. (2015a) recognise that current studies on BIM implementation and adoption lack the context. Providing the context would enable other practitioners to understand solutions better and use the knowledge for their own needs. Being a study that explores the project-level type of innovation, as defined by Bossink (2014), this research study achieves that too. However, a difference between this study and Poirer et al. (2015a, 2015b, 2015c), is that they investigate a case study of an SME, they mostly show a few factors that were all emerging from data and they provide some insights on how the industry, organisation and project contexts are connected. This study incorporates interview findings from the experienced industry professionals and a case study, from which findings are derived by testing theoretical concepts; and the context of this research study is also different, by focusing on organisational and project contexts.

This research study also applies models of CM and KM to support IM processes, which is another distinction between other studies on BIM and IM and this research study. This is discussed in the following sections and Chapter 3. As part of the discussion, the comparison with these studies is also present in Chapter 7.

1.1.2 Knowledge challenges, KM within IM and application of Knowledge Management (KM) to BIM team development

The role of knowledge and KM for BIM team development emerged from two fundamental discussions – first on BIM challenges and second on Innovation Management. Firstly, the list of challenges in Section 1.1 identifies a number of knowledge-related challenges such as, the lack of skilled professionals and teams, issues with the knowledge transfer and education, inability to adapt to a learning-oriented practice and continuous learning, complexity of tools which impacts the education and training and the lack of understanding about the tools and processes. The investigations on IM have also shown that Knowledge Management is the central topic within IM (Kamara et al. 2002, Egbu 2004, Maqsood et al. 2007, Hidalgo and Albors 2008). KM can enhance the ability of organisations to innovate and adapt to innovations. This is further discussed in Chapter 3, Section 3.3.4. Due to this evidence, this research applies some of the key KM theories, the work of Ikujiro Nonaka, to achieve BIM team development and overcome the knowledge-related challenges.

While the literature on BIM adoption identifies the knowledge challenges that exist in the industry, there are a few studies that integrate concepts of Knowledge Management and BIM. Those studies that do, use BIM to achieve more effective KM in organisations, rather than KM to achieve more effective BIM adoption or BIM team development. One of the first studies, the work of Lin (2014), shows how BIM models can be used to share knowledge in a 3D environment. The study by Kivits and Furneaux (2013), discusses BIM as the enabler of KM, rather than KM as the enabler of BIM team development. Another study by Deshpande, Azhar and Amireddya (2014) also shows how BIM models can be used for the knowledge-storage and for improving KM processes in the organisation. There are also no academic studies that implement the work of Nonaka to achieve BIM team development, while the work of Nonaka is one of the central theories in KM.

Previously identified knowledge-related challenges and the central role of KM within IM are the foundations for KM application in this study, to achieve the BIM team development. It is also clear that the scope of BIM tools and practice is very broad and being ‘proficient in BIM’ can have multiple meanings or levels. It would be difficult for anyone to be trained in all aspects of BIM practice (Sacks and Pikas 2013). Having a great diversity within the AEC roles makes challenging for any AEC professional, involved in BIM management, to have a detailed knowledge of all aspects of BIM within design and construction processes. This is not a new issue for the AEC industry or other industries, as different roles and responsibilities, together with the lack of experience, affect not only BIM but generally the “adoption of groupware technologies” (Singh, Gu and Wang 2011: 143). For those reasons, the approach this study takes is not to focus on identifying needed competencies in the team, but instead implement theories of KM and IM that suggest principles that can create a continuous, on-going development within the team. This simultaneously helps with the investment and education issues, which are also among the key challenges to BIM adoption (Ahn et al. 2016, Dossick et al. 2010, Babič et al. 2010, Arayici et al. 2011b, Linderoth 2010, Succar and Kassem 2015). How this is achieved is discussed in Chapter 3, by presenting models of knowledge creation and the work of KM theorists, such as Nonaka and Boisot, and applying them to BIM team development context. As a result, this study can provide insights for team development for other similar technologies in the AEC industry, not only BIM.

As previously discussed in Section 1.1.1, the contextual evidence about the knowledge-related challenges and solutions is also of a high importance for a greater understanding of the BIM team development. The extent of these challenges, such as BIM training, cost challenges, lack of experience, can be different in different organisational settings, however, the mechanisms and principles that allow the team to adapt and build their knowledge are universal and shall be in accordance with KM theories. By obtaining the rich primary data, this study is then able to identify the mechanisms behind, connect and compare these with KM and other theories.

1.1.3 Issues of motivation and application of Change Management to BIM team development

Other than Knowledge and Innovation Management, Change Management (CM) is another area that can help with BIM team development in the AEC organisations. Firstly, Section 1.1 identifies several motivation-related challenges to BIM team development. There is a resistance to accept the BIM change, the lack of enthusiasm to learn about BIM tools and practice or generally to improve the existing BIM practice (Mahalingam et al. 2015, Arayici et al. 2011b, Sackey et al. 2015, Ahn et al. 2016, Won et al. 2013). The rationale behind applying CM theories is that CM addresses the resistance and lack of motivation that inhibit the adoption of any new practice or new technology (Kotter 2012, Lewin 1947, Schein 2017).

It is not clear why the resistance occurs. Often the studies on BIM challenges and BIM adoption touch upon these limitations and briefly explain that this could be due to the absence of management support and not recognising benefits (Arayici et al. 2011b, Zakaria et al. 2013), while for example, Babič et al. (2010) highlights the relation between resistance and slow business processes. It is even less clear what are the mechanisms to address the resistance. For this, a study about the adoption of BIM in the Malaysian construction industry by Zakaria et al. (2013) recommends explaining benefits of BIM practice, more education, in-house support and clarifying the roles and responsibilities. This study does not provide a discussion on CM theoretical models, but it does recognise ‘change management’ within one of its index terms. CM provides steps to address the resistance and motivation, therefore, by comparing CM theories with in-depth primary data this research study identifies gaps in BIM team development practice and mechanisms for managing the resistance. The question this study investigates is – how can people become more enthusiastic, motivated and therefore more receptive to BIM technology and processes and learning? These have been discussed within Chapters 3, 5, 6 and 7.

Searches have been made in several databases, particularly Google Scholar and EBSCO database to find other studies which integrate BIM and CM, and a particular search was '"BIM" AND "change management" OR "organisational development" OR "organisational change"'. This search was periodically repeated to find more studies. So far, there is limited research on CM and BIM in academic studies, while studies already recognise the need to manage the resistance to BIM change (Zakaria et al. 2013, Singh 2014, Elmualim and Gilder 2014). There are a few studies that discuss changes that occur in teams such as the conference proceeding by Lindblad and Vass (2015) and the conference proceeding by Gu et al. (2007), that investigate challenges of BIM change and drivers to BIM change. Recently there has been more research, a study on BIM implementation challenges for public sector clients by Vass and Gustavsson (2017) that recognises the value of CM models. Vass and Gustavsson (2017) explain that the future studies need to investigate multidisciplinary context to understand BIM implementation, and suggest a longitudinal case study. This is achieved in this research study by having both an in-depth case study and a range of interviews from different roles and organisations. Therefore, CM and BIM is an emerging topic that has great potential to be further explored.

There is a need for more studies to conduct research on CM within the AEC companies. In Lines et al. (2015) and Lines and Vardireddy (2017), it was explained that general research on CM, so far explored issues such as resistance of team members towards change and the complexity of CM, however, there is little research about the AEC companies and this topic. There is a need for more research on resistance to change and CM factors in the AEC industry (Lines et al. 2015, Lines and Vardireddy 2017).

In addition to the lack of studies on CM in the context of the AEC industry and BIM team development, a further argument for applying CM is the connection between knowledge and resistance. It was found that the lack of knowledge about BIM practice, leads to a lack of motivation to accept the BIM change (Singh et al. 2011, Azhar et al. 2015, Zakaria et al. 2013). As a result, and as well as one of the contributions, this research study has also found and explained these interconnectivities between knowledge and resistance, between KM and CM. The findings also show how applying both KM and CM together can help BIM team development process and resistance to change, which is one of the key contributions of this study.

When implementing any Information and Communication Technology (ICT), organisational, management and human issues are some of the most critical issues to address (Adriaanse et al. 2010). To achieve this, Adriaanse et al. (2010) recommend addressing motivation, people engagement and management of behaviour, which are all key components in CM (Kotter 2012). Recommendations by Peansupap and Walker (2005) and Adriaanse et al. (2010) on ICT adoption, further confirm that solutions are in enhancing collaboration, creating the same language in the team and aligning the team's needs, which are all also steps in CM models, as described in Chapter 3. Therefore, these ICT studies provide additional arguments for the application of CM to BIM team development context.

1.2 Aim and objectives

The aim of this study is to establish the critical factors for successful BIM implementation and team development processes for the AEC organisations.

By implementing principles identified within those factors, construction organisations will be able to achieve improvements in terms of their individual and team skills, particularly: the development of BIM practice, the motivation to use BIM technology and practice and the knowledge about BIM technology and processes.

To achieve the aim of the study, the following objectives are put forward:

1. To identify challenges and development strategies for BIM implementation in the AEC industry.

2. To investigate principles of Innovation Management, Knowledge Management and Change Management that can help BIM team development, within the context of the AEC project teams.

3. To establish key enabling factors for strategic planning of BIM Change Management process and team development. To critically evaluate the theoretical list of factors established.

4. To evaluate existing theories of CM, KM and IM and show how they benefit BIM team development processes.

The research objectives, connections between objectives, the research process, brief descriptions of objectives, methods and contributions of each objective are presented below in Table 1.1.

Table 1.1 Summary of research objectives, methods and their contributions

Objective	Description	Method	Contribution
1.	BIM team development strategies and challenges in the AEC industry.	• Literature review of the relevant literature for BIM team development - review of the AEC literature and management literature; • In-depth longitudinal case study; • In-depth interviews with experienced BIM industry practitioners.	Identifying the main issues to be addressed and guiding principles in management to address these challenges. In-depth understanding of challenges. In-depth understanding of solutions present in the industry.
2.	IM, KM and CM.	Literature review of management studies and studies of organisational behaviour.	Demonstrating the importance and application of these theories to achieve BIM team development.
3	Theoretical list of critical factors to contribute to BIM team development in the AEC teams. Critically evaluate the theoretical list of factors established.	Theoretical findings from Chapter 3 are summarised into 'Summary of critical factors for BIM team development' (Section 3.5). Evaluation of theoretical findings via: • In-depth longitudinal case study; • In-depth interviews with experienced BIM industry practitioners.	Developing a list of critical factors for BIM team development. Showing interconnectivities between existing theories of CM, IM and KM. The theoretical model is reformed and validated. Development of a validated list of critical factors for BIM team development. Demonstrating practical means of achieving factors – for each factor. Demonstrating guiding principles behind critical factors. In-depth information about factors and their interconnectivities.
4	Evaluate existing theories of CM, KM and IM.	Evaluation of the existing theories with primary data, for BIM team development.	Showing interconnectivities between existing theories of CM, IM and KM. Evaluation of the existing theories of CM, IM and KM.

1.3 Overview of the research process and methodology

The research philosophy of this research study is pragmatism. This study applies a qualitative inquiry and the case study research method, in accordance with pragmatism. This study includes elements of both theory-testing and theory-building. The theory-testing element involves testing the conceptual, theoretical list of factors and theory-building involves the incorporation of new, additional findings into the previously built, conceptual, theoretical list in order to revise it. The data collection methods are interviews with experienced professionals and a case study within one large AEC project team in the UK.

Firstly, there is a need to obtain a greater understanding about the extent of the industry problems, such as the lack of BIM training and initiatives (Singh, Gu and Wang 2011, Elmualim and Gilder 2014) and create a summary of challenges that exist within the AEC BIM teams. In addition, there is a need for a case study and real-life examples to further explain BIM practice and BIM innovation in the AEC organisations (Elmualim and Gilder 2014). This is because the case study data method can obtain a deeper understanding of internal processes inside one organisation. In this study, an in-depth case study investigation of a construction project team helps to understand and connect the conditions that are behind the BIM team development. According to Yin (in Ridder 2012), a longitudinal case study allows for an investigation of managerial processes and it can document a change; therefore, it fits the purpose of this study. To conduct a longitudinal, theory-guided, exploratory and explanatory case study, this study applies interviews, observations and a documentary data review. As the most abundant source of information, observations and interviews are the primary data collection to establish an understanding about the project team.

The main findings of this research study are from the expert-elite interviews. While the case study explains in detail ‘how’ and ‘why’ things occur during the BIM implementation, in-depth, semi-structured industry interviews provide a range of practical ideas to achieve better BIM team development and gather practical experiences from experts in the industry. For example, the interviews investigate how learning can be organised with internal resources and how to manage resistance to change. These topics are relevant due to the lack of skilled professionals, training, cost challenges, resistance to change and the lack of commitment identified in Section 1.1. These results validate the conceptual theoretical model – the list of theoretical critical factors – and provide new ideas to revise the model. This is presented in Chapter 6. The primary data findings are compared in Chapter 7 to KM, IM and CM principles emerging from the literature. This is an overview of the research process, while more details on the research design are presented in Chapter 4.

1.4 Overview of the thesis

This study starts with the introduction chapter, which provides the rationale behind the topic of BIM team development and application of KM, IM and CM theories. This is followed by the second chapter, which presents a systematic review of the literature on BIM implementation in organisational settings. This chapter investigates the Objective 1, which includes identifying main issues and strategies in relation to BIM team development and BIM implementation in general. The third chapter of this thesis demonstrates the application of IM, KM and CM theories for BIM team development. As a result of this discussion, Chapter 3 concludes with a conceptual list – critical factors for BIM team development. Chapter 4 then provides a detailed justification for the research approach, philosophy, strategy, design and methods applied. Chapters 5 and 6 provide the results of this research study. Chapter 5 discusses the results of the case study. The following Chapter 6 presents the key findings of the expert-elite interviews and a validation of the previously established list of critical factors as well as the comprehensive discussion of results - for each factor. Chapter 7 provides the final list of critical factors and discussion on CM, IM and KM theories, as well as some other key findings emerging from the results. The thesis concludes with Chapter 8, which summarises the research outcomes and provides limitations of the study and recommendations for the future research.

1.5 Scope of the study

Due to human-related issues, such as resistance and learning, this study's approach is to investigate the micro-level of BIM team development. The micro-level focuses on individuals and project teams of the AEC organisations. The 'BIM team development' includes all processes an AEC team can implement to achieve a greater knowledge and efficiency with BIM practice. This includes the adoption phase, implementation of BIM technology and processes and further developments. The majority of the literature so far has been focused on the adoption and implementation phase; however, many organisations in the UK have advanced their skills in the last couple of years (NBS 2018). Therefore, organisations can benefit from investigations of BIM team development more than BIM adoption only. To be able to connect with the existing literature, this study also uses the term BIM adoption where appropriate.

There is a need to go in-depth with solutions to BIM team development and discuss how practically these measures can be achieved on a micro 'project team and people level'. The studies discussed in Section 1.1 provide a wide range of research on BIM adoption challenges and some suggestions on what can be done to achieve BIM team development and adoption. However, these studies mostly address the industry or organisational levels with little practical information that can benefit project teams or individual levels. For example, Adriaanse et al. (2010) discuss aligning ICT tools with organisational needs. On the other hand, there has been little overall guidance in the literature on how to connect organisational level implementation with people and project team levels. While Hartman et al. (2012) find it important to align strategies, needs and goals of BIM practice between organisational and individual levels, there has been little practical advice in other BIM management literature that managers can adopt within their project teams. As one of the contributions, this study shows how project and people-individual levels also need to be explored and connected with the organisational level to address some of the main challenges - resistance to change and knowledge challenges.

This study's investigations focus on the AEC teams. This study recognises that BIM adoption and development strategies should be optimised for different settings such as university classrooms, individuals, internal teams and wider project teams. Similar challenges exist within all of these settings and include: collaboration challenges, different roles and responsibilities, demand for different BIM knowledge levels, different training and different learning objectives, ability to learn on real-life projects, the limited time and the ability to adapt to a fast-developing technology (Sacks and Pikas 2013, Ghosh et al. 2015). Therefore, providing ideas on how to solve these challenges within one of these settings can inform and help others, which is another contribution of this study. Inspired by this idea, this study not only investigates the existing studies on BIM implementation, but the main originality of this study is created by bringing together the literature and ideas on change, learning and innovation; and applying it to the specific context of BIM development in the AEC organisations. The further rationale on why these topics are essential is presented in Section 1.2.4. and Chapters 3 and 7.

In-depth literature analysis of BIM development and implementation strategies such as 'top-down' and 'bottom-up' is needed to understand the current research on the topic fully and this study achieves this through the systematic review presented in Chapter 2. Furthermore, studies on ICT implementation can be beneficial, as mentioned in Section 1.2.2, particularly ICT implementation in the AEC industry, with the emphasis on studies on collaborative ICT implementation and adoption. It is also important to study change, innovation and knowledge management separately from these studies to get independent and new insights; and later, compare and integrate all the findings. As a result of these literature reviews, a list of conceptual, critical factors for BIM team development is developed (Table 3.2) with an aim to help managers with BIM team development, particularly in terms of people's skills and motivation. To understand real-world problems, this study conducts an in-depth longitudinal case study of a 'large construction project attempting to achieve BIM Level 2', to understand their challenges and established mechanisms. While the first primary data derives from the case study (Chapter 5.1), the main body of primary data derives from a number of expert interviews to build-upon the BIM team development conceptual list of factors and to further develop the final advice and the set of guidelines for practitioners (Chapters 5.2 and 6).

1.6 Contributions of the study

The main novelty and contribution of this research is in the first integration of principles of KM, IM and CM to benefit the BIM team development of the AEC organisations. Principles found in IM, CM and KM literature have been merged and discussed with insights found in the literature on BIM in the AEC industry. In addition to that, the majority of the current literature has been focused on BIM technology adoption, while this study not only explores the adoption but further team development. As a result, the novelty of this research is in creating a final list of factors and practical advice that can guide both the industry and academics.

An additional contribution of this study is in creating a strategy that responds to the individual needs of the AEC team members, which is lacking in the current literature. Previously it was mentioned that there is little evidence in the literature, that addresses the connection between the organisational BIM needs and individual peoples' needs. Therefore, this study explores ways of integrating the individual needs of members of the AEC teams into an overall BIM development process and strategy. Taking the needs of individuals into consideration has been achieved by implementing principles of IM, CM and KM, which all consider the level of individuals involved. This way, the resistance to change can be managed.

This study shows that investigating IM, CM and KM has the potential to improve the practice of the AEC teams when it comes to BIM team development. There are already some studies that mention these topics separately, particularly studies on organisational change and innovation adoption and diffusion. However, as explained, the novelty of this study is in integrating these principles. In addition to that, this study provides:

- Aside from a theoretical perspective, in-depth investigations and contextual information that can help the AEC management practitioners to inform their decisions;

- Solutions to some of the identified challenges, particularly the knowledge issues and resistance;
- Integrating theories of IM, KM and CM and showing interdependencies between these theories;
- Provides some practical advice on how those theories can be implemented;
- Long-term, sustainable and gradual BIM team development mechanisms, that are not too expensive or technically complex to implement.

Chapter 2. Identifying and evaluating Building Information Modelling implementation strategies: a systematic literature review

2.1 Introduction

The literature regarding the implementation of Building Information Modelling (BIM) in organisational settings is an important area of present discussions for both academia and people in organisations, willing to implement or develop their BIM working practices. As per Chapter 1, Section 1.1, the current literature has investigated a number of case studies, conducted industry surveys and discussed the challenges and opportunities with BIM technology. There is some advice on BIM implementation tactics within those studies, however, studies mostly discuss the technological dimension of the implementation. Therefore, a strict, systematic, overview of the existing literature on BIM implementation, a systematic review, would benefit both academia and organisations, as it would gather the advice about BIM implementation in one place. It would allow to discuss what are some of the critical factors, summarise the main recommendations and relations between them. This chapter identifies challenges and BIM implementation strategies, which is Objective 1. This objective is further investigated in Chapter 5 – through a case study.

2.1.1 Research design

The systematic review is a methodology used to collect and summarise all the evidence in the literature within a specific subject area. It is a method which leads to "unbiased, complete, reproducible reviews" (Boell and Cecez-Kecmanovic 2010: 130). It is appropriate to investigate the literature on BIM, as it is beneficial when there is literature investigating the topic, but there are still unanswered questions (Petticrew and Roberts 2006). The review in this study follows a protocol developed in accordance with the guidelines suggested by Pawson (2006) and Tranfield, Denyer and Smart (2003). Using the 'CIMO logic', as suggested by Denyer, Tranfield and Aken (2008), and the research objectives, this study developed a unique 'search strategy'. The chosen database was EBSCO for the selection of scholarly (peer-reviewed journals) between 2006 and 2016. The CIMO logic suggested a search of the following keywords that are specifically related to each other: 'construction', 'architectural', 'AEC', 'company', 'organisation', 'firm', 'Building Information Modelling', 'development', 'implementation', 'adoption' and 'training'. The search initially gathered 88 papers. After reading their abstracts, 36 were selected. After reading their content, the final selection included 19 articles. The analysis was conducted using an in-depth reading of the selected list of studies and in combination with the qualitative analysis software (NVivo). This helped to ensure that the most noted terms and topics within those articles were discussed in the review; and helped to obtain some understanding about relations that exist between the common topics. Further explanation of the systematic review methodology is presented in Chapter 4.

2.2 Strategic perspectives ‘top-down’ and ‘bottom-up approaches’ and ‘aligning business tools with BIM’

One of the key differences that exists in the literature on BIM implementation is on how assertive the implementation should be. Some literature advocates for a ‘top-down’ (also called ‘technology-push’) approach and for a radical approach to BIM implementation. In such cases, the initiative to implement BIM on a project comes from the top-management support.

Suggestions regarding a ‘top-down’ implementation exist in studies written by Ahn et al. (2016), Arayici et al. (2011a) and Dossick and Neff (2010). They all suggest an alignment of existing practices with new ways of working with BIM. A detailed example of a ‘top-down perspective’ is presented in the action case study of the architectural SME (Arayici et al. 2011a and 2011b). The company implemented ‘lean incentives’ with BIM intending to identify waste and develop more effective, collaborative working practice. This study proposed multiple solutions in order to successfully adopt BIM: the analysis of ICT systems and communication, SWOT analysis, KPIs control strategy, knowledge database, upskilling people with training and reconsidering and reorganising the existing business practices. The approach that the company applied integrated some principles of Change Management and lean incentives, therefore it was not as radical. The organisation managed motivation in the team by applying the ‘learning with doing’ training system on pilot projects. They also gave people (internally and externally, stakeholders) an opportunity to choose the most compatible software and discuss the BIM process as a team.

Another article, by Mahalingam et al. (2015), presented a study of an organisation aiming to also integrate ‘lean principles’ and BIM, as the study by Arayici et al. (2011a). However, this organisation implemented a bottom-up approach and it showed how this could lead to a successful BIM adoption. The project in this study was an infrastructure project and the organisation was a construction company. This study noted certain limitations of the ‘bottom-up’ approach, such as slow learning performance, as participants, project team members, only obtained an ‘understanding’ level of BIM. The implementation was also not complete, as the learning process had just started. However, the study identified a number of benefits of this approach such as: fewer actions needed initially, little disruptions to existing practice, improved productivity, commitment, communication and the creation of a ‘culture of collaboration and trust’, both internally and externally. The creation of a collaborative and motivated project culture is the creation of a good foundation, that can later help in accepting BIM more effectively (Babič et al. 2010, Hartmann et al. 2012, Mahalingam et al. 2015, Sebastian 2010).

The main advantage of a top-down focused approach is evident in a competitive market. In this context, there is a need to adapt quickly and implement a new organisational alignment that can achieve BIM implementation goals and a competitive advantage (Ahn et al. 2016). A study by Ahn et al. (2016), of a US commercial contractor, was less radical in terms of people, but it was in terms of business strategy and investment. The greatest changes were in organisational structure, contracts and IT infrastructure. Their successful implementation was similar to the studies by Arayici et al. (2011a and 2011b), and they both required a significant investment in terms of both time and cost. In both cases, they created an internal ‘BIM unit’, hired external expertise, invested in IT and created a dedicated educational platform. In this study by Ahn et al. (2016), the training strategy of employees was complex, but it was a long-term and a sustainable solution. The training was provided by the internal BIM development unit. They also created a solution for external partners and recognised the importance of educating their subcontractors. The main objective, for such an incentive, was that helping collaborators would reduce errors, risks and help the project. While the studies such as Ahn et al. (2016) and Arayici et al. (2011a), presented an approach that included a comprehensive, new organisational strategy, re-alignment and investment, the issue is the feasibility. There was a similar point about the feasibility of BIM team implementation strategies discussed in Hartmann et al. (2012), and this provides one of the key arguments for a bottom-up approach to BIM change.

2.2.1 Bottom-up or technology pull approach and middle-ground approach

Another approach found in the systematic review is the bottom-up approach. In comparison with the top-down, this is an incremental but more sustainable approach (studies by Babič et al. (2010), Hartmann et al. (2012), Linderoth (2010), Mahalingam et al. (2015), Poirier et al. (2015c), Sebastian (2010) and Son et al. (2015)). The systematic review also identified an approach between top-down and bottom-up, to be presented as the middle-ground approach. These studies were: Chien et al. (2014), Lee et al. (2015), Linderoth (2010) (both bottom-up and middle), Sackey et al. (2015) and Won et al. (2013).

The studies that identified bottom-up or middle-ground approaches identified many challenges in relation to the top-down strategy. The systematic review also identified some of the challenges in relation to the top-down approach to BIM team development and change. For example, a lack of trust and lack of communication was identified in Dossick and Neff (2010). This article presented a case of top-down BIM implementation, where one of the key challenges, coordination issues, was resolved due to the help of capable leaders, who were able to negotiate and address the issues singularly. However, this was not a sustainable practice and the study identified a number of collaborative issues in the team. In order to resolve difficulties, the authors suggested aligning the company practices with the project obligations. In respect to the issues of trust and collaboration, the study addressed these challenges only by advising that teams should improve their communication challenges and their team-working culture. After the review of this and other top-down studies, the systematic review identified that these studies contain little practical advice on addressing challenges, such as communication, motivation and collaboration. On the other hand, a bottom-up approach in studies addressed these issues with more care.

The middle-ground was found in the study by Linderoth (2010) which presented a case of a Swedish construction company. Initially, the BIM change in this team was bottom-up, however, this changed to a middle-ground approach. As a result, this study demonstrated a sustainable solution with a slow expansion of BIM change and BIM adoption across the company’s networks. According to the study, the BIM implementation starts with those who benefit the most, then diffuse onto others when they realise the benefits. Once they can visualise their own interests with BIM, other parties and clients would demand it. This study also recognises that the knowledge exists within those ‘networks’ and ‘experiences’ between parties; and once parties leave the network, there is a risk of knowledge being lost. Similarly, another middle-ground study by Sackey et al. (2015), of a UK construction company (2015), also recognises importance of understanding a ‘network’ and ‘organisational knowledge’. Both studies also suggest an evolving and dynamic approach to BIM change. According to the first one (Linderoth 2010), a slow adoption gives people an opportunity to understand the key principles of BIM practice, that they could replicate on new projects with new collaborators. The second study (Sackey et al. 2015), similarly to studies by Linderoth (2010), Chien et al. (2014), Son et al. (2015) and Succar et al. (2013), suggests continuous education and training, including in-house supportive unit, for a “constant learning loop” and “cross-project experience support” (Chien et al. 2014: 10). Therefore, these bottom-up and middle-ground studies recognise the BIM implementation process as a sociotechnical process that must address the disruptive and changing nature of the construction industry.

As a result, the main suggestions within bottom-up and middle-ground studies were on:

- Spreading the understanding in the team about the core principles of BIM (Linderoth 2010); to motivate people as they recognise the benefits (Babič et al. 2010, Hartmann et al. 2012, Mahalingam et al. 2015, Sebastian 2010);
- Motivation to accept the change (Sackey et al. 2015 and Sebastian 2010);
- Motivation to continually improve (Sackey et al. 2015).

While not specifically stated within all of these studies, the strength that these 'middle-ground' or 'bottom-up' studies demonstrated is that companies do not need to radically adapt for every new project, new collaborators or new networks. They can rather use their flexible knowledge, flexible approaches and motivation as strong drivers and a foundation to adapt quicker. This is a matter that can be explained through Knowledge Management literature and this is further discussed in Chapter 3. Taking care of social aspects, more than technical, can therefore be a more sustainable solution, as suggested by Mahalingam et al. (2015).

2.3 Results of the systematic review, key factors and risks identified in studies, TAM models and BIM adoption

The findings of the systematic review include a discussion of a few key studies that contribute to the understanding of BIM team development topic and factors that affect BIM implementation. Firstly, the study by Won et al. (2013) provides an excellent theoretical understanding of adoption factors such as willingness to share information, collaboration and technical support. These factors are further explored in this research study in Chapter 3, Chapter 5 and Chapter 6, by understanding practical measures that can guide managers, further investigations of connections between factors and by recognising if there are any other factors to support BIM team development. The study by Won et al. (2013) is also compared to other research conducted mostly after 2015. A parallel is made between Won et al. (2013) and a few studies that make a connection between the Technology Acceptance Model (TAM) models and BIM adoption in organisations. These were Lee et al. (2015) and Son et al. (2015), and a year after the systematic review another similar study was identified by Howard et al. (2017). Conclusions made in Won et al. (2013), Lee et al. (2015), Son et al. (2015) and Howard et al. (2017), on factors that impact technology adoption, have been found beneficial to understand BIM team development and their findings have been integrated and discussed further in Chapters 3 and 7.

The articles presented in this section of the systematic review, provide in-depth investigations on factors and risks that affect BIM implementation. These studies are Lee et al. (2015), Son et al. (2015), Won et al. (2013) and Chien et al. (2014). The conclusion from Won et al. (2013) is that there are many factors involved, such as: “people’s attitudes toward the technology, corporate culture, relationships between companies, characteristics of the specific projects, industry-wide issues of legal precedents, communication density, organisational barriers, and an individual’s resistance to change” (2013: 1). This is aligned with the perspective of bottom-up and middle-ground approaches to BIM adoption previously discussed in Section 2.2.1, which is that non-technical factors are of higher importance for BIM adoption than technological factors. These factors are tackling issues such as commitment, persistence, resistance to change, intention to use of BIM by company partners and owner’s incentive (Mahalingam et al. 2015: 2), all challenges that are previously discussed in Chapter 1, Section 1.1. Sackey et al. (2015) agrees with this point of view and explains that aligning BIM with structure, tasks and actors can motivate people, make them feel more engaged and allow them to recognise the benefits of the technology. In comparison with studies on TAM models and BIM adoption, Lee et al. (2015) and Son et al. (2015), this can be explained by ‘perceived usefulness’ factor, discussed and illustrated below and in Table 2.1.

The model of adoption for construction organisations developed by Lee et al. (2015) explains that the acceptance is possible when both organisation and individuals are willing to use and learn about the technology. Organisations also need to establish a structure which would encourage and support BIM - ‘top support’ (Lee et al. 2015) (top-support or ‘organisational competency’ in critical factors, Section 3.5) (Table 2.1). In Lee et al. (2015), other factors that affect an organisational decision to implement BIM are ‘team consensus’ and ‘individual intentions’. The ‘consensus’ is mainly affected by the ‘perceived ease of use’ for the technology, which results from the organisational competency (top-support, innovativeness, efficacy). The other factor, ‘individual intentions’, comes from the ‘perceived usefulness’, rather than other factors such as the ‘ease of use’, pressures in the organisation or a competitive market. This finding can also explain why bottom-up approaches succeed, as they address the ‘perceived usefulness’ early on. This finding is one of the results of the systematic review and it will also impact the creation of the final list of critical factors in Chapter 3, discussed in Chapter 7. This means that the critical factors identified at the end of Chapter 3 will address the understanding of individuals about BIM, precisely how useful is BIM technology for individual and organisational needs. This is achieved by applying theories of CM, IM and KM that lead to factors such as F1, F2, F12 and others.

Another TAM study, Son et al. (2015), identified by the systematic review also implemented a ‘technology acceptance model’ on architectural organisations and received similar results. The ‘ease of use’ was only slightly more important than the ‘perceived usefulness’, but the main sub-factor was the ‘compatibility’. This further confirms that it is important for employees to understand the benefits of BIM (‘usefulness’) and for organisations to choose the most compatible solutions to their existing practice (‘compatibility’). The systematic review findings conclude that the studies of Son et al. (2015) and Lee et al. (2015) strongly implicate that adoption depends on people’s perceptions and implicate addressing these needs to achieve BIM team development. In this study, this is achieved by implementing theories of CM.

Another result of this systematic review is a comparison and a parallel between TAM studies (Lee et al. 2015 and Son et al. 2015) and the study by Won et al. (2013). While Won et al. (2013) do not reference any relation to TAMs, this study investigates similar issues to TAM studies, just with less abstraction, as per Table 2.1. While Lee et al. (2015) and Son et al. (2015) identified and grouped conceptual TAM factors and recognised their relations, the study by Won et al. (2013) had the aim to gather key factors for a middle-ground BIM implementation. As a result, Won et al. (2013) described measures and straightforward advice on how BIM implementation can be achieved (see Table 2.1). As a result, Table 2.1 establishes that those studies on BIM factors provide similar conclusions in relation to BIM implementation.

The systematic review also established similarities between studies such as Won et al. (2013) and TAM models studies with other studies in the systematic review which suggests a consensus on the topic. It was found that the model and practical measures presented in Won et al. (2013) are aligned to the findings of other studies presented earlier in Section 2.2. However, in Table 2.1, it is noticed that most of the practical advice stands for the ‘top-support’ and ‘organisational strategies’ category of factors. There are a few strategies for managing people’s perception, usefulness and tool compatibility, which was found crucial in TAM studies. This also implicates that studies tend to provide advice on how to implement BIM top-down, although as suggested previously bottom-up approaches have valid strategical points that should not be ignored. Due to this, this research study addresses all factors identified by Lee et al. (2015) and Son et al. (2015), in particular people’s perceptions, perceptions about usefulness and compatibility through a number of critical factors presented in Chapter 3.

Table 2.1 Key factors and their interrelations

Factors presented by Lee et al. (2015) and Son et al. (2015)	Practical factors presented by the Won et al. (2013) which are crucial for BIM adoption	Practical factors presented by the Won et al. (2013) which are crucial in starting a BIM project
Top support (organisational competency)	Master BIM model team/manager, Organisational structure to support BIM, Continuous investment, The leadership of senior management Information-sharing protocols BIM training programs Technical supports of interoperability issues Standardized work procedures for BIM. Effective collaboration among project participant	PM interest and willingness to adopt BIM Request from the client on BIM Architectural firm's use of BIM
Perceived Ease of Use	Information-sharing protocols BIM training programs Technical supports of interoperability issues Standardized work procedures for BIM.	Availability of information on similar projects, which can be compared to results of a selected pilot project Field engineers interest and willingness to adopt BIM Architectural firm's use of BIM
Consensus on appropriation	Willingness to share information among project participants	Field engineers interest and willingness to adopt BIM Architectural firm's use of BIM
Individual intention	Willingness to share information among project participants Effective collaboration among project participant	/
Compatibility	Technical supports of interoperability issues Standardized work procedures for BIM.	Availability of information on similar projects, which can be compared to results of a selected pilot project
Perceived usefulness (competency and technological quality)	Continuous investment, The leadership of senior management BIM training program	Project complexity

2.4 Contract perspective

All identified studies support the idea of clearly stating BIM in contracts and potentially integrating their teams through a procurement strategy. The idea of aligning BIM and existing organisational practice was mentioned in every paper, but the specific advice on how to achieve the alignment was different.

The study by Linderoth (2010) explains that BIM can fit a project when contractual strategies are aligned to BIM practice and implement a choice of a more integrated project team, such as an integrated project team or a design and build team. Sackey et al. (2015), for example, explains a need to "foster cooperation and stop incentives that are ruining cooperation" (2015: 5). A study by Sebastian (2010) presented a successful pilot BIM project delivered by an integrated project team, which used a series of sessions organised by each project team member, which helped to achieve greater knowledge sharing and the coordination of information. Sebastian (2010) agreed with Linderoth (2010) that an integrated team is appropriate to BIM as it helps with BIM challenges such as motivation, coordination, lack of knowledge and teamwork - challenges also identified in many other studies as per Section 2.6, Table 2.2 and Chapter 1, Section 1.1.

It has been stated in studies that not stating BIM requirements clearly in contracts and having a 'lonely BIM' is also one of the key challenges for the delivery of BIM projects. The client or contractor has the greatest power regarding the clarity of BIM requirements, and they should suggest it (Linderoth 2010). This was also demonstrated in studies by Poirier et al. (2015c) and Dossick and Neff (2010). It was found that the BIM projects failed when only certain people in the supply chain were willing to adopt BIM, as a 'lonely BIM', while the project was lacking an adequate BIM top-support and requirements.

2.5 The technological aspect of BIM implementation

Regarding the technical implementation, the greatest challenge was in the 'compatibility' with existing systems (Chien et al. 2014). The compatibility was also a key factor in the choice of software (Won et al. 2013) and TAM studies. Chien et al. (2014) suggested solutions such as conducing a software-compatibility study and updating the software periodically. The study by Sackey et al. (2015) suggests using a single depository and the customisation of BIM systems. These suggestions were also found in Babič et al. (2010) (IFC customisation) and the study by Sackey et al. (2015), who recommended a technical team responsible to manage the compatibility of the software tools and responsible to explain and demonstrate working practice to all employees.

2.6 Summary

As a result of the systematic review, Table 2.2 summarises the key challenges in relation to BIM team development and types of BIM implementation strategies. This is followed by the summary of conclusions.

Table 2.2 Systematic review - summary of studies, key challenges and type of strategy presented in studies

	List of articles EBSCO database - Academic Search Complete	Reason to be within the systematic review	Study aim	Study context	Type of strategy presented in the study	Key challenges recognised in relation to this research study
1	Ahn et al. (2016)	directly associated, abstract	contractor's BIM transformation strategies	US, medium-size commercial contractors	top-down approach	investment, collaboration with external parties, lack of knowledge and skills, compatibility, change in culture, legal issues, liability issues, resistance to change, the complexity of work (workload), organisational structure
2	Arayici et al. (2011a)	directly associated, abstract	systematic BIM adoption and implementation	UK, architectural housing SME (sociotechnical view)	presented top-down approach	resistance to change, recognising benefits, training, investment, collaboration, interoperability, clear roles and responsibilities
3	Arayici et al. (2011b)	directly associated, abstract	systematic BIM evaluation and assessment for BIM adoption	UK, architectural housing SME (sociotechnical view)	presented both, pro bottom-up approach	resistance to change, training people, lack of knowledge and understanding, organising resources and investing in IT, changes in workflow, collaboration, interoperability, clear roles and responsibilities
4	Babič et al. (2010)	abstract	BIM implementation, aim: integrating mass production prefabrication with constr. activities	Slovenia, construction company SME (industrial projects)	presented bottom-up approach	information management, interoperability, slow process, resistance to change, management level changes, motivation, cost limitations
5	Chien et al. (2014)	abstract	BIM implementation risk assessment	Taiwan, construction professionals; case study construction project	middle-ground approach	changes in processes, technical and data compatibility, lack of experienced and skilled professionals, model and change management, committed management, information sharing, an increase of workload, cost and investment, standardisation, liabilities
6	Dossick et al. (2010)	abstract	BIM for MEP	US, MEP projects, two commercial construction projects	top-down approach	BIM requirements, 'lonely BIM', conflicting obligations for professionals, collaboration, information sharing, trust in information reliability and competencies, legal and IP risks, financial risk, training investment
7	Giel and Issa (2016)	abstract	investigating BIM competencies of building owners for BIM implementation	US, owners' perspective	/	lack of competencies of facility owners
8	Hartmann et al. (2012)	abstract	BIM implementation (cost estimating and risk management activities)	Netherlands, two construction companies	bottom-up approach	feasibility of technology push strategies, theoretical large-scale BIM implementation high-level guidelines with limited practical advice for practitioners, suitable methods of BIM implementation
9	Lee et al. (2015)	abstract	development of BIM acceptance model (behaviour-related	South Korea, construction organisations	middle-ground approach	unclear BIM benefits, motivation and acceptance, training, education and skills, supporting technical resource, collaboration on projects, unclear roles and responsibilities, legal frameworks to support clients

			theories)			
10	Linderoth (2010)	abstract	understanding BIM adoption and relations between project participants	Sweden, a construction company	bottom-up,middle -ground approach	The complexity of projects, collaboration, knowledge transfer, BIM requirements, lack of collaboration, lack of information sharing, focus on immediate goals, investment and feasibility, procurement methods, "disruptive nature of networks constituting building and construction projects" (2010: 71)
11	Mahalingam et al. (2015)	abstract	investigating how can lean practice support BIM adoption	India, two infrastructural projects, construction company	bottom-up approach	lack of coordination, fragmented nature of the industry, technical limitations of tools, trust in received BIM model information, lack of clarity about benefits, cost and investment, lack of experience, need for training, resistance to change, lack of commitment, lack of standards
12	Poirier et al. (2015c)	abstract	investigating the impact of BIM on labour-productivity	Canada, construction company SME, the context of BIM adoption	bottom-up approach	'lonely BIM', cost and investment, measuring benefits and impact of BIM
13	Sackey et al. (2015)	abstract	implementation of BIM, sociotechnical perspective	UK, multidisciplinary construction company	middle - ground approach	motivation to accept the change, motivation to improve, resistance to change, training, experience, new ways of thinking, evolving nature of tools and training, knowledge gap and transfer, understanding benefits, collaboration, "technology-centric view of BIM" (p.3), unpredictable nature of construction projects and automatization; technological, social and organisational challenges; interoperability; finding the correct information from the model
14	Sebastian (2010)	abstract	investigation of BIM implementation, a small housing project	Netherlands, housing development (SME) (integrated team)	bottom-up approach	practicality of methods, affordability, exchange of information, coordination, motivation, lack of systematic collaboration on projects
15	Son et al. (2015)	abstract	investigating factors that affect BIM adoption in arch. organisations	Korea, architectural company	bottom-up approach	afraid to adopt BIM tools, management support, technical support, compatibility of tools, software skills, organisational culture, knowledge about tools, training strategies, realisation of benefits
16	Succar and Kassem (2015)	abstract	understanding large scale BIM adoption	General, BIM diffusion policy development modelling	/	investment in both human and physical resources, other challenges identified are relevant for the macro (market-scale) BIM adoption
17	Succar et al. (2013)	abstract	understanding and assessing individual BIM competencies	General, BIM assessment model	/	development of competencies
18	Succar et al. (2012)	abstract	developing BIM assessment model	General, BIM assessment model	/	impatience to see benefits, having an understanding about BIM practice, development of competencies, measuring performance
19	Won et al. (2013)	abstract	investigating successful adoption of BIM and identifying key factors	General BIM adoption, management perspective	middle - ground approach	limited resources, investment, financial risks, technical compatibility, training and learning, liabilities, IP, trust, people's attitudes, culture, external relationships, internal collaboration, legal matters, communication, resistance to change, lack of direction, lack of top support, lack of communication - information sharing, organizational structure and management, security issues

Description: / - the studies were insightful for this research study, but studies mostly explored and presented other matters

The systematic review identifies different mechanisms that can be implemented to achieve BIM implementation, such as pilot projects, internal supportive units, new contract strategies, software customisation, training, feasibility studies, control mechanisms and others. However, this systematic review aims to understand strategic directions that can lead the AEC teams towards the successful and sustainable BIM adoption or BIM team development, rather than to identify small-scale initiatives. In particular, a level of precaution is being taken, because some of the identified case studies, had the technical support from universities or external BIM consultants, raising questions about the ability of these organisations to successfully implement the suggested mechanisms under the real-life conditions. For these reasons, this case study aims to summarise overall challenges and guiding principles that can be recreated in the context of other AEC teams.

Firstly, the systematic review in Section 2.2 differentiates between studies that adopt top-down, middle-ground and bottom-up approaches for BIM implementation. As a result of the systematic review, it has been found that the mechanisms in middle-ground and bottom-up studies (Babič et al. 2010, Hartmann et al. 2012, Mahalingam et al. 2015, Sebastian 2010, Sackey et al. 2015, Linderoth 2010, Chien et al. 2014, Son et al. 2015 and Succar et al. 2013) take care of matters such as motivation and resistance to change which allow for a more sustainable approach to BIM change, than in top-down implementation studies. Secondly, the level of investment makes them more feasible. Thirdly, the models of adoption presented in middle-ground and bottom-up studies also provide more recommendations on how to address issues such as lack of knowledge. For example, Linderoth (2010) suggests that greater collaboration in teams can enable better information sharing and knowledge transfer. This shows why bottom-up and middle-ground approaches to change are more suitable for BIM adoption.

There is a fourth line of studies, TAM studies and a study on BIM adoption factors, presented in Section 2.3 (Son et al. 2015, Lee et al. 2015 and Won et al. 2013). The recommendations from these studies are to address in particular - support, ease of use, compatibility with the existing systems and perceived usefulness about BIM tools. For example, Son et al. (2015) suggest that "training and support should focus on alleviating end-user concerns by providing related information on the use of BIM and compensating and enhancing their knowledge" (2015: 97). In that sense, they agree with the stance of 'bottom-up' and 'middle-ground' studies that non-technical factors have high importance and there is a need to manage perceptions.

The mentioned principles for managing a lack of skills and lack of commitment are analogue to principles suggested by CM and KM literature. In TAM model studies, 'middle-ground' and 'bottom-up' studies, special care is taken to manage perceptions and motivation to reduce the resistance. These principles are aligned to CM literature which addresses the perceptions and the resistance, which provides the additional rationale to apply CM literature in Chapter 3. Regarding KM, the review of bottom-up and middle-ground studies in Section 2.2 recognises the mechanisms such as continuous learning loops, knowledge networks and learning as a team. These mechanisms are aligned to recommendations from KM literature. Further to this, the list of challenges presented in Table 2.2 identifies that lack of experienced and skilled professionals and resistance towards new tools and practice are common challenges for BIM adoption. This, in addition to Section 1.1 discussion, provides additional grounds to apply CM and KM to understand and improve the practice of BIM team development.

This chapter presents a systematic review, a review of the key themes suggested in the literature on BIM implementation, summarises successful implementation strategies and discusses differences in managing BIM implementation. It would be difficult to establish one, all-encompassing guide based on the findings of these studies, because studies show different examples from different countries and organisations across the AEC industry. Middle-ground and bottom-up studies recommend BIM implementation strategy to fit the organisational needs, instead of aligning practice to achieve BIM adoption. Both bottom-up and top-down studies agreed that before applying any change or any technological implementation, it is essential to establish an in-depth understanding of the existing practices in an organisation of interest (Hartmann et al. 2012, Babič et al. 2010, Ahn et al. 2016). Considering these recommendations, this research study in Chapter 3 focuses firstly on overarching theories of CM, IM and KM which are identified as critical theories to address common challenges identified in Section 1.1 and Table 2.2. By applying these theories, the study establishes principles – critical factors, as the result. These are present in Chapter 3 (Table 3.3) and re-evaluated in Chapter 6 and Chapter 7 (Table 6.29, Table 7.1). This study can only recommend the mechanisms because each organisation would need to decide which mechanisms are the most suitable for their own needs and the context.

Chapter 3. Innovation Management, Knowledge Management and Change Management

3.1 Introduction

This chapter discusses the fundamental principles of Innovation Management (IM), Knowledge Management (KM), theories of knowledge sharing and Change Management (CM) and their application to the context of BIM team development. The discussion starts with a rationale on why the existing literature on change, innovation and knowledge is useful for BIM team development. This is followed by the application of this literature and theories to benefit the BIM implementation process and BIM skills development. The key findings are established to create a conceptual, theoretical list of critical factors. This is built gradually, as it emerges from the literature.

3.2 Innovation and Knowledge Management

3.2.1 BIM adoption process as BIM innovation process

Being innovative and using the organisational knowledge capital is vital to create new ideas, achieve a competitive advantage in the market and deliver better service for clients. According to Lu and Sexton (2006), innovation management is not only about the production of brand-new ideas; it is also a process of introducing new practices and ideas into the existing processes in the industry. This statement is in accordance with the first definition of innovation created by Schumpeter in 1934, who defined innovation as “the introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned” (Schumpeter 2017: 66). From that perspective, innovation is seen as a product or a service that is relatively new for a team who is implementing it. Therefore, being relatively new for the AEC teams, BIM adoption process and development process can be called an ‘innovation management process’.

It was found that the AEC teams need continuous improvements to remain productive and stay competitive (Robinson et al. 2005, Kamara et al. 2002, Abdirad and Pishdad-Bozorgi 2014). This can be achieved by implementing principles of IM, which can improve teams’ capabilities to innovate, improve and become more adaptable to market and technological changes (Hidalgo and Albors 2008). Improvements are achieved by developing an innovative and flexible team, able to continuously learn and share the knowledge. With IM, a team, therefore, improves the ability to respond to a dynamic environment of BIM software tools and practices. An innovative team is also able to find solutions to utilise BIM tools for their own needs, without disrupting what is already an effective existing practice; which was found to be an effective bottom-up and middle-ground tactic in Chapter 2.

On the other hand, the literature recognised certain barriers to innovation in the construction industry, such as a poor strategy, vision, top-support and leadership, poor knowledge management in companies, resistance to change and a lack of understanding of benefits (Maqsood et al. 2007: 94 - 95). Some of these issues, such as attitudes of top-management, lack of a vision and knowledge management, were also found to be critical factors in IM methodologies, according to Hidalgo and Albors (2008). This shows the importance of translating the principles of IM and making these easy to understand for the industry practitioners, for them to overcome those barriers with BIM team development process.

It should be noted that some of these issues are not only found to be key topics in Innovation and Knowledge Management but also in Change Management theories. Some of these are ‘leadership’ to support new processes and practice, creating a vision and tackling resistance to change and motivation. This shows a parallel between principles of IM and CM and the potential for these subjects to work together to support the BIM team development and this is explored in the discussion chapter, Chapter 7, in this study. However, to be able to narrow the scope of this research study and to build a theoretical list of critical factors, the focus is on the concept of knowledge, critical to IM and key theories of CM. To make the discussion more relevant, the literature search includes the key theorist and the latest developments in the AEC journal articles which investigated previously mentioned topics of interest.

3.3 Managing innovation

Managing innovation is an organisational management process that involves enabling several vital factors. There are different perspectives in the IM literature regarding what those critical factors are. There is also no consensus on this topic which would help the industry practitioners (Tidd 2001). This study finds that the most common correlation is between the ‘innovation’ and ‘knowledge’ and that is explained in more detail later in this study. The preliminary investigations of IM literature reveal many critical factors, but this study narrows its scope by prioritising those ‘internal’ factors that organisations can control. The emphasis is on the soft dimensions, including ‘organisational culture’, ‘empowerment’, ‘climate’, to enable the long-term success of innovation (Ahmed 1999). This is also the stance of other authors. For example, according to Goodman and Dingli (2017), IM is contingent upon supportive culture, trust and teamwork, among other human factors; while according to Moran (2015), it is also critical to build an adaptable team capable of delivering innovations. Considering these and previously mentioned findings, the findings are discussed within the following topics:

- 3.3.1 about setting the right culture and leadership to support innovation,
- 3.3.2 about motivating and involving people,
- 3.3.3 about the flexible and capable team to deliver innovation,
- 3.3.4 about the knowledge aspect and
- 3.4 about change management perspective.

3.3.1 Culture and leadership to support innovation

In terms of culture and leadership, some of the dimensions are vision, commitment, culture to support creativity and creation of new ideas and the role of trust.

Having a vision established early is one of the key factors. A vision is often described as an idea of a future that should inspire and lead the team to achieve innovations. According to Goodman and Dingli (2017) without communicating a vision to the team, people tend to return to their traditional ways of working. An organisational vision also has one of the critical roles in creating a creative culture in a company (Duggan 1999). While, a way to transfer the vision is via champions, enthusiasts, who need to be persistent in their role to share and support the vision and the new ideas (Goodman and Dingli 2017). Other than communicating a vision, other IM studies explain that the vision's message needs to be also understood by all team members (Steele and Murray 2004, Duggan 1999).

A way to ensure that a vision is followed is by involving the team in its creation (Goodman and Dingli 2017, Christenson and Walker 2004). A vision is more effective when created with the input from all key stakeholders, when it incorporates different opinions and when it is created as a 'win-win' solution among them, particularly if the project is more complex (Christenson and Walker 2004). However, the vision can also be created solely by leaders (Christenson and Walker 2004). In fact, some authors do not mention that the vision needs to be created as a team. Lu and Sexton (2006: 1279-1280) explain that the vision needs to be created by the management to balance "individual and organisational needs", inspire "knowledge workers" and focus on their project goals. The fact that their research was focused on smaller design organisations, where members could have been more easily involved in the vision creation process, in comparison with larger organisations, shows that vision does not need to be created as a team.

While there is no consensus in the literature on how a vision needs to be created, there is more clarity on its characteristics. It needs to show a “realistic, credible, attractive future for an organisation” (Nanus 1998). Similarly, Christenson and Walker explain that the key is for a vision to be easy to understand, inspiring, credible and challenging (2004: 51). Here, the ‘credibility’ is in showing that the values of the company are aligned with the value of the vision. Miettinen and Paavola suggest that for the BIM vision to be followed it needs to be achievable (2014). Hartmann’s work on IM, in construction organisations, shows that people follow and support what they believe in (2006). Therefore, a vision needs to address people’s values and beliefs; and by appreciating these, vision shows a ‘reasonable value’ of innovation. In the context of this study, this implies that the vision should include benefits of BIM team development. The empirical data in Chapter 5, 6 and 7 further discuss this factor – how vision is defined, communicated and how important it is for BIM team development.

The commitment of top-management is another common suggestion in the IM literature, considering that:

- Top-management is the critical element of IM in the work of Goodman and Dingli (2017).
- Innovations are influenced by management attitudes (Hidalgo and Albors 2008);
- Important for ‘exploitative’ innovations (Lu and Sexton 2006).

Lu and Sexton (2006) investigate critical factors of ‘exploitative’ and ‘explorative’ innovations in design organisations. An exploitative innovation is an improvement on the organisational level, while explorative is a project-based-innovation. The difference between the two is that an explorative innovation does not need to rely on the support and capability of higher management. Such innovation does not need ‘structure capital’, which include supportive processes such as tools, administration, control and strategies created by the top-management (Lu and Sexton 2006). However, BIM innovation process is both exploitative and explorative innovation. It may start as a pilot or an explorative opportunity, but ultimately needs to become a development of the entire team and organisation to achieve long-term benefits. Therefore, the support, commitment and structure capital created by the top-management are necessary. However, a challenge might exist in the creation of structure capital, as the management might not have the knowledge and capabilities to develop this.

Creating a culture to support new, innovative ideas and creativity is another factor or a pre-requisite to a successful IM (Ahmed 1999, Duggan 1999, Steele and Murray 2004). There is a need for the culture to be strong - where employees believe and consensually agree with the current organisational norms, but they are also receptive to change (Ahmed 1999). Many elements determine such a culture. A way to support it is through an openness from the leading management towards new ideas, by enabling the entire team to contribute and by supporting a non-judgmental environment where people are allowed to try and make mistakes (Duggan 1999, Ahmed 1999). Duggan also suggests other enablers such as several brainstorming techniques, improving teamwork, open communication and working on shared values such as “mutual trust, honesty, risk-taking, openness, fairness, a low blame culture, learning and commitment” (1999: 86-87). Schneider, Brief and Guzzo (1996), in their work on defining a culture for a sustainable change, mention the following dimensions as enablers of a thriving creative climate: trust in employees, collaboration, support and respect for employees, a sense of teamwork, collaborative decisions, making the work challenging and exciting, making the work flexible and less routinised and providing resources, support and rewards (in Ahmed 1999:376 on IM). According to Ahmed (1999), who discusses a number of different case studies and theories, the following elements need to work together to enable an innovative culture: commitment to results of employees, providing employees with the freedom to try, empowerment of people, having a forward-looking organisation, external orientation, a culture of trust and emotional safety for employees, leaders’ openness to innovation, freedom to debate, encouraged interaction (which includes a teamwork and a flexible team), celebrating success, the commitment of management, vision, awards, respect for new ideas, enough time and resources, organisational identification, flexible organisational structure and enabling innovation with less bureaucracy. Ahmed also states some ‘controlling’ factors such as clarity about risks, tolerances and accountability of employees to stand behind their ideas (1999: 385-396).

Newer studies, such as Goodman and Dingli (2017), Moran (2015), Steele and Murray (2004) and Hartmann (2006), provide a similar perspective regarding the culture as a critical factor. Compatible to views of previous authors, Moran (2015) and Steele and Murray (2004), discuss IM and explain that critical factors needed for innovation are ‘openness to ideas’ within the team and support and openness to new ideas from the management. In terms of achieving that ‘openness’ Moran suggests less hierarchy, Agile-like structure, more collaboration, continuous communication and administrative processes that do not inhibit new ideas. He recommends creating a “continually self-renewing organisation” by having a “balanced distribution of power”, adaptability within the team and engaging the entire team in the creation of ideas and problem solving (2015: 55). Goodman and Dingli (2017) also talk about the importance of having the right supportive culture, which includes the culture of trust and teamwork. For them, trust enables engagement, teamwork, commitment, communication and confidence in the team. Like Duggan, Ahmed and Moran, they also discuss how management should support the 'idea generation' in the entire team and make connections between right ideas and their practical realisation. The IM literature also recommends for the management to identify creative potentials of employees and match with opportunities and projects where they can apply their ideas and skills (Steele and Murray 2004); to enable the creative and innovative culture.

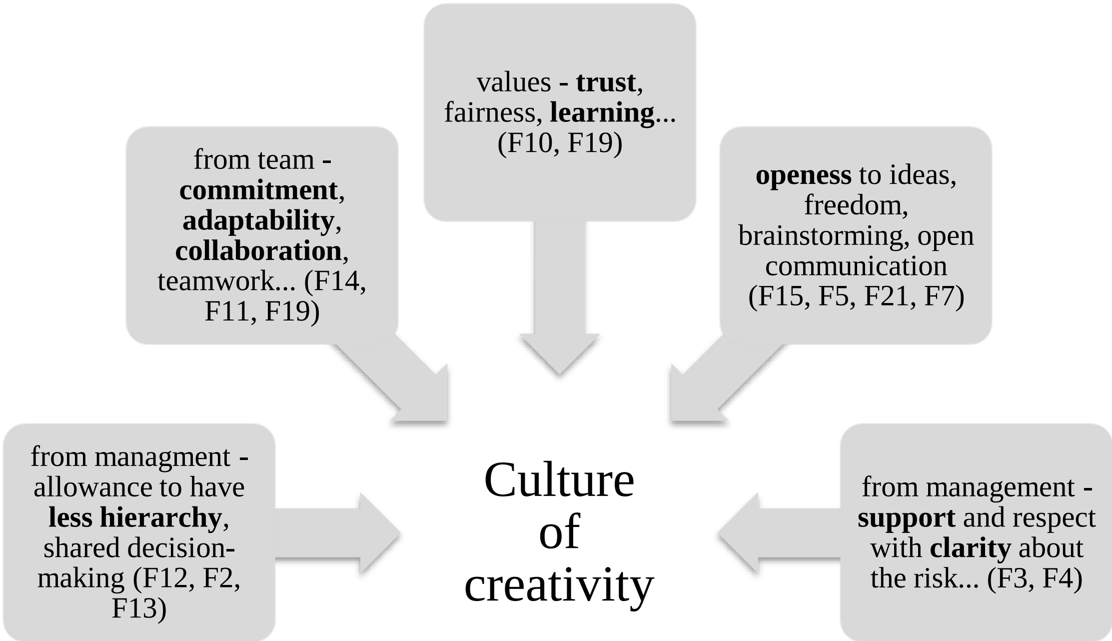

Figure 3.1 Mapping enablers of the culture of creativity and innovation and the connection with the final factors

Another emerging factor from IM studies and discussions on creating an innovative culture is about communication. IM recommends "open" and "extensive three-way" communication (Duggan 1999: 86). Improved communication is also a critical dimension in the work of Steele and Murray (2004), who explain how the diffusion of innovation depends on how effective communication is. They also describe IM as a process of negotiation and knowledge transfer within social groups (2004: 318). Hartmann also identifies that, for IM, information needs to flow between "all levels and units of the organisation"; and in terms of enabling communication, he suggests dialogue and "open workplaces, public spaces, workshops, information days…" (2006:162). In particular, the face-to-face communication is further recommended, being suitable for problem-solving and complex issues (Emmitt and Gorse 2007). To summarise, recommendations are to have a face-to-face, open communication across all levels of the team, to contribute the IM for BIM team development. As a result, in Section 3.5, this idea translates into critical factors F7, F5, F8 and F21.

It is noticed that there are many elements when it comes to the creation of an innovative culture and these are summarised in Figure 3.1. The key topics, such as ‘vision’ and ‘engagement of people’ are also discussed in more details in this chapter. What is also observed from the literature is that suggested elements are interrelated, but it is not clear to what extent. This varies from author to author and it also depends on the context of innovation, innovation type, organisations and nature of their work. This study clarifies how these elements (factors) are interrelated in the context of BIM team development in the AEC organisations and also shows the importance of certain elements compared to others.

3.3.2 Involvement of team members and motivation

IM process is a social exercise. It was previously discussed that for IM, to enable a culture of creativity and innovation, the team members should be encouraged to participate in the change, provide ideas, communicate and collaborate. It was also previously mentioned in Chapter 1 that CM also has a potential to contribute towards the BIM team development process, and that one of the leading principles of CM, parallel to IM, is to encourage the engagement of people in the process of change. This is explored in Section 3.4. In Chapter 2, it is also found that a middle-ground approach, as a decentralised IM process, has its benefits over the top-down approach. Therefore, it is essential to further discuss the idea of ‘engagement’ of a wider team and how that can be practically achieved. The first insights are that it can be achieved by brainstorming with a team, planning and making decisions regarding BIM adoption and development as a team, working together on different tasks in relation to BIM development and encouraging the wider team to participate in BIM change. This is presented below.

Recent research on ICT adoption and ICT adoption in the construction industry (Peansupap and Walker 2005 and 2006) and BIM adoption (Lee 2015, Mahalingam et al. 2015) to a great extent elaborate on how the commitment of team members is a significant problem and at the same time one of the key factors to innovation adoption such as ICT and BIM. This issue is resolved in IM literature, organisational psychology, organisational development and behavioural studies, which explain that commitment can be enabled by involving people, giving them a voice and the ability to participate. This idea is aligned with the neo-human perspective and participative pattern of management by Likert (1961). In Davis (1968), it was described as a ‘supportive model’ of organisational behaviour which is based on the employee-oriented management style. In this theory, employees are proactive and willing to contribute and they can have more independence in meeting tasks; but there must also be two-way communication and strong leadership from the leaders (Likert 1961, Davis 1968). This view, that shows many benefits of participation, is also supported in the work of many others, such as Gary Latham and Rosabeth Moss Kanter, according to Locke et al. (1986).

In alignment with the previous discussions, it was found in IM literature that “involvement and participation create a sense of ownership and responsibility, out of which develop a greater commitment to the organisation and a growing capacity to operate under conditions of ambiguity” (Ahmed 1999: 380). This can be achieved by encouragement to participate and by providing an ‘infrastructure’ or a place where team members can interact (Ahmed 1999). Similar suggestions are also made in the study on innovation in the construction industry by Hartmann (2006). A way to encourage participation is also by creating an environment where people are free to express their opinion, something that was discussed as a “voice” in the work of De Dreu and West (2001) and Carson et al. (2007). As a result, in Section 3.5, within the list of critical factors, this is established through factors such as F5 on open culture and F21 reflection.

The previously mentioned management theory by Likert also suggests including team members in shared decision-making (Locke et al. 1986). In IM guidelines by Goodman and Dingli (2017), it is also recommended to involve team members to make decisions together and establish a ‘consensus’, particularly with complex problems. In IM literature, it is also suggested to have shared planning in organisations (Duggan 1999). Duggan explains that there might be different levels of contribution, but the overall idea of shared planning is to have alignment and clarification about the business among all members. Deciding as a team also helps to create a shared vision, discussed previously in Section 3.1.1, as it helps to align the vision and clarify it across the team. The context of this study, an AEC team, is also a context where ‘consensus’ and deciding as a team is essential, due to the complex nature of construction projects and the interdependency of roles (Senaratne and Sexton 2009).

Benefits of involving more people in the decision-making and planning process are explained in studies on applied psychology by De Dreu and West (2001). They argue that having different people together and having minor dissenting opinions help in effective decision-making and creativity by “preventing premature movement to consensus, defective decision making and by promoting cognitive complexity” (2001: 1192). However, such initiatives need to be encouraged by leaders. The process also must have a critical dimension, a sort of validation, to ensure that ideas are not only creative but applicable (2001). This discussion further implicates that diversity will help shared decision-making (more on diversity is discussed below in Section 3.3.3).

In their work on building an innovative organisation, Goodman and Dingli suggest having a 'shared leadership' (2017: 239, 155). Shared-task ownership is also suggested by Moran (2015), who explains that it helps the flexibility of ideas and motivation. The research by Carson et al. (2007) further explains how "shared" or - how they also refer to it - "distributed" leadership, benefits team performance and the quality of a final product. Shared leadership is found to be useful in supporting critical, urgent, complex tasks, or an integrated type of task where there is a need for different inputs, by different roles (Pearce and Sims 2000), such as BIM team development context. Pearce and Sims (2000) found that in terms of benefits, such a team structure encourages creativity and the ability to find more solutions. Therefore, shared leadership can be a beneficial approach to BIM development as BIM projects have all those characteristics, particularly, include several disciplines, have an integrated nature of work and complex tasks. To achieve it Carson et al. (2007) recommend having the support from external leaders to enable distributed leadership (factor F3), having a team with a clear direction (F1), a supportive and encouraging environment to enable a 'voice' (F5) and the ability to be involved and engaged in a team. Those suggestions were also previously discussed in Section 3.3.1., which further enhances their importance.

One of the ways to encourage engagement and participation are 'group discussions', which later becomes a factor - F21. Brainstorming sessions and facilitated discussions are a tool to encourage idea generation and problem-solving. They can be applied to solve creative tasks (Pearce and Sims 2000). They are suitable for the context of this study as they support the idea of having an 'open environment' where people can discuss and solve problems together. Such an environment is one of the key dimensions in the work of Peansupap and Walker on ICT adoption in construction organisations (2005); and it is also suggested previously in discussions on the creation of a culture of innovation by many authors. In the discussion on innovation and problem-solving, Duggan (1999) discusses brainstorming techniques such as 'synectics' and 'problem redefinition'. The former is a process of bringing different views to provide new perspectives and second is modifying the way we define the problem statement as a team. The idea is that the entire team can participate and that such a process would enhance the team's creativity. For all those reasons group discussions and brainstorming sessions can be a tool to support BIM team planning, decision-making, problem-solving and other processes that lead to BIM team development.

However, while the 'employee-oriented' model (Likert, Davis and others) responds to the needs of employees and tackles motivation, we should be aware that ultimately the team needs to employ BIM and deliver results. Previously mentioned studies claim that a happy employee delivers results and better productivity (Locke et al. 1986). However, a study on technology (ICT) adoption by Cudanov and Jasko (2012) shows different results. While recognising values of a human-oriented management style, particularly for the use of collaborative technologies, their results indisputably show that the result-oriented management model was a more deployed style in practice and also more effective towards ICT adoption than the human-oriented managerial style. The work of Locke et al. (1986) also argue that participation is not always suitable. They discuss findings of previous theorists and explain how other means such as: financial rewards, setting a goal and job enrichment, are more beneficial to motivate employees to be more productive. It is explained that if the role is clear there is no need for participation to motivate employees. Instead, the focus should be on assigning interesting and significant tasks, giving feedback, allowing a certain level of autonomy, fair pay and security, rewards and promotions, decent working conditions, cooperative working environment, knowledgeable supervisors and respectful and competent management. The participative style is found to be useful when team members have experience and knowledge that can contribute to those decisions. If this is not the case, such decisions made as a team might not be the most effective or of the highest of quality. However, when there is no time, when the task is individual, and leaders have significantly more experience than others, there is no need for participation (Locke et al. 1986). Therefore, the opinions on participation are that it needs to fit the team, situation, and the interview and case study findings need to investigate the role and value of ‘participation’ factors such as F1, F2, F12 and F13 for the context of BIM team development.

3.3.2.1 Motivation

There are more discussions on the importance and ways to achieve motivation in IM literature, previously discussed in Section 3.3.1. This topic is also one of the key aspects of KM and CM, and for those reasons, it is further discussed in separate Section 3.3.4.3. to integrate those findings and review them simultaneously.

3.3.3 Flexible and capable team

The systematic review, Chapter 2, finds that management support is needed to help the team with the right equipment, training and other financial and non-financial means of support to achieve BIM adoption. According to Hartmann (2006: 159), the ability to innovate depends on resources a construction organisation is willing to allocate. However, to achieve BIM capabilities, other than top-support resources, the team also needs to be structured and skilled in a way that is responsive to a dynamic BIM environment - to be adaptable to a change of BIM tools. This concept is aligned with the work of Wheatley (2007), who presents a modern view of an organisational team, a team described as 'self-renewing'. In the discussions about IM and agile management, Moran also suggests that adaptability is one of the key factors that can contribute to IM (2015). An adaptable team allows the organisation to keep up with the constant change and stay consistently competitive.

One of the contributions of this study is that it emphasises the importance of adaptability for BIM team development and discusses ways of achieving it. This is a factor F14. Current studies on BIM and ICT adoption provide little information on improving the adaptability. When discussing the development of capabilities studies suggest: top-support, employing new people, explaining benefits and providing professional development. It is suggested to 'already have' employees with computer skills and confidence, who are willing to learn and be committed (Peansupap and Walker 2005). In terms of flexibility, a study by Henderson and Ruikar (2010) briefly recognises that adaptability to change can be improved with leadership and culture. Steele and Murray (2004) mention that the 'agility' of the team is an important factor and it depends on the 'intellectual capital' of the team. However, this was explained to be built by encouraging creativity and building the innovative reputation of the company to retain and attract new people with 'intellectual capital' (Steele and Murray 2004). This indicates that a team needs to build capabilities and adaptability by appointing new people; however, that could bring issues in terms of organisational knowledge dynamic, loss of tacit knowledge, time, cost and potentially trust, when a team changes its members. To investigate the issue, the critical factors incorporate a factor on team dynamics, which investigates potentials of changing the team structure when there is a need for it - F16.

There might be a potential of having such a flexible team structure (F16) to be more adaptable to innovation and change (Schlegelmilch et al. 2003 in Hidalgo and Albors 2008). However, having a matrix team structure - where employees work on a few different projects simultaneously, join when needed, or have a temporary team structure - can have its challenges. If they do not spend much time together, they might lose the sense of the team and it might be difficult for them to achieve an innovation (Cole 2019). For this, Cole (2019) suggests relationship building and more communication – factors F11 and F7. These suggestions and issues are investigated in the primary data under the factor F16.

3.3.3.1 Application of IM IT studies

This study finds that Innovation Management IT studies provide answers on how to improve the adaptability of an existing team and those solutions can be applied to BIM team development context. For example, Moran emphasises the importance of both the adaptability of the team and building the openness of the team towards the new ideas (2015). He explains that adaptability comes from having individuals with a "range of interests", who are open to new experiences and have problem-solving skills (2015:52). Therefore, to improve the adaptability, Moran (2015) suggests the following:

- The management needs to be open to new ideas, encourage the creation of new ideas, to be a 'servant leader' and to encourage problem-solving skills;
- Communication, collaboration and Agile-like structure should be encouraged with a "balanced distribution of power" (2015: 55);
- Adopt shared task ownership, to also help motivation and openness to ideas, which was discussed in Section 3.3.2;
- Support diversity in terms of skills, perspectives and cultures within the team to help both managers and the team in terms of openness to new ideas.

Moran's approach of building a "continuously self-renewing" organisation (2015:55) is suitable for the aim of this study as it can be applied to a dynamic BIM technological environment. However, this study is mindful that those ideas are based on Agile IT management. Therefore, it needs to be checked to what extent those suggestions are applicable for the AEC teams based on the interview and the case study data.

3.3.3.2 Role of diversity

The work of Nonaka and von Krogh (2009) on organisational knowledge, discussed in more detail in Section 3.3.4, agree with Moran (2015) that bringing people with diverse knowledge and social backgrounds creates more opportunities for innovation. Other studies on KM and change in construction organisations also recognise that bringing different people encourages learning (Senaratne and Sexton 2009). Other authors, such as Brewer and Mendelson (2003) and Horwitz and Horwitz (2007) also recognise that diversity in terms of skills, education, roles in organisations, is beneficial for multidisciplinary teams. A previously mentioned study on applied psychology, De Dreu and West (2001), also confirms that diversity in terms of functions, skills and attitudes is helpful for the culture of innovation. However, there can also be a risk of conflicts when diversity is too high (Leonard and Sensiper 1998). Conclusions are that team members should be diverse, but also compatible (Brewer and Mendelson 2003) and to have a certain amount of knowledge in common (De Dreu and West 2001). As a result, the topic of diversity is investigated as factor F6.

It was also found that diversity can enable another concept – access to more information (F8). Wheatley suggests that "open access to information" and generally more ways of sharing the information can contribute organisational efficiency, innovation and knowledge management (2007: 116). She suggests achieving it through an open culture (F5) (discussed in Section 3.3.1), engagement of different disciplines – diversity (F6) and engagement mechanisms discussed in Section 3.3.2. This topic, F8, is also explored and recommended in KM, as discussed within Section 3.3.4.

3.3.4 Knowledge, Innovation and Knowledge Management

According to the new theories of innovation, the main way of managing the innovation is the application of Knowledge Management (Urbancová and Königová 2013, Cabrilo and Grubic-Nesic 2013, Buckley and Jakovljevic 2013, Kamara et al. 2002, Egbu 2004, Maqsood et al. 2007, Hidalgo and Albors 2008). The rationale behind this connection between Knowledge and Innovation Management is mostly due to the direct relationship between the tacit knowledge and innovation, further explained below in Section 3.3.4. Whilst this is one of the key reasons to implement both KM and IM theories simultaneously to identify BIM team development critical factors, there are also other reasons for the application of KM. These points, previously discussed in Chapter 1, Chapter 2 and Section 3.3. are summarised below.

The literature on BIM implementation in Chapter 1 and the systematic review, Table 2.2 in Chapter 2, identifies that challenges in relation to knowledge and knowledge sharing are some of the most significant and frequent in the AEC teams developing their BIM competencies. These challenges are: lack of knowledge and skills in the AEC teams (Ahn et al. 2016, Arayici et al. 2011a, Arayici et al. 2011b, Chien et al. 2014, Son et al. 2015), lack of training in organisations and needs for more training (Arayici et al. 2011a, Arayici et al. 2011b, Lee et al. 2015, Mahalingam et al. 2015, Puolitaival and Forsythe 2016, Sackey et al. 2015, Son et al. 2015, Won et al. 2013), lack of understanding about BIM practice (Arayici et al. 2011b), investment in training (Dossick et al. 2010, Lee et al. 2015), issues with the knowledge transfer (Linderoth 2010, Sackey et al. 2015) as well as the inability of professionals to adapt to the complex and evolving nature of software tools (Sackey et al. 2015). The KM can help organisations address those challenges by enabling knowledge transfer in the team, enabling positive culture and by improving organisational ability to utilise the existing knowledge (Urbancová and Königová 2013, Cabrilo and Grubic-Nesic 2013, Nonaka and von Krogh 2009). It was also found that, for BIM education, there is a need for self-organised teams that can address the lack of skills and knowledge without extensively relying on external sources (Puolitaival and Forsythe 2016), which is also a benefit of KM (Urbancová and Königová 2013). Therefore, this study applies KM to identify the enablers of knowledge transfer in the AEC teams to benefit BIM team development.

An additional rationale for implementing KM is found in some middle-ground and bottom-up studies (see Table 2.2). For example, Sackey et al. (2015) suggest constant learning loops, which is aligned to the learning 'spiral' in the work of Nonaka (Nonaka and Toyama 2003). Another study, Linderoth (2010), points to the importance of networks of knowledge, which is also aligned to the work of Nonaka, in the section on *ba* later discussed in Section 3.3.4.1.1. Further, having a flexible and gradual approach to learning and building individual and team knowledge, to achieve an easier management of motivation and resources, presented in those studies, is also aligned to KM principles. Currently, there are no studies that show the benefits of Nonaka's and other KM theories for the purpose of BIM team development, whilst there are studies that show that KM should be employed more in the AEC industry and a few studies that demonstrate how BIM can benefit KM in the AEC teams, as per Chapter 1, Section 1.1.2. This is a further rationale for applying KM to establish critical factors to BIM team development.

KM is a "process of creating, capturing, and using knowledge to enhance organisational performance" (Bassi, 1999: 424 in Vera and Crossan 2005). There are different perspectives in the KM theory, however, this study follows the 'organic' and 'integrated view' of KM (Vera and Crossan 2005) where KM is seen as a human and social process that can be supported with the technology. Furthermore, this study follows the definition of knowledge as a "product of human reflection and experience" (Long and Fahey 2000: 113).

A common perspective about KM is that its purpose is to create a competitive advantage and innovation (Al-Ghassani et al. 2004, Frappaolo 2006). It was also found that the ability to innovate and accept innovation highly depends on and ensue from tacit knowledge (Leonard and Sensiper 1998, Nonaka and von Krogh (2009). This knowledge is defined as a contextual knowledge and includes experiences, thinking, commitment, values, beliefs and emotions, while explicit knowledge is codified, structured and articulated (Nonaka and von Krogh 2009, Kothari et al. 2011, Shin et al. 2001). Tacit knowledge is important for problem-solving, creative problem finding and the ability to predict (Leonard and Sensiper 1998), which shows how it enhances the ability to innovate and find new solutions. For those reasons, to implement IM to BIM team development context, this study investigates ways of improving tacit knowledge.

To understand the principles of tacit knowledge this study consulted models of KM that can be applied in the AEC organisations. This study follows the SECI model suggested firstly by Nonaka and developed by Nonaka and Takeuchi (1995), similar perspectives to organisational knowledge creation discussed by Leonard and Sensiper (1998) and the work of other authors such as Davenport and Prusak (1998, 2000), Boisot (1998), among others. While some literature such as McAdam and McCreedy (in Maqsood et al. 2007) recognised the Skandia Intellectual Capital (IC) model as a KM model, this can be debated. The IC model perspective is less beneficial for the aim of this study as it perceives the knowledge as an organisational asset, while this study investigates knowledge creation and transfer. For example, the first IC model, the Skandia Intellectual Capital (IC) model developed by Edvinsson in 1997, discussed commercialising the knowledge to benefit companies (Frappaolo 2006), which is not the objective of this study.

There is also the concept of Organisational Learning (OL), which is a similar and complementary perspective to KM (King et al. 2008, Vera and Crossan 2005). Vera and Crossan elaborate on how KM and OL are fields which are discussing the same issues such as knowledge creation and development, and topics are majorly overlapping, although researchers and the industry tend to focus only on one or the other. OL is about improving business processes through knowledge (King et al. 2008), and it "focuses on learning as a process of change" (Vera and Crossan 2005: 127). KM, on the other hand, is about achieving a competitive advantage, it discusses its management and commonly applies the use of IT tools to achieve that (2005: 124-127). While Vera and Crossan recommend the use of both, due to the scope of this study and the high number of theories and studies in both OL and KM, this research focuses on KM. The main argument for KM is that while investigating IM, the relation was specifically made between IM and KM, as IM recommends KM. Another argument is that KM investigates how knowledge is created, used, stored and protected within the team (Pablos et al. 2013). Another argument for the use of KM is that OL does not consider sociological and economic aspects as KM does (Prusak 2001). For those reasons, this research will incorporate findings of KM models.

The KM perspective of Nonaka and Takeuchi (1995) SECI model and the work of Blumentritt and Johnston (1999), Frappaolo and Capshaw (1999), Davenport, Long and Beers (1998a) and many others, see knowledge as a process and an organisation as a knowledge-based entity (Shin et al. 2001). A similar perspective was also found in the work of Leonard and Sensiper (1998), Davenport and Prusak (1998, 2000) and Boisot model (1998). The SECI model is also a well-known, accepted model that discusses knowledge types, the knowledge conversion process in the organisation and the team, explains how that impacts IM; and due to those reasons, it is the most suitable theoretical model to support the process of BIM team development. The work of Leonard and Sensiper, Davenport and Prusak and others, is also used to provide additional perspectives. The study also discusses recent literature about KM in the AEC industry to complete the review.

3.3.4.1 Knowledge Management and organisational knowledge creation theories

3.3.4.1.1 SECI model Nonaka (1991), Nonaka and Takeuchi (1995)

The SECI model, created by Nonaka in 1991 and further developed by Nonaka and Takeuchi in 1995, was the first to mention and explain the concept of a “knowledge-creating company” (Nonaka 1991, Vera, Crossan and Apaydin 2011). In the SECI model, tacit knowledge in an organisation is created when people interact, socialise and work together as a group (Nonaka and von Krogh 2009). Similar approaches are discussed by Leonard and Sensiper (1998) and Davenport and Prusak (1998, 2000). They all explain that KM is about managing ‘interactions’ of people. Therefore, to encourage the ‘team interaction’, the final list of factors includes factors such as: F5 Ensuring an open environment, F7 Communication – exchange of information, F12 (Shared) Decision-making and F11 Team building.

The knowledge creation model is a spiral model of four phases which transfer the knowledge from tacit to tacit, tacit to explicit, explicit to explicit and explicit to tacit. The idea of the model is to connect the individual and organisational knowledge levels. This is established through processes of:

- Socialisation – where people interact, exchange knowledge, spend time together, learn together from experience;
- Externalisation – where tacit knowledge is summarised, clarified and transformed into explicit;
- Combination – where explicit knowledge is combined, integrated and systematised; and
- Internalisation – where explicit knowledge is applied and transformed into tacit (Nonaka and Toyama 2003) (Figure 3.2 below).

Nonaka also discusses the importance of the ‘team’. A team provides a space for interaction, dialogue and reflection and a context to connect individual and collective knowledge (Nonaka

2008). He explains that ideas emerge from 'dialogue and discussion'; as dialogue is an effective tool to externalise the knowledge (Nonaka and Toyama 2003). Therefore, this study incorporates factors that encourage teamwork, dialogue, interaction, reflection and discussion – such as F7 and F21. He also explains that knowledge is acquired through perception and experience, which are part of 'socialisation' and 'internalisation' processes. This becomes a factor F19 experiential learning. To clarify how is this achieved and how is the SECI model applied - Figure 3.2 presents how factors fit different phases of the knowledge-creating model.

	Tacit →	***Tacit →***	
	Socialisation	**Externalisation**	
Tacit →	• F7 Communication: regular meetings, face-to-face meetings, discussions • F8 Enabling access to information: interconnectivity of team members • F21 Opportunity for reflection • F5 Ensuring an open culture • F11 Team building • F12 Shared decision-making: everything understood by all members • F13 Shared leadership • F19 'Shared' experiential learning *Key words: discussion, socialisation*	• F21 Opportunity for reflection • F1 Aligning vision, agreeing a common vision • F2 Planning future actions as a team • F4 Clarity about the change process • F12 Shared decision-making: everything understood by all members • F18* Structured organised training: by internal members *Key words: summarising, clarifying, documenting, planning*	***Explicit →***
	Internalisation	**Combination**	
Tacit →	• F19 Experiential learning *Key words: applying, operating, individual*	• F18 Structured organised training • F9 Ensuring reliability of information – defining rules and standards *Key words: integrating knowledge, organising and systematising knowledge*	***Explicit →***
	← Explicit	***←Explicit***	

Figure 3.2 Applying SECI model to BIM team development context – showing relationships with factors

Nonaka also stresses the importance of considering a 'context' – by adding the concept of *ba* (Nonaka et al. 2000 in Nonaka et al. 2006) and explains that knowledge creation happens through interaction with the environment. Knowledge is context-specific, and it is dependent on time, space and relationships, while *ba* is a "shared context in motion" (Nonaka and Toyama 2003:6).

Ba is not limited by the borders of an organisation, neither is determined by its members, instead, it is fluid. Nonaka added that it is also beneficial for team members to share the space, particularly for the 'socialisation' and 'externalisation' phases, which allows them to have a common language. This is related to the previously discussed 'face-to-face communication', factor F7, in Section 3.3.1.

There are a few other points presented in their work which are beneficial for the context of this study. In the revisited knowledge-creating theory by Nonaka, the knowledge synthesis is described as an "integration of opposing aspects through a dynamic process of dialogue and practice" (Nonaka and Toyama 2003: 2). Therefore, they encourage interaction between people with different points of view. In fact, they explain how these differences enable knowledge creation in organisations. While discussing *ba*, they explain that different perspectives, contexts, bringing contradictions and fostering them with the same direction create the 'active ba' (2003:7). This was previously discussed as an enabler of IM, in Section 3.3.3 as 'diversity'; while the other suggestion on having a 'direction' was previously discussed as 'vision' in Section 3.3.1. They explicitly later in the work suggest discussions with different team members, to discuss the rationale to enable knowledge synthesis. Therefore, whilst implementing these principles and exploring the key factors, it would also be beneficial to understand what is *ba* and 'environment' in the context of BIM team development and see what emerges from the data.

3.3.4.1.2 Leonard and Sensiper (1998)

Another perspective on KM and innovation is given by Leonard and Sensiper (1998). Their work was also followed by Davenport and Prusak (1998) which is discussed below. They agree with Nonaka and other theorists that tacit knowledge has a key role in innovation and they also build their theory on work of Polanyi. However, there are some differences in comparison to Nonaka. Firstly, they perceive that knowledge is rarely only tacit or only explicit. Secondly, like Davenport and Prusak (2000) and Frappaolo (2006), they explain how not all knowledge can be documented. Unlike Nonaka, they suggest occasions when there is no need for the knowledge to be externalised into explicit. For this, example situations are lack of time or when it comes to the transfer of skills that are better learnt by observation or through experience. There are also several other points they explain, that match points discussed in previous sections and other KM theories and therefore they provide additional evidence that they can be relevant factors in BIM team development process.

As in the literature on innovation, it is important to build creativity. This was previously discussed in Section 3.3.1. Creativity can emerge from interaction and combination of different skills (previously in Section 3.3. mentioned as ‘interaction’ and ‘diversity’). Diversity is suggested in terms of skills, intellect and background. However, they also mention that too much diversity can be challenging, as it can lead to emotional and intellectual conflicts, where they particularly stress gender, race, age, education and personality differences. To tackle this challenge, the team needs to be focused by having the same direction or a vision.

In terms of knowledge creation, the emphasis is on building experience and social interaction. They suggest that tacit knowledge can be developed through trial-and-error learning, shared experiences, observations of other team members and apprenticeships. Other mechanisms to create both tacit knowledge and creativity, are by having brainstorming sessions (factor F21), which would need to be coordinated and interactive sessions (F21) with a specific concept, previously mentioned as vision (F1). They explain that these are tools that encourage new ideas and that can improve the existing practices of the company.

One of the points they suggest, about managing innovation by rethinking about the ‘existing practice’ is also confirmed by Frappaolo (2006), who explains how KM uses existing experience and practice and also confirmed in Chapter 2 systematic review. Chapter 2 concludes that BIM adoption process needs to start from understanding the existing practice (Hartmann et al. 2012 and Babič et al. 2010 and Ahn et al. 2016) and then BIM ideas should be implemented to improve the existing practice (Ahn et al. 2016, Arayici et al. 2011b, Dossick and Neff 2010, Son et al. 2015, among others). This is incorporated through factors F17 and F21 (Figure 3.3).

Leonard and Sensiper (1998) also discuss challenges that occur in practice, that inhibit tacit knowledge and suggest a number of solutions for the managers:

- Encourage mentoring and sharing of knowledge;
- Think about overcoming a problem of inequality in terms of status;
- Encourage multiple ways of communicating ideas, particularly face-to-face;
- Encourage sharing ideas without “hard evidence” that an idea could work;
- Encourage expressing new ideas based on “intuition and insight” (1998: 125);
- Encourage different ways of thinking.

To summarise, Figure 3.3 below shows different factors that are defined based on findings in the study by Leonard and Sensiper (1998).

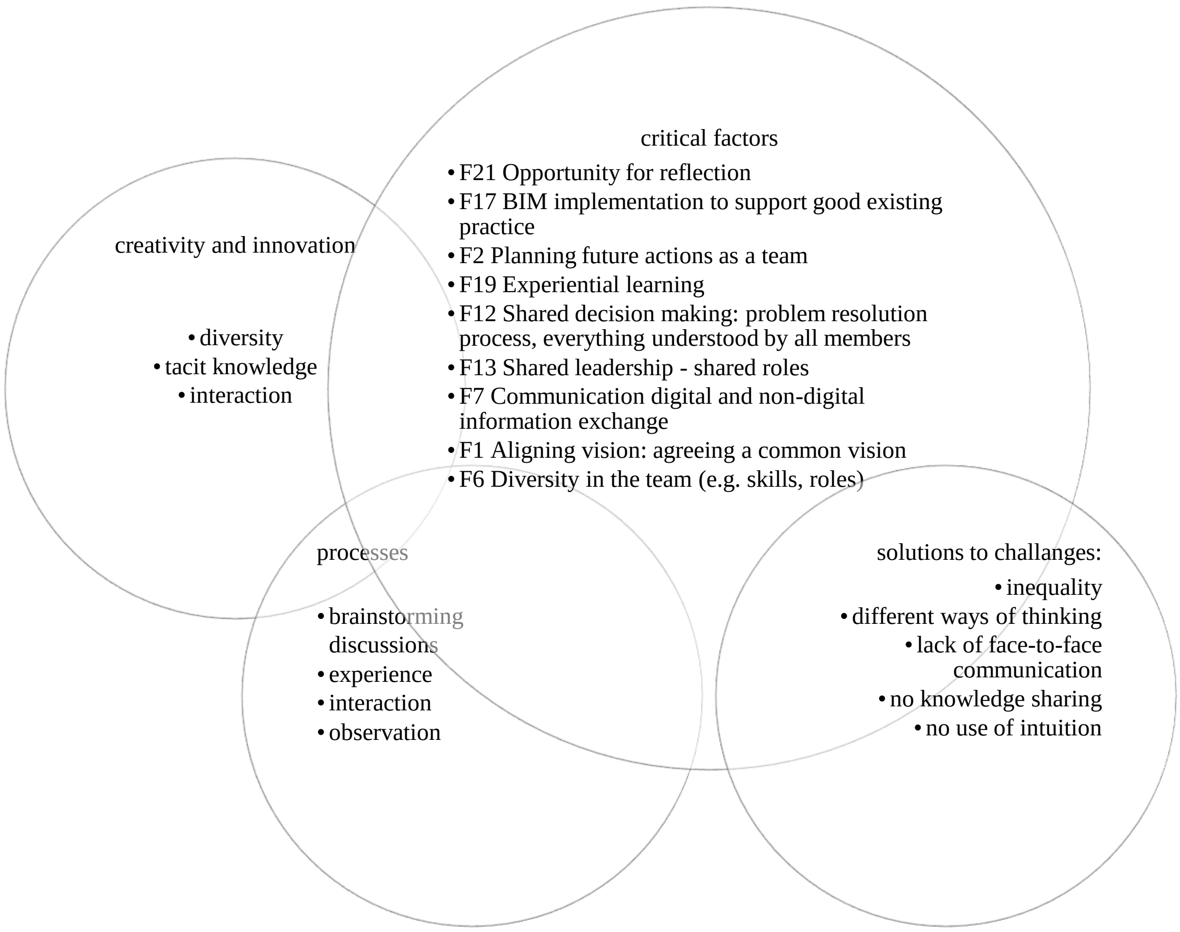

Figure 3.3 Mapping principles from the literature, work of Leonard and Sensiper (1998) and application of them to BIM team development context – relations to factors

3.3.4.1.3 Davenport and Prusak (1998/2000)

The work of Davenport and Prusak (1998) has similarities with, and follows both Leonard and Sensiper and Nonaka and Takeuchi, particularly in emphasising the importance of interaction. However, they are more focused on practical activities that can be developed in organisations, which is useful for the aim and approach this study has taken. For Davenport and Prusak, KM needs to include phases of knowledge generation, codification and transfer. The generation process can include the process of ‘copying’, purchasing, appointing consultants, having dedicated resources such as a research and development team, a ‘fusion’ process and networks of knowledge. Purchasing external knowledge will not be included as a factor or a suggestion, as the goal of this study is to create a sustainable approach to BIM team development and the stance is that the AEC teams already have the skills to develop further their BIM skills. While the 'fusion process' is integrated into the factors, being previously already mentioned in the work of Leonard and Sensiper as 'creative abrasion' and 'brainstorming' (F21). According to Leonard and Sensiper, such sessions need to include diverse participants and networks of knowledge, as these can all contribute with different ideas, which was also found to enable innovative decision-making. Therefore, it could be concluded that involving people in the planning and decision-making process is beneficial; and this is incorporated through factors such as F2, F12, F13. Another point in the book of Davenport and Prusak, is about top-management commitment and how important it is that they provide "time and space" (67), particularly shared spaces for interaction; and this is also translated into several factors, such as F3, F2 or F21.

The following aspect, 'codification', is essentially about the importance of providing access to knowledge and information. It is very similar to the 'externalisation' and 'socialisation' suggested by Nonaka. The knowledge that is useful and possible to code should be made explicit, portable and easy to understand and this knowledge should be transferred into an IT system or a library with 'knowledge maps'. Other useful knowledge that cannot be coded, should be communicated one-to-one, through conversations or apprenticeships, as suggested by Leonard and Sensiper (1998) and Frappaolo (2006) (F7). In fact, Frappaolo (2006) stresses that this is the most effective way of transferring the tacit knowledge.

The final phase of knowledge transfer is suggested to be through interaction, conversation and unstructured talks (Davenport and Prusak 2000) and this will be incorporated through many factors (such as F7, F21, F2). Davenport and Prusak (2000) also suggest forums and space for informal conversation. They explain that conversation is important because knowledge mostly comes from face-to-face meetings and phone conversations (2000). Further, they also discuss the benefits of attending conferences, which is also confirmed in the work of Maqsood et al. (2007) which is specifically investigating the AEC organisations and similar initiatives. In terms of knowledge transfer, both Leonard and Sensiper and Davenport and Prusak (1998) discuss the challenge of team dispersion across different locations and lack of communication face-to-face. They explain that the knowledge has the value of an asset only if it accessible (1998: 18) (F8). As a solution, they suggest technology systems to collect knowledge, while they explain that internet, intranet and e-mail systems have the benefit of storage, but this does not always result with knowledge creation. This is different in comparison to recent work on KM from the late 1990s onwards. For example, Massingham and Diment (2009), Frappaolo (2006), Hayes (2011) and

Alavi and Denford (2011), who explain the use of technology for not only knowledge sharing but also creation. Other authors, such as Senaratne and Bacic (2015), Robinson et al. (2005) and Egbu (2012), mention the use of KM technologies such as groupware, intranet, portals and others, for information sharing, communication, transfer and storage of knowledge but not for knowledge creation.

3.3.4.1.4 Other insights from the literature on KM

Top-management support

The management support is not only important for IM (see Section 3.3.1) but also for KM. KM authors, Davenport and Prusak (1998) discuss this as 'commitment'. Robinson et al. (2005) on KM in construction companies also finds that management support and leadership are necessary components to define strategies, clarify objectives and provide resources. The role of leadership is also discussed in the work of von Krogh, Nonaka and Rechsteiner (2012) as a sequel to knowledge creation theory by Nonaka and Takeuchi. Although leadership is not discussed much in the KM literature (von Krogh et al. 2012), it is discussed significantly in the IM literature and that is presented in Section 3.3.1.

In terms of leadership in KM, von Krogh et al. (2012) suggest having both centralised and distributed leadership (F13), because both planned and spontaneous types of leadership can benefit the knowledge-creation process and team performance (von Krogh et al. 2012, Carson et al. 2007). This is in accordance with previous discussions on IM, particularly Section 3.3.2, which present the idea of 'shared leadership' or a 'distributed leadership'. Chapters 5 and 6 compare this, factor F13, with the primary data to develop conclusions.

Trust

Frappaolo (2006), Davenport and Prusak, Long and Fahey (2000), all explain how important it is to have trust and collaboration to enable the knowledge-sharing culture. The role of trust is already discussed in IM Section 3.3.1. The concept is that trust enables access to knowledge. For example, Frappaolo (2006) explains that tacit knowledge can be shared through a mechanism such as 'communities of practice' and these are based on trust. In the context of a BIM team, these would be, for example, BIM champions or steering groups. The topic of trust is a broad subject in the KM and IM literature; therefore, to make conclusions that are the most relevant to the aim of this study, the key findings need to emerge from the data and experience of the industry experts.

Codification versus abstraction

During the 1990s, Boisot presented a model that provided more complexity to Nonaka and Takeuchi's model. His I-space model has 3 dimensions of knowledge, that measure knowledge in terms of codification, abstraction and diffusion (Boisot 1998). He discusses how undiffused knowledge has the highest value for a company (Boisot 1998). The more knowledge is coded, the easier it becomes to be diffused among other organisations. He explains that a technological innovation that is coded, but not yet diffused, presents a 'key technology' (Boisot 1998). This implicates that some knowledge does not need to be coded, but rather shared through the team in its tacit dimension – e.g. through socialisation. The KM work of Leonard and Sensiper (1998) also argues that some knowledge does not need coding.

Other evidence about the importance of tacit dimension is a study on KM and the management of unplanned change in construction by Senaratne and Sexton (2009), who explain that the change in construction teams is mostly managed with the help of experience, help of other team members, therefore tacit dimensions, rather than explicit knowledge within manuals or documents. This means that factors need to emphasise the tacit and social dimensions over the dimension of externalisation, particularly over the documenting aspect. Enabling socialisation and synchronous intermediation to provide access to knowledge, can be supported through: "intranets, instant messaging, online collaboration, e-mail, groupware applications… [and the] dossiers of individuals" (Frappaolo 2006: 33). However, technology cannot be a complete substitute for face-to-face knowledge exchange (Frappaolo 2006).

Frappaolo's (2006: 23) discussions on intermediation, also reminds us that there cannot always be a direct or timely communication between knowledge-seekers and knowledge-providers. For example, people work in different locations, they retire or they leave an organisation. Therefore, it might be beneficial to keep that knowledge and enable long-term access to that knowledge. A challenge of losing critical knowledge by losing staff is also mentioned in case studies of construction organisations such as Robinson et al. (2005) and Carrillo et al. (2013). Therefore, a solution is to code and document knowledge, particularly the explicit one, by using different technological solutions such as portals. Other solutions are expert systems, artificial intelligence and data mining (Robinson et al. 2005: 432). Chapter 6 compares this to practices to enable knowledge-sharing found in the data.

The KM literature provides several different ways of achieving codification, but it is not clear what dimensions of knowledge need to be documented for the purpose of BIM team development and this is one of the discussions of this study. For example, a study by Robinson et al. (2005) like previous KM theorists Leonard and Sansiper, Davenport and Prusak and Frappaolo, confirms that explicit needs to be supported through the technology. However, this suggestion is not easy to apply, as previously discussed, there is no clear distinction between tacit and explicit and knowledge is mostly in-between these dimensions. In the context of this study, knowledge about BIM software tools is a mixture of both procedures, rules and formulas and also has tacit dimensions: experience, social, cultural and aesthetic values, values on what is important to, for example, to present and accent in the model or data take-offs. Another challenge in practice is keeping competitive knowledge by storing it in an 'uncoded' dimension. Therefore, the findings need to show the industry's perspective and recommendations on achieving this in established teams, to find what specifically suits BIM team development context.

Learning from the experience

Experiential learning is important for both IM and KM. It was explained how experiential, tacit dimension is the key to innovation. Highlighting the importance of experiential learning, rather than software training organised by external providers currently present in the industry, is one of the contributions of this study and this literature discussion. This recommendation comes from investigations on IM and KM. At the beginning of this Section 3.3.4, it is explained how knowledge comes from experience and how experience belongs to a 'tacit' dimension of knowledge (such as Long and Fahey, Nonaka and von Krogh, Nonaka and Takeuchi, Kothari et al., Leonard and Sensiper).

Therefore, it is not surprising that new studies on KM also emphasise the importance of experiential learning. For example, there is a study on unplanned changes during construction projects by Senaratne and Sexton (2009). This study found that learning in construction teams during change events occurs through experience, although they did not explicitly describe it as an 'experiential' learning. A study on 'hybrid' BIM implementation by Davies et al. (2017), concludes that improvisation is needed to achieve BIM innovation process. They say that finding solutions, achieving a balance between desirable new practice and the existing one is an explorative process, that enables to build knowledge, skills and capabilities. From this study, it can be concluded that those organisations learnt from trying a new practice and experimenting, which is experiential learning. However, some other studies on KM in construction organisations, such as Robinsons et al. (2005), do not discuss this type of learning as part of organisational KM strategies, but rather stress the importance of transferring the knowledge between people, through communities and discussions.

Social knowledge and collaboration

Nonaka and Takeuchi mostly focus on individual and organisational levels of knowledge. While these levels of knowledge are critical in terms of creating ideas, there are also other levels of knowledge recognised. Long and Fahey (2000) distinguished between 'human', 'social' and 'structured' types of knowledge and these dimensions of knowledge provide additional insights for this study. 'Human' or 'individual' knowledge can be both tacit and explicit (Long and Fahey 2000). 'Social', mostly tacit knowledge is embedded into relationships between individuals, and it ensues from collaboration (Long and Fahey 2000). Being a team that consists of different disciples coming from one or multiple organisations, BIM team could have unstable levels of social knowledge. Therefore, in terms of development, from this point of view, there is an obvious implication of how beneficial is to have long-term team collaboration and to invest in building a team and trust inside the team, to support the social levels of knowledge (factors F10 and F11).

Conclusions by Bhatt (2002) state that there must be a collaborative environment, informal coordination and a highly flexible organisational structure; to create an organisational knowledge capital and also help individual knowledge. Bhatt discusses that an organisation "cannot dictate the rules of coordination and knowledge sharing" (2002: 34), however, it can support an open culture and an informal organisational environment that will help in knowledge sharing (F5). The idea of having a flexible organisational structure is also discussed previously in Section 3.3.3. as F16; and recommended in Section 3.3.1 by Ahmed (1999) as an enabler of an innovative culture.

Structured knowledge

The third, 'structured' type of knowledge, according to Long and Fahey (2000), is a part of a day-to-day practice and it is part of rules, procedures, processes, tools in an organisation. Unlike Polanyi's definition of knowledge (in Frappaolo 2006), they argue that knowledge can exist independently of humans and their example of such a knowledge entity was 'software' (2000). The structured type of knowledge helps information and knowledge to be shared, for ideas created by individual and social knowledge to be dispersed. Therefore, these rules should be flexible enough to accommodate new ideas and should also encourage trust and willingness to share information. This could be a practice of weekly group meetings where people would communicate their ideas regarding BIM team development (F7, F21) or a set of rules for communication exchange (F9). It is also important to check the existing communication practice in the company to make sure that there is no barrier that could lead to insufficient communication regarding BIM (F8). These actions would help a friendly, 'structured knowledge' environment for the purpose of individual and organisational BIM knowledge building.

Management of unknown and change

Managing knowledge is difficult as it is a management of 'unknown' and not "physical and tangible resources" (Bhatt 2002: 31). A challenge with KM today is in the inability of managers to have strictly defined future goals and plans due to the 'unstructured nature of knowledge' and their inability to have expertise in all knowledge areas (Bhatt 2002). In the case of BIM, this is a prominent problem as being an expert in all aspects of BIM would mean that an individual would also need to be an expert in all phases of the building cycle including design, construction, facility management, demolition or refurbishment, and an expert in BIM practice. An additional challenge is that the software environment is a highly dynamic environment, which means a need to be up to date. However, continuous innovation and the knowledge work are about continuous learning (Drucker 1999) and KM principles support this constant change and innovation (Frappaolo 2006). This makes KM ideal for the BIM team development process. This is another argument for implementing principles of KM for the purpose of this study.

Participation and independence - for sustainable change

An organisation, that Bhatt (2002) categorises as a 'highly interdependent organisation' 'without a strict routine' in terms of tasks, is the equivalent to an AEC company in this study. Bhatt explains that in such organisations experts are the key. However, for such organisations to grow and develop collaborative knowledge, as explained previously, there is a need to enhance the interaction between all members. Relying on one person, such as a BIM expert, would not allow the team to develop and change their ways of working. All team members involved in a change must participate and build the organisational knowledge as a team, so as to make that change sustainable.

The main suggestions on managing 'highly independent', 'non-routine task' teams are:

- Support 'self-organised teams' and social interactions – such as informal meetings or internet groups (Bhatt 2002). This is applied as F7;
- Have 'multiple interpretations' of tasks; brainstorming tasks and suggesting different solutions until all parties come to a consensus and a 'shared understanding' (Dierkes, Child and Nonaka 2003). This is applied as F21, F12, F2, F13;
- Empowering employees will motivate them "to take extra responsibilities to solve organisational problems by learning new skills at the jobs" (Anahotu 1998 in Bhatt 2002: 38). Making people feel safe, independent and appreciated is key to make an open and collaborative environment (Steiber 2014). These translate into factors F10 and F5.

Lessons learnt

Lessons learnt, in the form of post-project reviews or periodical project reviews, is a practice of understanding and reflecting on project challenges and positives, that can benefit knowledge of the team and future projects of the organisation. Lessons learnt are a common tool in the construction industry to improve the existing practice (Carrillo et al. 2013). It was previously explained how knowledge is a result of reflection and how beneficial is to reflect and discuss, in the work of Nonaka. It was also explained that this principle is applied as the factor F21. However, in the construction industry, due to time pressures, project team members often do not reflect on how they tackled project challenges or changes, which could benefit future projects but also benefit their learning (Senaratne and Sexton 2009). Other reasons for the lack of reflection are people being involved in multiple projects, leaving the project towards the end or simply not willing to share their knowledge or not willing to share negatives about the project.

According to Senaratne and Sexton (2009), having lessons learnt enables the knowledge to be externalised and codified and avoids 'superficial learning'. There is more evidence about benefits of 'lessons learnt' in other studies such as Carrillo, Ruikar and Fuller (2013), Senaratne and Bacic (2015), Frappaolo (2006) and Carrillo (2005). However, there are also challenges in the way lessons learnt are prioritised, organised, time limitations and in terms of future use of documented findings. Carrillo et al. (2013) explain that lessons learnt are sometimes a part of organisational requirements to store the knowledge, however, that might not benefit those who helped to create those lessons.

3.3.4.1.5 Conclusions and additional implications for this study

One of the main conclusions from Section 3.3.4 on KM, is that shared, organisational knowledge is built through the interactions of people. "By interacting and sharing tacit and explicit knowledge with others, the individual enhances the capacity to define a situation or problem" (Nonaka et al. 2006: 1182). There is, therefore, the potential to improve both 'organisational' and 'individual' knowledge if managers improve the interaction. In the context of BIM team development, this can be achieved with more meetings or other mechanisms such as brainstorming sessions, planning as a team, having interest groups, deciding together and providing space and time to share ideas. Encouraging a culture of openness and trust also helps the interaction. As a result of these findings, there are factors F7, F21, F2, F12, F13, F5 and F10.

KM literature suggests that, apart from the interaction and involvement of people, to acquire and share knowledge. KM literature, such as Leonard and Sensiper (1998), Frappaolo (2006), and the systematic review findings (F17), also recommend to focus on improving the existing practice. By merging these two ideas, for the purpose of BIM team development, it can be beneficial to encourage people to take an active part in BIM learning process: exchange ideas between each other and clarify as a team how can BIM improve the existing activities. This is translated into several factors, such as F17 and also factors on planning and discussing as a team.

In terms of access to knowledge, this can be achieved with guidelines, structured training and intranet libraries (Frappaolo 2006). In BIM team development context, literature findings suggest that internal structured training can be a way of both coding and transferring the knowledge, when organised by internal members of an organisation. This would also provide a context and time for people to meet and discuss issues they are facing. Having an internal training would enable people to openly ask questions as they know each other. However, the structured training has a risk of being 'too structured' which is not recommended in KM (Davenport and Prusak 1998). These ideas are later compared to primary data on training – under factor F18 (Section 6.19).

Innovation stems from its collaborative and tacit knowledge dimension in an organisation. Therefore, an additional conclusion, based on this literature discussion, is that for BIM innovation and team development, having a 'BIM expert' who is not able to transfer the knowledge or who is discouraged of sharing it, would not help the organisation in the long-term. There must be an incentive to encourage BIM experts to share knowledge.

3.3.4.2 Additional insights for KM and IM: case study examples

This study also searched for some current examples of managing knowledge and technological innovations in different industries related to software or technological design - to inform this study's direction. A well-known example of an interactive, knowledge-sharing environment is Google. They claim to have as many channels for peoples' expressions as they can such as: weekly open meetings where people are free to talk with executives; or the Google Moderator tool, also used during meetings, which encourages people to ask any question and to respond to a question of their choice (He 2013). They also encourage people to spend free time together, e.g. Google café, to discuss ideas during informal meetings as according to their management "ideas come from the collective wisdom of people" (Steiber 2014: 54). They also encourage new employees to act independently and work on their own pilot projects, which further supports the culture of trust and appreciation (Steiber 2014). This encourages people to share their potentially innovative and effective ideas with people who have the power to put these ideas into reality.

Seeking an idea outside the organisation is also encouraged. This approach is relatively new for most of the organisations, but big creative companies such as Danish electronics company Bang and Olufsen (B&O) after their crisis in early 2000 realised the potential of an open culture (F5). They implemented principles of IM; one of them being able to “recognise that the basic unit of innovation is a network that includes people and knowledge both inside and outside the organisation” (Parikh 2008: 2). Therefore, they also recognised the importance of having a collaborative and engaging environment to support knowledge sharing and therefore also help knowledge building. Other than providing recommendations for KM, these findings are also in accordance with IM discussions within Section 3.3.2 on the involvement of team members.

Creating a flexible organisation and B&O example

A flexible organisational structure is a team able to learn quickly when it comes to a new software solution or new client demands. This idea was also previously discussed within IM discussions, Section 3.3.3. The idea is that an organisation should be open to research and go through trial projects in order to learn. Previously mentioned company B&O did not overlap the production of new projects and it took them years of time to lunch a new idea. This linear, non-experimental process inhibited learning and development (Parikh 2008). In terms of BIM development, this case suggests that a team should try implementing BIM even as a trial as it can learn and benefit from that experience.

Parikh (2008) noted that the inability of the top-management to understand the design decisions was another challenge for the team, as the management could not decide without relying on designers and their ideas. For the aim of this study, this indicates that new ideas should be understood and supported both bottom-up (design-driven) and top-down (top-management driven) to find solutions more quickly and provide greater flexibility in the decision-making process. Apart from the project team, other professions in the wider team, such as law professionals or financial managers, should also have some understanding about BIM. This is a principle that supports the idea of engaging more people, discussed several times in Chapter 3 (e.g. ‘Participation and independency’ in Section 3.3.4.1.4.).

3.3.4.3 Motivation and opening mindsets – KM and IM perspective

People are a critical source of knowledge and consequently, a key source of innovation. Without skilled and motivated people, there would not be a generation of new ideas (Baumard 2002 in Lu and Sexton 2006: 1271). Motivation is an aspect connected with both KM and IM and for those reasons, motivation is discussed separately below.

<u>IM literature on motivation</u>
IM studies by Ahmed (1999) and Hartmann (2006) suggest managers to use a system of rewards. While Ahmed (1999) argues for intrinsic rewards as being more effective to encourage innovation adoption, Hartmann suggests both intrinsic and extrinsic ones, explaining that managers need to set goals, provide feedback and give rewards or incentives (2006). A different perspective is given by Peansupap and Walker (2005) who find that rewards have very little impact on people adopting ICT technologies, particularly extrinsic ones. It is not clear if and how rewards could contribute towards BIM team development, therefore this dimension is not incorporated as a separate factor, but the study is open for suggestions to emerge from the data.

Another idea that emerged from the literature is the ‘concept of pressure’. In Duggan (1999), the concept is about bringing the pressure - such as competitions - to support a culture of innovation (F20). In the study of BIM innovation by Singh (2014), a similar concept discussed is the ‘perceived degree of freedom’. Singh argues that there needs to be a pressure for people to accept an innovation. There are more findings in studies on applied psychology, to bring the competition as a tool to enable the independence and creativity of opinions (Runco 1994 in De Dreu and West 2001). However, Ahmed (1999) explains that pressure is not productive for IM. The ‘concept of pressure’ becomes a factor F20 and it is later discussed with the primary data.

Supporting creativity, new ideas and not being afraid to make mistakes are some of the dimensions that support both IM, motivation and commitment (Hartman 2006) (F5, F15). These are also discussed in ‘Culture and leadership’ (Section 3.3.1.) and applied through a few factors – such as F5 and F15. Motivation is one of the key dimensions in IM literature and it is previously discussed in Section 3.3.2 that a way to achieve it is through greater engagement of team members. This is previously discussed in Section 3.3.2 and is only briefly noted here to complete the discussion about the motivation and IM.

KM literature on motivation

The importance of motivation is already mentioned in Section 3.3.4. Lu and Sexton (2006) and Davenport and Prusak (1998) claim that motivation is one of the crucial factors that affect the creation and management of KM and innovation. Alvesson and Empson (2008) also explain that there are significant correlations between the knowledge sharing, strategic choices, organisational identity and motivation and commitment. However, there are suggestions in the KM literature, such as Nonaka and von Krogh (2009), that there is more to investigate to understand how to manage motivation and commitment of people to improve the organisational knowledge.

A study on KM in the construction industry by Robinson et al. (2005) confirms that there must be incentives or systems of rewards to support KM. They recognise a need for “financial, promotional or peer acclaim” (2005: 433), where they particularly suggest the peer acclamation method and “soft rewards”. This is similar to the work of Venkateswaran and Aundhe (2013) on KM in the AEC industry, who also recommend a system of rewards to support the knowledge sharing. While both KM and IM literature lean towards intrinsic, soft measures the recommendations are broad. The primary data findings need to investigate the role of rewards and understand if rewards need to be incorporated as a separate factor or within the existing ones.

Achieving motivation

There are many studies and models on managing motivation (Hartmann 2006). However, due to the scope of this study, the focus is on a few, key theoretical models. A study on training effectiveness by Noe (1986) expresses the close relationship between motivation and learning development explaining that “motivation and attitudes are malleable personal difference factors that play a critical role in achieving training effectiveness”. According to George and Jones (2005: 175), it is a factor which determines peoples’ behaviour when facing challenges in general. According to the ‘need theory’ and psychologists, work of Abraham Maslow and Clayton Alderfer, motivation is based on satisfying needs of employees, which is according to Alderfer ‘existence’ (Maslow’s concepts: ‘safety’, ‘physiological’), but also higher levels of needs such as ‘relatedness’, ‘open communication’, ‘good interpersonal relations’ (which are similar to Maslow’s ‘belongingness’ and ‘esteem’) and ‘growth’ (Maslow’s: ‘self-development’, ‘ability to work creatively and productively’) (George and Jones 2005: 181-184). Looking at the BIM development context, this study proposes that the training and development should focus on ‘relatedness needs’ and particularly on ‘growth needs’; and this is incorporated into factors: F12 shared decision-making, F1 shared vision, and factors to support collaboration - F5 open culture, F7 open communication, F21 creation of ideas through reflection and F19 experiential learning.

Two studies about BIM implementation strategies, discussed in Chapter 2, Lee et al. (2015) and Son et al. (2015), investigate the intention of people to adopt BIM in a similar way as theories of motivation. Son et al. (2015) recognise these needs as 'behavioural intention' which depends mainly from questions - 'how useful can BIM be?' and 'how easy would be to use it?'; while Lee et al. (2015) also identify categories of 'behavioural control' - top-support or pressure; as more significant ones, and team consensus as less significant. The 'pressure' factor is also identified by Tabassi et al. (2012) who explain that motivation is higher when the training is compulsory – which is factor F18. The 'perceived usefulness' is the critical category in studies by Son et al. (2015) and Lee at al. (2015); and this can be explained with the 'expectancy theory': "do individuals believe that their inputs will result in a given level of performance?" (George and Jones 2005: 181). Therefore, the focus of the motivational strategy should be on clarifying how useful BIM can be for peoples' skills and projects, and how BIM can help them to achieve their project's outcomes (F1, F4). There must also be a 'pressure' or top-management support towards BIM initiative (F18, F20). It should also be clarified what actions should be taken to develop BIM skills or work with BIM (F2, F4). In the 'need theory', this aspect is defined as 'an input' or 'an effort'.

In terms of the categorisation of motivation, to understand how each factor contributes towards motivation, the researcher adopted the categorisation made by Adriaanse, Voordijk and Dewulf (2010). There are other categorisations, with the most common one being 'intrinsic' and 'extrinsic' (Deci and Ryan's 'Theory of Motivation' 1985, George and Jones 2005). However, this model is more suitable, being a model constructed specifically for an ICT change or adoption in organisations. Therefore, it is more precise and practical, being customised for the purpose similar to this study. Adriaanse, Voordijk and Dewulf (2010) model divide motivation factors into:

- Personal motivation (perceived benefits and disadvantages of ICT use; perceived time pressure);
- External motivation (availability of contractual arrangements; the presence of requesting actor);
- Knowledge and skills (clarity of procedural agreements; clarity about the operation of ICT);
- Acting opportunities (alignment between ICT and working practices; availability of technical means).

There is a parallel between this model and previously mentioned theoretical models, however, as mentioned, this model suits the aim of this study more closely. This model and previous theoretical findings both contributed to defining the final BIM team development factors. A way to integrate Adriaanse, Voordijk and Dewulf (2010) model is achieved in this study by ensuring that all motivational aspects are translated into factors; and this is presented in the final Table 3.4.

3.4 Change Management perspective

This chapter shows how the key conclusions emerging from the CM literature are applied to help BIM team development. Firstly, there is a reflection on previous findings about BIM team implementation challenges to show the relation between CM and BIM adoption. Then there is a summary of previous IM findings, which reveals a connection between IM and CM. Then, to understand the concept of change and principles of CM, well-known CM models – Lewin, Kotter and ADKAR, are discussed. However, due to the scope of the study, this study applies principles of one model by Kotter, found to be the most applicable, widely accepted and well-known model. The discussion also includes studies on CM in the AEC industry and incorporates these findings as well.

3.4.1 Planning BIM team development process and strategy: reflection on IM suggestions and the application of CM to BIM team development

The rationale behind the application of CM has been discussed previously in Chapter 1, Section 1.1.3 and Chapter 2. Firstly, the existing literature on BIM implementation highlights that there is a lack of enthusiasm in the AEC teams to learn more about BIM practice and develop skills (Mahalingam et al. 2015, Arayici et al. 2011b, Sackey et al. 2015, Ahn et al. 2016, Won et al. 2013) and resistance to change the existing practice (Ahn et al. 2016, Arayici et al. 2011a, Arayici et al. 201b, Babič et al. 2010, Mahalingam et al. 2015, Sackey et al. 2015, Won et al. 2013). Some of these studies, discussed in Section 2.3, by applying TAM models already explore factors that contribute to a greater acceptance of technology in the AEC teams. They identified how important is to address ‘perceived usefulness’, provide ‘top-support’, manage perceived ‘ease of use’ in teams, ensure ‘compatibility’ of tools and other factors. It is found that TAM studies and studies that argue for middle-ground and bottom-up implementation (See Table 2.2) provide insights on managing resistance and motivation; however, they do not apply formal CM models such as Kotter, ADKAR or Lewin. It is also found that more recent studies recommend more research to be conducted to investigate change management factors in the AEC industry and issues such as resistance to change (Lines et al. 2015 and Lines and Vardireddy 2017). By applying CM models, this study obtains a better understanding of managing BIM implementation issues such as commitment and resistance, topics which are central to CM (Kotter 2012, Dawson and Andriopoulos 2014). This study also provides a greater body of research for CM in the AEC industry.

There is a connection between CM and IM. Creating an innovative organisation means creating an opportunity for a change in an organisation. Through IM discussions it was found that there are many overlapping points between CM and IM, such as the importance of vision, culture, motivation, understanding benefits and others. Furthermore, particularly when it comes to a ‘technological change’, CM can be better explained and seen through both innovation and CM perspective, as they complement each other (Hughes 2006). King and Anderson (2002) also discuss innovation and change together. Therefore, there is a sense to bond principles of innovation and change together; and see BIM team development as a ‘technological change’, ‘cultural change’, IM matter, ‘individual and organisational change’, ‘group and team-based change’ and a ‘knowledge management’ matter. This was also discussed previously in Section 3.2. Discussing BIM team development as both CM and IM, is also one of the main contributions of this study for both the industry and the academia.

In the previous systematic literature on BIM implementation (Chapter 2) and KM discussions, it was advised to have the innovation to ‘support the existing practice’. CM literature also suggests not to have a radical change in practice, particularly in terms of culture (e.g. Hughes 2006). Another point discussed in Section 3.3.2 was about the importance of having the involvement of the team members, which is also found to be important in CM. Therefore, a solution presented in this study reflects the idea to engage people with BIM change and learning process as if it is their own project. This can be achieved through factors such as: F12 shared decision-making, F1 creation of vision as a team, F19 experiential learning, F21 reflection, F2 planning as a team and F13 shared leadership. The participants would not only learn, but also share their knowledge, brainstorm learning objectives as a team and potentially participate in teaching others. This way, the process is flexible, specific to peoples’ needs and sustainable for future improvements. Through individual and team engagement participants can also develop collaborative skills, build an innovative culture, idea generation and problem-solving skills, which are also beneficial to support BIM culture and practice.

3.4.2 Theoretical models of change

CM is a structured management approach that enables teams to accept new products, processes or a practice and effectively manage resistance to change. To achieve the aim, this study applies Kotter's model, Lewin's model and other relevant suggestions from CM literature. Kotter's model is classified as an N-step change model and it comes from Lewin's three-step model (Dawson and Andriopoulos 2014). Aside from Lewin's 1947 model, there are other CM models, ADKAR (Hiatt 2006), Fullan (2011) and many others. These models suggest similar key processes to implement a change. For example, the 'unfreezing' phase in Lewin's model suggests that the creation of discomfort will motivate people towards the change, similar to Kotter's first principle on increasing urgency (Lewin 1947, Schein 2017, Kotter 2012). The similarity of CM models is specifically investigated by a few authors such as Brisson-Banks (2010) who confirms that there is a similarity between models created by Lewin, Beckhard, Thurley, Bridges and Kotter. Similarly, Biech confirms the similarity between Lewin, Kotter, Ulrich and Evans and Schaefer (2007). This similarly shows that applying Kotter's model means applying universal and well-known principles which are proven to deliver results. However, this study shows later in Section 3.5 and in Chapter 7 that Kotter's model does not cover all aspects needed to achieve BIM team development change.

3.4.2.1 Lewin model

The '3-Step Model' model by Lewin is one of the first models of CM. It emerged from his work on force field theory (Lewin 1947). In accordance with it, Lewin suggests that change occurs when there are forces that change the team's values, beliefs and habits. A way to achieve this is through group discussions, also suggested in IM, and established as F21 and F2 in this study. In this model, the CM process includes: 'unfreezing', 'change' and 'refreezing' phrase. The first phase includes challenging the present state and envisioning the future – achieved in this study with F1. Work of Schein further continues and explains Lewin's model (2017). He discusses how the refreezing phase causes survival anxiety and learning anxiety. Survival anxiety is caused by leaders while learning anxiety is caused by a discomfort about unlearning previous knowledge, fear of incompetence, issues with identity and group recognition. To overcome learning anxiety and start with the second step, he suggested creating a safe environment where people are not afraid to make mistakes.

To achieve that he recommends:

- The creation and distribution of a positive vision by senior management (translated to F1 in the theoretical list of factors),
- Organised training for all team members and letting people individualise their learning (F18),
- Providing resources to support learning (F3),
- The ability to practice (F19),
- Role models to enable observational learning and supporting groups (F3),
- Rewards and control (Schein 2017: 328-329) (F3, F9).

These suggestions are also in accordance with IM (such as rewards, communities of practice and vision). This also shows how KM is an enabler of both IM and CM and confirms that CM enables IM (Figure 3.4 below).

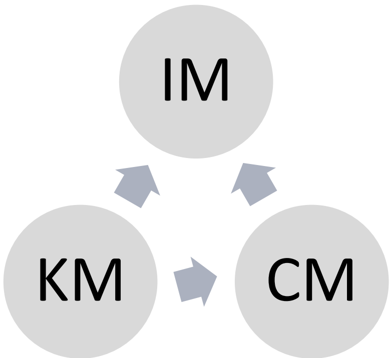

Figure 3.4 Relations between concepts of IM, KM and CM

The 'change' step in Lewin's model includes people's engagement in the process. Indeed, a failure to adopt new technologies is often due to a lack of communication and people's engagement (Levasseur 2001 and 2005). Therefore, active participation would be key in this CM strategy. This idea is also in accordance with other theories such as the ADKAR and Kotter model. The ADKAR individual model of change similarly explains that there must be a desire to participate in change as "participation creates passion and commitment to success" (Hiatt 2006: 97). Involving people is one of the aspects discussed in Section 3.3.2, which is another alignment between IM and CM, and this is incorporated through F1, F2, F7, F12, F13 and F21.

The 'change' phase according to Schein should include trial-and-error learning and learning by imitation (2017). For the imitation, there needs to be a role model which might be difficult to find for all BIM teams, as the person needs to have not only skills but also the right attitude and beliefs.

The trial-and-error is more suitable as it fits the change that cannot be fully visualised (Schein 2017), therefore it suits BIM team development.

The last step, 'refreezing', is about ensuring that the change is sustainable, through evaluation, 'lessons learnt' and through integration into the existing practice (Lewin 1947 in Cameron and Green 2012), which is also in accordance with IM and systematic review findings. Lewin also suggests the use of experiential learning and then reflection (Lewin 1951). This later inspired the well-known Kolb model on experiential learning (Miettinen 2000). As a result of this discussion, principles are integrated as factors on 'reflection' F21, F17 'supporting existing practice' and F19 'experiential learning'.

3.4.2.2 Notes from 'Leading change' and BIM team development model

Table 3.1 Kotter change model and its application within factors

Kotter's model principle (2012)	Explanation	Factor in this study
Urgency (1)	Vision to show benefits, what can be improved. Top-management to initiate the change.	F1 – vision; F20 – pressure; F21 - what can be improved; F3, F18 – support and training; Others in text: F2, F12, F13, F5, F1, F17.
Creating a coalition (2)	Management support, experienced members and encouragement for ideas from the whole team	F3 – management support; Others in text: F12, F13, F5, F15, F21, F11, F7, F8, F9.
Developing vision (3)	Having the vision to inspire and guide the team. Created by the guiding team.	F1 – vision.
Communicating vision (4)	Many ways of communicating a vision about BIM.	F1 – vision; F4 – clarity about change.
Empowering action (5)	Having a motivating vision. Identifying challenges and solutions, involving the team.	F1; F21, potentially F2, F12.
Short-term wins (6)	Having rewards.	Within F3 – management support.
Consolidating change (7)	Providing enough time – not giving up from the change.	Potentially F3.
Anchoring it in culture (8)	Understanding within the team how BIM change helped the practice.	F1 – communicate benefits; F21 – lessons learnt on how BIM helped the practice.

A well-known model of Kotter (2012) presents eight phases or eight common errors in change management, summarised in Table 3.1. They are discussed below and applied to benefit BIM team development and CM process.

Implementing principle 1: establishing a sense of urgency (error: allowing too much complacency) (Kotter 2012: 37)

Change can be challenging if people believe that there is no reason to improve their practice. On the other hand, realising problems as a challenge or a change that they cannot overcome is equally problematic (Kotter 2012). Kotter suggests encouraging identifying problems but also solutions straight away. For example, the team can focus on areas of improvement, instead of challenges. The management should increase urgency, but also create a non-judgmental and supportive environment that produces solutions. Urgency can be created in the form of a top-management initiative to assign a BIM training and investing more effort and resources, regarding BIM (F3, F18). Challenges and solutions could be discussed through brainstorming sessions (F21). A supportive environment is created if tasks are assigned to teams rather than individuals (F2, F12, F13). It can also be created by having a culture of openness, by having a common vision and by implementing ideas that are supporting a good existing practice (F5, F1, F17).

Implementing principle 2: creating the guiding coalition (error: failing to create a sufficiently powerful guiding coalition) (Kotter 2012: 53)

This step affects the motivation of the entire team. Kotter suggests that change can only be possible when "the head of the organisation is an active supporter" and the change coalition is powerful in terms of reputation, relationships, leadership, experience, titles (2012: 6). People cannot make a significant change on their own unless they have a team on their side to support their ideas (Kotter and Rathgeber 2006). This means that for BIM team development, we must:

- Include management support (F3);
- Have people with experience to tackle short-term goals. They should have an interest in BIM and be resistant to go back to the previous way of working (F3);
- Create an environment which asks for new ideas and suggestions from the entire team. This is later incorporated through factors: shared leadership and decision making - F13, F12, team building F11, openness to new ideas F15, open environment F5 and reflection F21.

Sometimes, even when individuals can develop a change on their own, due to their title or authority they might be limited, particularly if there is a lack of understanding from management. The case of B&O, in Section 3.3.4.2, explains why this could be challenging. It is important for both management and team members to understand new ways of working and processes and avoid relying on individuals. This helps the team in terms of adaptability when members are missing or when tools change (F14). Including more people also helps to generate new ideas.

Kotter suggests that there must be a change embedded as a structural change to have a behavioural change (2012: 6). The discussion on KM, Section 3.3.4.1.4, recognised structured knowledge to be a set of rules or processes that enables knowledge transfer and allows an innovation to happen. Therefore, the process should be fully supported by the management: in terms of time and communication strategy (F7, F8, F9) and the project should not be considered as an option, even if it is a trial BIM project (F20).

Implementing principle 3: developing a vision and strategy (error: underestimating the power of vision) (Kotter 2012: 69)

According to Kotter and the literature on organisational management, there must be a sensible vision to "direct, align and inspire action" (2012: 8) created by a guiding team (Kotter and Dan Cohen 2002). Creating a strategy or plans without a vision is not efficient because the main ideas about the change would not be communicated clearly. According to Kotter, this vision should be explained in less than five minutes. It is also important that this vision motivates and encourages the entire team to contribute. This is incorporated as F1 and F4.

Implementing principle 4: communicating the change vision (error: under-communicating the vision by a factor of 10, or 100 or even 1000) (Kotter 2012: 87)

The vision should be communicated in more than a few meetings. It should be communicated by all managers and their decisions must be in accordance with this vision.

Implementing principle 5: empowering broad-based action (error: permitting obstacles to block the new vision) (Kotter 2012: 105)

Kotter explains that "initiatives fail when people are disempowered" (2012: 10). Therefore, it is important to create a vision that motivates everyone. It is also important to identify existing obstacles with the management, but also with the entire team. Then as a team, it is important to find solutions to those obstacles, in accordance with the new vision. However, ultimately, it is up to the company how they would like to empower their employees. This is incorporated as F1 and F21, and partly through F2, F12.

Implementing principle 6: generating short-term wins (error: failing to create short-term wins) (Kotter 2012: 121)

Although it takes significant time to achieve the main vision, there should be some 'wins' in-between. People should be rewarded, as suggested previously, in multiple ways, such as recognitions or promotions. This is included in F3 top-management support factor.

Implementing principle 7: consolidating gains and producing more change (error: declaring victory too soon) (Kotter 2012: 137)

Usually, it takes several years until the change is truly embedded in everyday practice. Kotter notes it could take 3-10 years for that (2012: 13). It is important that the company keeps updating the process with new people, knowledge and new supportive practices. For BIM implementation to see results, waiting for several years and a constant investment could be challenging.

Implementing principle 8: anchoring new approaches in the culture (error: neglecting to anchor changes firmly in the corporate culture) (Kotter 2012: 153)

There must be a clear vision on how a desired change can benefit the organisation. Regarding BIM team development this can be: being better than competitors, better project communication, more effective practice, working on Government projects or with any other company who wants to utilise BIM and other organisation-specific goals. This vision also influences behaviour and social values. The best way to achieve it is to "show people how specific behaviours and attitudes helped improve performance" (2012: 15), preferably after achieving short-term targets.

3.4.2.3 Other conclusions from the literature on CM and IT adoption

Looking into the recent literature on CM and technology adoption in the context of the construction industry there are a few new and some repeated recommendations. The work of Lines and Vardireddy summarise key factors for CM (2017) - managers need to be aware that a project's type and size, experience and hierarchy within the project can all influence the change. Another key point is that managers need to set achievable expectations and deliver the message about the change through education (2017). This is similar to the concept of vision in Lewin's and Kotter's model (Figure 3.4). The leading management also needs to prepare a leading team, as previously recommended in Kotter's model (1995). As a conclusion, Lines and Vardireddy (2017) explain that leadership is very important for CM. This is also aligned with IM discussions, in Section 3.2.1 and 3.3.1, where it is explained how top-support and leadership are critical to IM. For this, Lines and Vardireddy (2017) suggest a leading team to be with the project team daily to support the new practice. Other ways to tackle the resistance are in terms of having patience, time and achievable goals. They also suggest implementing a less radical change; which is in accordance with Hughes (2006), conclusions about supporting existing practice made in the systematic review (Chapter 2) and IM. It should be mentioned that the number of studies that investigate CM in the construction sector is very limited. Lines and Vardireddy (2017) claim how they were a first empirical study on CM in the AEC industry, and they published their work in 2017.

There is more work on CM and IT adoption in general, such as that of Henderson and Ruikar (2010) who explain that CM cannot be improvised, but structured and managed. Their key idea was to reduce uncertainty about the change, while other suggestions were to involve more people across the team, regardless of their position. This was already suggested in IM and CM theories – in Section 3.3.2. For this, they recommend a suggestion forum, which would encourage communication and idea creation. Like previous literature, Henderson and Ruikar also suggest that management needs to tackle challenges and provide resources, such as training, time and "communities of practice" (2010: 326). Other key points include having "enhanced levels of training, education and two-way communication" (2010: 326), which aligns with previous literature discussions. Overall, their approach was that technology implementation is firstly a human behavioural challenge, rather than technical.

Some literature discusses the classification of change and innovation as radical or incremental, planned or emerging, transforming or readjusting (Dawson and Andriopoulos 2014, Cameron and Green 2012, Hughes 2006). However, in BIM team development context, change can be both, depending on the existing situation in the team and their choice. The level of change might be higher or lower depending on the existing practice, skills, software and standards, the team is already employing. Their choice can be to have either radical or incremental change, depending on their adaptability and agility discussed in Section 3.3.3. However, the systematic review in Chapter 2 finds that incremental BIM change, applied as a bottom-up implementation, is more successful. Another previously made conclusion is that it is beneficial to implement the change to support what is already 'good' practice in the existing team and an incremental change can achieve this more easily than a radical one (F17).

However, the concept of competitive advantage in IM suggests that potentially radical and quick change may also be a solution. In fact, Worley and Mohrman (2014) argue that traditional CM models are incremental in nature and they might be outdated and not fit the new, dynamic age. It is argued that Lewin's 'equilibrium' does not exist and that companies need to be prepared for both radical and incremental change. They suggest a new model which incorporates principles of 'awareness' about the team, the ability to 'react quickly' ('adaptability' in Section 3.3.3 and factor F14), 'customising' the change strategy, 'monitoring' and 'adjusting' the process. This study agrees that the strategy needs to be adjusted to fit the context. They also suggest more power to be given to a wider team and networks, which is also suggested in the systematic review, Chapter 2, and in IM, Section 3.3.2. However, it is also noticed that their core idea of having a 'continuously adapting team' who constantly learns through change is, in fact, one of the core principles of IM and Agile discussed previously in this study. This further proves how beneficial is to integrate CM and IM principles to get the benefits of both (see Figure 3.4). Further discussion on the topic comes from the primary data, that provides additional opinions on the topic from the industry experts to confirm or argue these suggestions.

Looking into a number of factors that emerge repeatedly in IM, KM and CM, it can be concluded that these 'repeating' factors are the key factors for BIM team development process. This also shows how closely related these fields area. The findings need to show how the primary data support these factors, to what extent there is an agreement and where are the differences. Furthermore, the analysis should allow for new critical and emerging ideas to come from the primary data, that were not emphasised or mentioned in the previous literature.

3.5 Summary of critical factors for BIM change management and team development

This study aims to build, implement, test and further improve BIM team development strategy presented in Table 3.2. Whilst investigating IM, KM and CM literature and literature on BIM team development, this study identifies a number of factors relevant for the process of BIM team development. These factors, or areas of improvement, are presented in Table 3.2 and tested with the primary data in Chapter 5 and Chapter 6. Some factors are concepts present in the existing literature, whilst others are conclusions derived from literature discussions in Chapters 1, 2 and 3.

Table 3.2 Summary of factors for improvement, their relation to motivation and collaboration and references which helped in defining them

n	Variable – Area of improvement	Motivation factor – model by Adriaanse, Voordijk and Dewulf (2010)	Collaboration factor	A non-exclusive list of literature which influenced the creation of the factors
1	Aligning vision (agreeing a common vision)	c) Knowledge and skills		Carson et al. (2007); SECI model (Nonaka and Takeuchi 1995); Motivation, authors such as George and Jones (2005) (See 3.3.4.3); Lewin (1951) model; Kotter model (Kotter 2012); Leonard and Sensiper (1998); Dierkes, Child and Nonaka (2003)
2	Planning future actions as a team	c) Knowledge and skills		Discussion in 3.3.2: conclusion based on Mayo (1933 in Davis 1968), Likert (1961), Davis (1968), Locke et al. (1986), Ahmed (1999), Hartmann (2006), Goodman and Dingli (2017), Senaratne and Sexton (2009), Duggan (1999), De Dreu and West (2001), Peansupap and Walker (2005); Kotter model (Kotter 2012); SECI model (Nonaka and Takeuchi 1995); Dierkes, Child, Nonaka, (2003) Leonard and Sensiper (1998); Lewin (1951) model; ADKAR model (Hiatt 2006); **Figure 3.1** Different opinion: Cudanov and Jasko (2012), Locke et al. (1986).
3	Establishing top-support sub-topics: structure, empowerment, rewards, innovation champions, knowledge portals, leadership	b) External m.		Carson et al. (2007); Davenport and Prusak (1998); Steiber (2014) (‘empowerment); Kotter model (Kotter 2012); Moran (2015); Case B&O; Case Google; Bhatt (2002) (‘empowerment’); Goodman and Dingli (2017); **Figure 3.1**
4	Clarity about the change process	c) Knowledge and skills		SECI model (Nonaka and Takeuchi 1995); Adriaanse, Voordijk and Dewulf (2010); Kotter model (Kotter 2012); **Figure 3.1**
5	Ensuring an open culture			De Dreu and West (2001); Carson et al. (2007); Wheatley (2007); SECI model (Nonaka and Takeuchi 1995); Davenport and Prusak (1998); Leonard and Sensiper (1998); Bhatt (2002); Steiber (2014); Discussion in 3.1.4.3; George and Jones (2005); Kotter model (Kotter 2012); Bhatt (2002); Goodman and Dingli (2017); **Figure 3.1**
6	Diversity in the team (e.g. skills, roles)			Nonaka and von Krogh (2009); SECI model (Nonaka and Takeuchi 1995); Wheatley (2007);

				Leonard and Sensiper (1998); Brewer and Mendelson (2003); Horwitz and Horwitz (2007); Senaratne and Sexton (2009); De Dreu and West (2001); Moran (2015)
7	Communication digital and non-digital information exchange (regular meetings, face-to-face meetings, discussions)	c) Knowledge and skills		Cole (2019); SECI model (Nonaka and Takeuchi 1995); Leonard and Sensiper (1998); Davenport and Prusak (1998); Nonaka and von Krogh (2009); Nonaka et al. (2000, 2006); Bhatt (2002); Discussion in 3.1.4.3; George and Jones (2005); Leonard and Sensiper (1998); Levasseur (2001 and 2005); Kotter model (Kotter 2012); Moran (2015) Goodman and Dingli (2017); **Figure 3.1**
8	Enabling access to information (interconnectivity of team members, ability to get information)	c) Knowledge and skills		Bhatt (2002) Wheatley (2007); SECI model (Nonaka and Takeuchi 1995)
9	Ensuring reliability of information (a transparent flow of information, ensuring up-to-date information)	c) Knowledge and skills		SECI model (Nonaka and Takeuchi 1995); Kotter model (Kotter 2012); Long and Fahey (2000); Different opinion: Bhatt (2002)
10	The culture of trust and respect	a) Personal motivation b) External m.		Goodman and Dingli (2017) Lu and Sexton (2006); Duggan (1999); Brief and Guzzo (1996); Ahmed (1999); Frappaolo (2006); Davenport and Prusak (1998); Long and Fahey (2000); Case Google - Steiber (2014); Discussions in 3.3.4.1.5; **Figure 3.1**
11	Team building			Goodman and Dingli (2017); Cole (2019); SECI model (Nonaka and Takeuchi 1995); Nonaka and von Krogh (2009); Bhatt (2002); Long and Fahey (2000); Kotter model (Kotter 2012); **Figure 3.1**
12	Shared decision making (shared problem resolution process, everything understood by all members)	c) Knowledge and skills		Discussion in 3.3.2 conclusion based on Mayo (1933 in Davis 1968), Likert (1961), Davis (1968), Locke et al. (1986), Ahmed (1999), Hartmann (2006), Goodman and Dingli (2017), Senaratne and Sexton (2009), Duggan (1999), De Dreu and West (2001), Peansupap and Walker (2005); SECI model (Nonaka and Takeuchi 1995); Dierkes, Child, Nonaka, (2003); Davenport and Prusak (1998); Leonard and Sensiper (1998); Discussion in 3.1.4.3; George and Jones

				(2005); Kotter model (Kotter 2012); Lewin (1951) model; ADKAR model (Hiatt 2006); The case B&O **Figure 3.1**
13	Shared leadership	a) Personal motivation		Discussion in 3.3.2 Goodman and Dingli (2017); Carson et al. (2007); Moran (2015); Pearce and Sims (2000); von Krogh et al. (2012); SECI model (Nonaka and Takeuchi 1995); Davenport and Prusak (1998); Leonard and Sensiper (1998); Dierkes, Child, Nonaka, (2003); Kotter model (2012);
14	Flexibility 1 – Adaptability of the team (adaptable to equipment changes or changes within the team structure)			Bhatt (2002); Case B&O; Worley and Mohrman (2014); **Figure 3.1**
15	Flexibility 2 - Openness to new ideas			Kotter model (2012); **Figure 3.1;** Ahmed (1999) – openness of management; Duggan (1999); Moran (2015); Steele and Murray (2004); Peansupap and Walker (2005); Case B&O, Case Google
16	Flexibility 3 – Flexible team (the team is not a fixed structure; it should be modified when there is a need for it)			Discussion in 3.3.3 Schlegelmilch et al. (2003) in Hidalgo and Albors (2008); Moran (2015); Goodman and Dingli (2017); Different opinion: Cole (2019)
17	BIM implementation to support good existing practice	d)Acting opportunities		Chapter 2: Ahn et al. (2016); Arayici et al. (2011b): Dossick and Neff (2010); Sackey et al. (2015); Son et al. (2015); Lewin 1947 in Cameron and Green (2012); Kotter (2012); Leonard and Sensiper (1998)
18	Structured organised training (Training as an assignment)	b) External motivation		SECI model (Nonaka and Takeuchi 1995); Kotter model (Kotter 2012); Tabassi et al. (2012)
19	Experiential learning (learning through active participation or learning by doing)	a) Personal motivation c) Knowledge and skills		SECI model (Nonaka and Takeuchi 1995); Nonaka and von Krogh (2009); Kothari et al. (2011); Long and Fahey (2000); Discussion in 3.3.4.3; Lewin model (1951); Levasseur (2001 and 2005); ADKAR model (Hiatt 2006); Schein (2017); Cameron and Green (2012)

				Leonard and Sensiper (1998) **Figure 3.1**
20	Creative pressure (competitions, time limitations, mandate)	b) External motivation d)Acting opportunities		Kotter model (2012) Duggan (1999); De Dreu and West (2001); Singh (2014) Different opinion: Ahmed (1999)
21	Opportunity for reflection (confusion, brainstorming, positive deviance, deep reflection)	a) Personal motivation d)Acting opportunities		Discussion in 3.3.2 Ahmed (1999); Hartmann (2006); De Dreu and West (2001); Carson et al. (2007); Pearce and Sims (2000); SECI model (Nonaka and Takeuchi 1995); Davenport and Prusak (1998); Dierkes, Child, Nonaka, (2003); Discussion in 3.3.4.3; Lewin (1951); Kotter model (Kotter 2012); Leonard and Sensiper (1998); **Figure 3.1** Duggan (1999), Ahmed (1999); Moran (2015); Goodman and Dingli (2017)

Previously discussed interconnections between theories of IM, KM and CM, are illustrated in Figure 3.5 and Table 3.3. This also shows the connections between factors and theories.

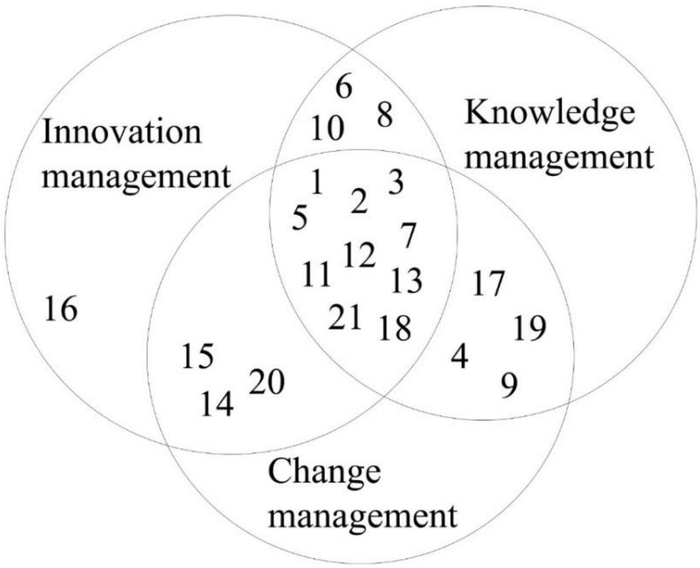

Figure 3.5 Summary of factors and connections with theories

Table 3.3 Summary of factors per theory

theories	*factors*
Innovation Management	1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 18, 20, 21
Knowledge Management	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 17, 18, 19, 21
Change Management	1, 2, 3, 4, 5, 7, 9, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21

*Key: **1** Aligning visions, agreeing a common vision; **2** Identifying what kind of future actions needs to be taken as a team; **3** Ensuring top support, sub-topics: empowerment, rewards, innovation champions, knowledge portals, leadership; **4** Clarity about change management program; **5** Ensuring an open environment (culture); **6** Diversity in team (e.g. skills, roles); **7** Communication flow 1 – regular meetings, face-to-face productive meetings, discussions (information exchange); **8** Communication flow 2 – interconnectivity of team members, ability to get information (information access); **9** Communication flow 3 – transparent flow of information, ensuring up-to date information (information reliability); **10** Trust and respect; **11** Team building; **12** Decision-making: problem resolution process, everything understood by all members; **13** Shared leadership to increase commitment; **14** Flexibility 1 – adaptability - if tool changes, or a member is missing; **15** Flexibility 2 - open to new ideas, compromise; **16** Flexibility 3 - team is not a fixed structure, it should be modified when there is a need for it; **17** BIM implementation to support good existing practice; **18** Training as an assignment; **19** Active participation – learning with doing; **20** Adding creative pressure – support idea generation, time limitations; **21** Opportunity for reflection*

**Light colour on a factor means that the factor is not as significant for those theories as other factors are.*

Chapter 4. Research methodology and research design

4.1 Introduction

This chapter presents a discussion regarding the philosophical stance of this study and the study design step by step. This research is in its nature applied research (Kumar 2011), therefore, it applies principles of methodology to achieve research aim and objectives. The research design starts with explaining the research approach, philosophical stance and then connecting it with the adequate research methods. It discusses the applicability of these methods, the rationale for every choice in the research design, validity, reliability of methods and provides a reflection on challenges that exit and how the study responded to those challenges.

4.2 Establishing a research approach and philosophical paradigm for the study

The foundation for every research is defining its philosophical stance. This shall occur prior to defining the research as qualitative, quantitative or both. The first step is to choose a paradigm, a term established by Thomas Kuhn that means a set of beliefs established by researchers and their communities on how they respond to research questions (Morgan 2014a). This 'set of beliefs' determines the research design strategy, from posing research questions to analysis and evaluation of the results (Naoum 2013); therefore, it should be the starting point of every research study.

Paradigms are defined by their ontological, epistemological and methodological assumptions. Ontology is concerned with the nature of reality and differentiates between objectivism, a perspective that there is one, objective reality, and subjectivism, where the reality cannot exist independently from the social influence (Pasian 2015, Saunders et al. 2009, Creswell and Clark 2011). The second assumption is epistemological, which is concerned with how a researcher perceives the knowledge acquisition (Creswell and Clark 2011). There is also an axiological stance, which is an assumption about the ethics and the role that values have for a researcher and their impact on the data (Pasian 2015). From this, the first two aspects, ontology and epistemology, are the key ones in determining the research approach (Creswell 1998). These are the assumptions that a researcher must address, to be able to define a research strategy.

In the field of management research, the established paradigms are positivism, realism, interpretivism and pragmatism (Saunders et al. 2009, Pasian 2015). Each paradigm has established views on the nature of reality, knowledge and the role of values - ontological, epistemological and axiological assumptions. The following sections discuss how each of these philosophies perceives reality and knowledge acquisition and the rationale behind adopting the pragmatic stance for this research study.

4.2.1 Pragmatism – the philosophical paradigm for the study

Pragmatism was found by Charles Sanders Peirce and further developed by William James, Ferdinand C. S. Schiller, John Dewey and Richard Rorty in the late nineteenth and early twentieth century (Creswell and Clark 2011, Johnson and Duberley 2004). The first rationale for choosing pragmatism is the way it perceives the reality and the truth. For pragmatists such as John Dewey and Richard Rorty, the reality can only be perceived through human experience (Morgan 2014b: 39, Bradbury 2008, Stoller 2018), which makes pragmatist perspective different to positivism. This is in accordance with the nature of this study and the researcher's stance, that the reality about the BIM team development cannot be perceived independently of human influence. The aim of this study and research questions determine that the interest is to investigate the human perspective, as the topic of this research study is to investigate the way people learn and the way they are motivated. That is the level of reality and the truth this study is seeking. This further anchors this study within the pragmatic tradition, as according to Dewey and Peirce, both ontological and epistemological stances in pragmatism are determined by the research question (Peirce 1992, Saunders et al. 2012, Stoller 2018).

For a pragmatist, the 'truth' is the knowledge that can be applied in practice. For pragmatists, this positions the aim of the study and the research questions over methods and allows researchers to combine different methods to answer research questions (Tashakkori and Teddlie 2010, Creswell and Clark 2011). The epistemological stance of pragmatism is that "the knowledge of the world is based on the experience" (Morgan 2014b: 39). This impacts the choice of research methods and places the emphasis on obtaining knowledge and experience by understanding others. In this study this is achieved by the case study and expert interviews.

Another rationale for adopting the pragmatic perspective is that it supports flexibility in reasoning (Creswell and Clark 2011, Paavola 2015). This flexibility is important for this research as the aim of this study is to combine, implement and evaluate existing theories, to result in a creation of a new, revised theory; conduct firstly theoretical research then continue with the empirical research. The pragmatic stance allows for preliminary, conceptual and theoretical findings to be deductively evaluated and revised, with the primary data. As explained previously, the 'knowledge' that pragmatists seek is to understand 'what works in practice', therefore allowing knowledge to emerge from the data is very important for this study. It is essential to allow knowledgeable participants from the industry to add their knowledge and experiences into the existing theoretical evidence to revise the theory. It is also important to investigate mechanisms and challenges in practice, to demonstrate the value of the preliminary theory - preliminary set of theoretical factors.

4.2.2 Other traditions and their impact on the research

There are four main established paradigms: positivism, realism, interpretivism and pragmatism, as discussed previously. The positivistic approach "emphasises the model of natural science" where the researcher believes in the objectivity of the data and explains the results using the "chain of causality" (Finch 1986 in Noor 2008: 1602). Due to the nature of this study and the researcher's ontological and epistemological stance, this approach was not found adequate.

On the other hand, interpretivism was found closer to the nature of this research and the epistemological stance of the researcher, that the knowledge is socially constructed and it cannot be isolated from humans (Morgan 2014b, Gaus 2017). This tradition believes in subjective reality and 'knowledge' that depends on the human factor; and explains that the research design depends on how the researcher perceives and interprets the reality (Gray 2014, Saunders et al. 2012, Pasian 2015). From the perspective of Easterby-Smith et al. (2002) and their comparisons between positivist and social constructivist epistemological perspective, this study is closer to the latter. Followers of this approach have no intention to separate the researcher from the reality. Their interest is in understanding how people perceive the reality, experiences and beliefs and in understanding different interpretations (Taylor and Wallace 2007, Mackenzie and Knipe 2006, Gaus 2017). These principles guide this study as well. The researcher acknowledges the 'subjectivity in the data' before interpreting it, but the researcher also understands that such subjectivity contributes to an in-depth understanding of the object of the study (Rubin and Babbie 2010). While agreeing with the epistemological perspective of interpretivism, the research aim, practical ways of reasoning and ontological stance determine that pragmatism is rather a suitable tradition to follow for this study. Similar to an interpretivist study, this study aims to collect people's understandings and experiences, particularly through interviews; however, these are collected with the aim to find practical ways of achieving BIM team development, to understand mechanisms and factors underlying those experiences, that can be implemented in practice. Therefore, these experiences are a descriptive aspect of this study, but the description is not the central point of the study.

In this study, the pragmatist stance is implemented as an “umbrella philosophy” as suggested by Creswell and Clark (2011). The way this study is designed is also influenced by the previously discussed interpretivist stance and the critical realist (CR) stance, which is ontologically in-between previously discussed stances and their methods. The CR tradition, developed by Roy Bhaskar, established in social science research, ontologically follows that there is a reality independent of our perceptions, but it has the interpretivist epistemological stance (Maxwell 2012, Blaikie 2007). It combines the ontology of transcendental realism, which believes in the existence of real mechanisms and critical naturalisms, which supports the use of social scientific methods (Bhaskar 1998, Danermark et al. 2005). Therefore, the ontological stance is that there are real, actual and empirical levels of the reality (Bhaskar 1998, Blaikie 2007, Danermark et al. 2005). This divides events on those that are empirical or observable, actual events and ‘real’ mechanisms which create those observable events (Blaikie 2007). Epistemologically, it has the interpretivist stance that the knowledge can only be socially constructed (Saunders et al. 2009) and that knowledge about the reality depends from the observers and it might not be observable (Johnson and Duberley 2004). As pragmatism, it also has the ability to combine qualitative and quantitative methods (Creswell and Clark 2011). These are the key points which are in accordance with the researcher’s view and could benefit the aim of this study, therefore, some aspects of this research are influenced by realist tradition. The realist stance in this study impacts the literature review, which applies the systematic review (Chapter 2). The critical realist stance also has an impact on the way the research design is built, as this research attempts to reveal some of the causal relations that contribute to BIM team development.

While not being as present in the management research (Johnson and Duberley 2004); CR is accepted and used in the social science investigations and it is an adequate method to explain “sociotechnical phenomena that take into account the breadth of information technology, social, organisational and environmental factors which may have played a causal role in their occurrence” (Wynn and Williams 2012: 787). These elements also describe the context of BIM project teams and BIM change, which further shows how the CR stance fits with the nature of this research. To summarise, there are other important aspects of CR which also suit the nature of this study and which inform the study:

- It has the ability to understand causal relationships between events and enable generalisability of the results through abstraction (Wynn and Williams 2012);
- Causal explanations are achieved by understanding causes and effects (Johnson and Duberley 2004);
- These explanations can guide the management practice (Johnson and Duberley 2004);

- “If social reality consists of causal structures it must be possible to intervene and manipulate that structure” (Johnson and Duberley 2004: 145);
- CR allows different interpretations of the same reality and adoption of different methods (Danermark et al. 2005);
- It can be used for both theory building or theory refinement, which is the objective of this study (Wynn and Williams 2012, Danermark et al. 2005);
- Can and should start the research informed by theories (Danermark et al. 2005).

To effectively implement CR and effectively analyse the data Wynn and Williams (2012: 796) suggested the following: an explication of events (event abstraction), explication of structure and context, abduction, retroduction (explaining and understanding how structure and context influenced events), empirical corroboration (understanding mechanisms), triangulation and multi-methods (using multiple methods in data collection and analysis). These suggestions influenced the research design.

There is a connection between the CR and the pragmatic stance. Authors such as Johnson and Duberley (2004) explain how some ideas of critical realists, such as Andrew Sayer, were in fact, leaning towards the pragmatism, and the ontological perspective of Dewey and James was close to Bhaskar’s realist ontology. For example, there is a quote from pragmatist William James, “we give up the doctrine of objective certitude, we do not thereby give up the quest or hope of truth itself” (James 1897:17 in Johnson and Duberley 2004: 143). Ontologically, Blaikie (2007) differentiates between shallow, conceptual, cautious, depth realism, relativist and subtle realism; while epistemologically, she named the pragmatic stance - conventionalism (Blaikie 2007). Norman Blaikie explains that epistemological conventionalism can work well together with subtle or cautious realism to achieve induction and deduction. From her point of view, cautious realism is closer to the critical realist perspective, while subtle is closer to interpretivism. Subtle realism, a term established by Hammersley in 1992, accepts that there is an independent reality, but in terms of knowledge and truth is closer to interpretivism, believing that there are no certain findings and that findings can only be reasonably confident (Duncan and Nicol 2004). Due to the nature of this study, ways of reasoning, this study is subtle realist.

The research methods are thus influenced by the critical realist perspective and the interpretivist epistemology. However, there are a few reasons why the pragmatist tradition is above the critical realist perspective in this study. Firstly, the study aims to find mechanisms and factors that impact BIM team development, however, it is pivotal not only to explore mechanisms but to identify and explain what solutions are practical to implement and what can help management professionals in organisations, which makes the stance of this study pragmatic (Morgan 2014b, Johnson and Duberley 2004). The second reason is the nature of the topic. This topic includes a high number of sub-topics and explores different theories. As identified in the theoretical list of factors, there are 21 conceptual factors. Due to the level of experience expert interviewees have, this list will be revised. It is enabled for new factors and concepts to emerge from the data and to be generalised due to the purposive sample. This produces a large number of qualitative data, a number of topics and qualitatively analysing each in-depth and attempting to map the context and mechanisms for each would not be practical. The participants discuss events and initiatives that lead to BIM team development, however identifying all possible mechanisms that lead to those events would not be practical or possible even through hour-long interviews. As pragmatists explain, causal relations exist, but it is challenging to identify all causes (Teddlie and Tashakkori 2009). Instead, this study notes, discusses and maps the key ideas as ‘patterns’ that emerge for each factor. It shows the cause and effect by understanding challenges in practice, noting ideas and solutions and showing how factors resolve the challenges. This study also illustrates some relations and connections by creating diagrams for each factor. This also shows the importance of factors and causal relations.

4.2.3 Concluding the research stance

By adopting pragmatism, this study achieves more significant contributions for both academia and the AEC industry. This is achieved firstly by focusing on practical solutions that practitioners can apply and adapt for themselves. For academic research, this study provides a greater understanding of what are the critical factors emerging from KM, CM and IM, that can contribute to BIM team development, but also development and implementation of other similar collaborative IT technologies. This is achieved by the pragmatist stance, as pragmatism allows transferability of theories and application of them within different contexts (Shannon-Baker 2016). This also allowed the researcher to consider the literature on IT and ICT technology adoption and adapt that knowledge for the context of this study. In terms of limitations, in pragmatism, the term ‘usefulness’ can be broad and unclear (Johnson and Onwuegbuzie 2004), and therefore in the context of this study, a ‘useful’ or ‘practical’ solution means a solution whose complexity, cost and time characteristics are such that they can be accepted in the practice of the AEC organisations.

In addition, there are some other principles of pragmatism, taken from Johnson and Duberley (2004), Johnson and Onwuegbuzie (2004) and Morgan (2014b), which inform this study:

- There are natural, physical, social and psychological dimensions of the world;
- Accepting that the knowledge can never represent the reality with the maximum certainty and that knowledge is changing with time;
- Theories are instruments and their findings show how applicable they are;
- Accepting that empirical data can show practical measures, however, the causal relations might not be apparent, or the theory behind them might not be defined yet;
- Having the ability to demonstrate practical measures and their outcomes by showing the causal relations;
- Having the ability to assess those practical measures or interventions;
- Through practice we can achieve a greater understanding of mechanisms – in this study by being part of the case study and by understanding the experiences of interviewees;
- Understanding that the knowledge is established through practice and understanding of what worked well;
- It is recommended to adopt different perspectives and methods to view the data.

4.2.4 Research approach

The pragmatic stance supports and suggests implementing inductive, deductive, abductive and retroductive ways of reasoning (De Waal 2013, Peirce 1992, Paavola 2015). The subtle realist influence in this study further supports this, as per Blaikie (2007), it allows inductive, deductive, retroductive and abductive logic. While purists advise against combining the methods, multimethod and pragmatic researchers encourage this (Johnson and Onwuegbuzie 2004, Tashakkori and Teddlie 2010, De Waal 2013). For example, Patton (2002) and Bryman (2016) explain that qualitative research can contain both inductive and deductive dimensions. White (1997: 744) adds "it becomes clear that induction and deduction collapse into one another". However, for the purpose of clarity for both purists and pluralists, this research establishes one overarching or an "umbrella" research approach for this study to be deductive.

A deductive approach is suitable for the study aim and objectives, in particular, Objective 3 "To critically evaluate the theoretical list of factors established" and Objective 4 "To evaluate existing theories of CM, KM and IM and show how they benefit BIM team development processes". "Deductive inference is commonly used in the analysis of qualitative theory-driven research" (Meyer and Lunnay 2013: 86), such as this study. Deductive Qualitative Analysis is, in fact, a well-known approach in the Chicago School of Sociology, the school that follows the work of John Dewey, who was one of the leaders of pragmatism and a school that is also associated with grounded theory and fieldwork (Gilgun 2013: 119). In the work of Jane Gilgun, an established author for qualitative research methods, it was found that Dewey "called this movement 'complete thinking'"; and for Dewey deduction was "a process of testing hypothesis for the purposes of confirming, refuting and modifying them whilst induction guides researchers to attempt to be open-minded and set aside their preconceptions and biases, to see construct in a new way" (Gilgun 2013: 114).

Paavola (2015) and Pathirage et al. (2008) also agree with this stance, that deductive theory-testing can result in theoretical concepts being modified. In this study, theory-testing and theory re-development occur in Framework Analysis (FA) of interviews, where theoretical factors from Section 3.5 are approved, rejected or modified and this is later presented in final Table 6.29 in Section 6.26. This logic has the ability to explain causal relations, the ability to compare existing theories with the data, provides a structured way of collecting and understanding the data and also reduces bias (Saunders et al. 2009, Pathirage et al. 2008). Traditionally deduction relies on the quantitative data (Saunders et al. 2009) which are also present in this study within the content analysis (CA), discussed in more details in Section 4.4.5, however it can also be applied for a qualitative study (Gilgun 2013). As a result, Deductive Qualitative Analysis is suitable for the aim of the study and key Objectives 3 and 4 of this research, therefore it will provide a structure for this study.

In contrast, induction starts with the empirical data, identifies patterns and establishes connections with existing theories or contribute towards the development of new theories (Patton 2002, Bryman 2016, Pathirage et al. 2008). The inductive reasoning is useful to explain observed or experienced events (Gill and Johnson 2002 in Pathirage et al. 2008). It has a flexible way of reasoning and is used in the social sciences (Pathirage et al. 2008). Induction can address the exploratory aspect of this study – Objectives 1 and 2 and be used to further develop the theory. However, it would not be appropriate for the overall research approach, to achieve Objectives 3 and 4 and the aim of the study, as it starts from the empirical data.

The abductive reasoning is aligned to the work of pragmatists. However, by only applying abductive reasoning conclusions would be 'at best, only possible correct' (Lipscomb 2012). Established by pragmatists, Charles Sanders Peirce, also adopted by realists, abduction seeks for the best explanation of events and attempts to understand mechanisms that exist under observable, empirical data (Mueller and Urbach 2017, Reichertz 2007). The process is dynamic, and the researcher continuously seeks for explanations, where the most suitable ones substitute the weaker ones (Mueller and Urbach 2017). While there are different interpretations of 'abduction', even within the work of Peirce, it has been consistent in both work of Peirce and Dewey, that abduction is "a weak mode of reasoning on searching explanatory hypothesis on the basis of observations and anomalies" (Paavola 2015: 235). It has also been found that "it is suggested that abductively derived claims require support from deductive and inductively sourced evidence if they are to 'hold' and, yet, in qualitative research, this is clearly problematic" (Lipscomb 2012: 244); and similarly in the work of De Waal (2013), that scientific reasoning needs to combine abduction with deductive and inductive reasoning. "Abduction also starts with data or a surprising fact that need explanation" (Mabsout 2014: 494). For those reasons, abductive reasoning could be applied during the exploratory phase of this study, to achieve Objective 1 and 2, however it would not be sufficient to test the concept generated in Chapter 3 (critical factors) by the qualitative inquiry and to achieve Objective 3 and Objective 4.

As a result, the overall or guiding research approach is deductive. To achieve this, this study follows guidelines by Jane Gilgun on Deductive Qualitative Analysis, a pragmatist approach used in the Chicago School of Sociology, that also follows the work of Dewey (Gilgun 2013). This way a theoretical concept can be created by modifying and applying existing theories, finding patterns in the data and then systematically testing and revising conceptual, theoretical concepts (Gilgun 2013).

4.2.5 Research design

There is a growing interest in the research towards the philosophical pluralism and with it towards the methodological pluralism (Pathirage et al. 2008, Johnson and Onwuegbuzie 2004). The pragmatist research stance allows for the pluralism and the adoption of mixed methods. It allows for the adoption of both quantitative and quantitative approaches within the same study (Shannon-Baker 2016). In fact, pragmatists believe that the true knowledge can only be accessed by having different research methods and that pluralism can create more superior research (Morgan 2014a, Shannon-Baker 2016, Johnson and Onwuegbuzie 2004). It was also found that methodologies can complement each other and combining methodologies can provide new perspectives, a better understanding and can collect a variety of data (Pathirage et al. 2008, Creswell 1998, Dainty 2008, Shannon-Baker 2016).

To achieve the research objectives the study needs to conduct separate studies, firstly to achieve an understanding of real-world challenges and processes in the AEC organisations, and secondly to evaluate the role of existing IM, KM and CM theories, then conduct a study that can evaluate critical theoretical factors established in Chapter 3, Section 3.5. It has also been established in Section 4.2.1 that this study has the interpretivist epistemological stance, which is more closely aligned to and oriented towards the qualitative data (further discussed in Section 4.3) and this is confirmed in Section 4.2.4, by adopting Deductive Qualitative approach suggested by Jane Gilgun (2013). Therefore, in accordance with the aim of the study and the epistemological stance, this study follows guidelines on mixed-methods for the qualitative inquiry, guidelines on conducting simultaneous and sequential qualitative mixed-method designs, by Janice Morse (Morse and Neihaus 2009, Morse and Neihaus 2016, Morse 2010), an author recognised and used in work of many other well-known authors such as Denzin and Lincoln (2011) and Creswell (2015). Following the work of Morse and Neihaus (2009, 2016) and Morse (2010), this study contains a core method or a core study and a supplemental study. The supplemental study is there to provide a better understanding or additional evidence to support the core study (Morse 2009). In this study, this is achieved by implementing a research design Morse named as 'QUAL + qual'. It is suggested to separately conduct two studies and separately collect two sets of data, using samples that can be the same or different, then merge the findings once the data have been examined (Morse 2010, Morse and Neihaus 2016).

In accordance with Morse (2010) and Morse and Neihaus (2009, 2016), the research design is established and presented below in Figure 4.1. As an organisational management research, this study also follows the work of Pritchard (2012), who suggests that the qualitative mixed-method researchers shall also compare their strategy with the existing body of knowledge on traditional mixed-methods. Therefore, in comparison with the work of Creswell and Clark (2011), this study follows the principles of a convergent parallel study and a multiphase study and combines them (Figure 4.1). A multiphase study allows for new findings to emerge and also allows for a theory-testing, therefore it is aligned to the objectives of this study. The results are triangulated and different perspectives are gathered on the same topic (Creswell and Clark 2011). Creswell and Clark (2011) also explain that such an approach is useful when different study types are found valuable, and when the researcher is experienced with similar methods, whilst disadvantages are that the result can be an extensive study and amount of data. The researcher had experience with interviews, while the case study and content analysis were relatively new for the researcher, however well-known to the support team. This further confirms the suitability of the research design presented in Figure 4.1 for this study.

The research is divided into the exploratory case study and qualitative inquiry - expert interviews (Figure 4.1), which Section 4.3 further discusses. The findings of the two studies are firstly separately discussed within Chapter 5, then Chapter 6 conducts an in-depth discussion based solely on interview findings and compares them to each critical theoretical factor from the Chapter 3 to achieve the third objective. The following chapter, Chapter 7, presents the discussion of the results and merges the results of previous phases. This is also organised as per suggestions of Morse (2010: 485) who explains that for such studies it is necessary that "each data set must be kept separate and analysed separately", therefore, the findings are discussed separately until the final presentation sections (Section 5.2) and discussion chapter – Chapter 7.

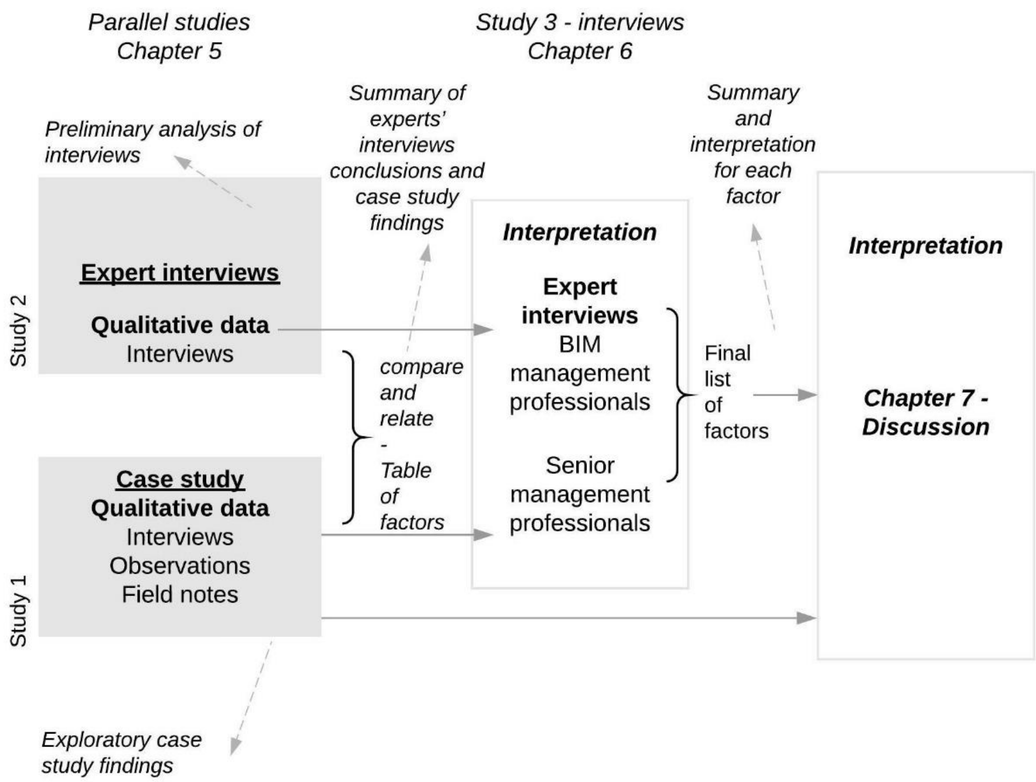

Figure 4.1 The research design

4.3 Research strategy, design and methods

Pragmatic studies can adopt both qualitative and quantitative approaches (Morgan 2014b). However, in discussions in Section 4.2.2 about epistemology and other stances that influence this study, it was established that this study is influenced by the interpretivism and CR. While the CR can integrate both qualitative and quantitative data, the interpretivist and subtle realist perspectives lead towards dominantly qualitative studies (Wynn and Williams 2012, Blaikie 2007).

It is also the aim of this study that determines the study to be dominantly qualitative. Due to the pragmatic perspective, methods also depend on the nature and the aim of the research. This study aims to gather an in-depth understanding of both the context of BIM team development and an in-depth understanding of participants' views; therefore, the research is dominantly qualitative. This is because the qualitative research has the ability to collect in-depth perspectives, attitudes and experiences (Naoum 2013). These benefits of qualitative research are critical for this study, as this study aims to understand people and social phenomena such as learning, motivation and change. As a result, methodological choices of this study, from the philosophical stance to data analysis are presented in Figure 4.2, which is developed in accordance with the work of Saunders et al. (2009). Whilst there are many strategies for conducting the qualitative inquiry, such as survey, case study, grounded theory, phenomenology or action research (Saunders et al. 2009, Denzin and Lincoln 2013, Creswell 1998), this study combines a qualitative survey and a case study approach.

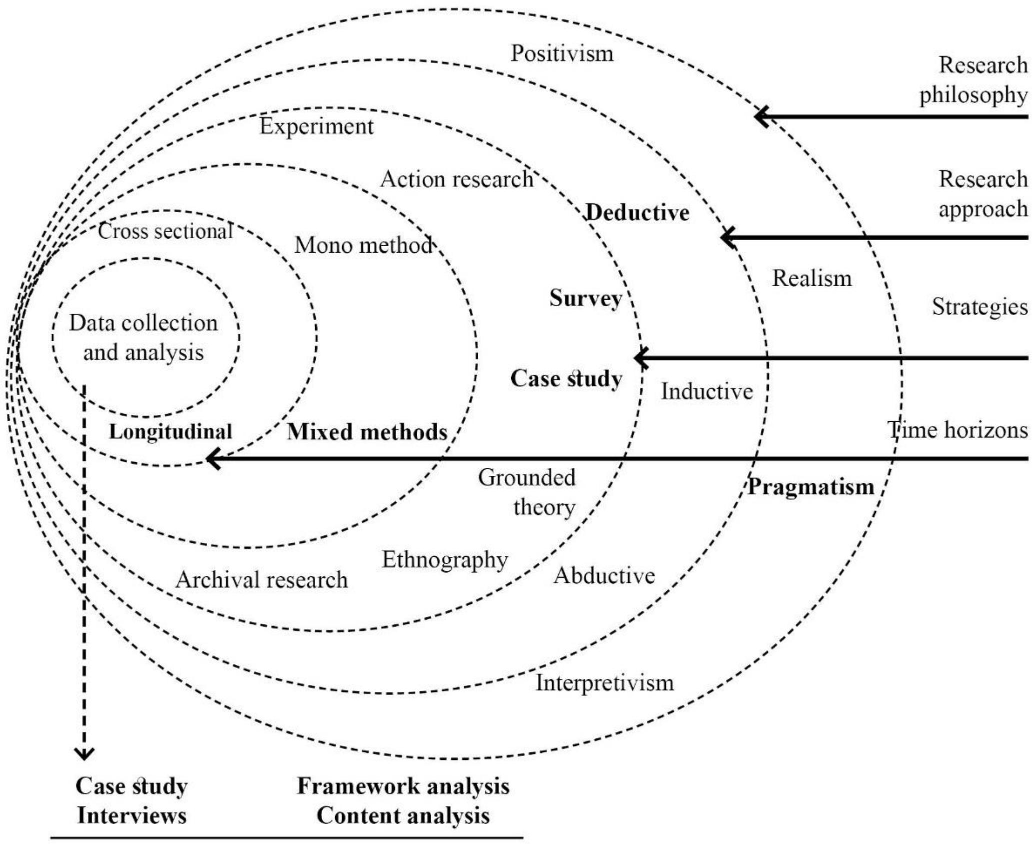

Figure 4.2 Adapted and modified from Saunders et al. (2009: 108)

It should be explained why the Grounded Theory (GT) and the action research are not suitable for this study. The GT is well-established and it is in accordance with the epistemological views of this study (Reichertz 2007) and it would be suitable to achieve some of the objectives of this study, as the GT results in a development of a theory (Bryant and Charmaz 2007, Charmaz 2005, Khan 2014, Reichertz 2007, Denzin 2007). It was created in the 1970s by sociologists, Barney Glaser and Anselm Strauss (Glaser and Strauss 1968, Denzin 2007). There are different philosophical stances for the GT and different interpretations. For example, according to Crotty (1998), Denzin (2007), Khan (2014), Ralph, Birks and Chapman (2015), the 1970s work of Glaser and Strauss and the 1990s work of Strauss and Corbin belongs to post-positivism, as they believe in an independent reality. The other stance is the constructivist stance of Charmaz and Bryant and the situational stance by Clarke (Charmaz 2005, Ralph, Birks and Chapman 2015). The GT would be suitable to investigate a socially constructed phenomenon and to understand some causal relations, as this study aims. Particularly the pragmatist perspective of Bryant (2017) would be suitable for this study, as Bryant allows some literature investigations to be conducted prior to the data investigations. However, the third objective in this study is to test the theoretical factors and this does not align to key principles of GT, therefore it is not a suitable strategy for this study (Rubin and Rubin 2012).

Regarding the action research, this method would not be practical to implement to achieve the aim of this study. The action research would allow for the testing of theoretical factors developed in Chapter 3. However, to be able to implement an action research, the researcher would need to have an established role in an AEC team. Another barrier to conducting an action research is that the context and conditions within the study (case study) cannot be fully isolated from external influences, which would challenge the results. For these reasons, this study conducts a case study and a qualitative survey research.

4.4 Qualitative inquiry

The researcher follows the principles of pragmatism with an influence from constructivist epistemology. This impacts the choice of the research methods and the analysis strategy. As a result, this study adopts expert-elite interviews and Framework Analysis (FA). The study also adopts Content Analysis (CA). The sampling is purposive which is explained later. Further discussions on interview design, data collection and analysis are below.

4.4.1 Expert-elite interviews

In accordance with the nature of the qualitative research and the research philosophy, using the interview method for the data collection was appropriate. Qualitative interviews are frequently used to investigate organisational practice (Saunders and Townsend 2016) and for this reason, interviews were implemented both as stand-alone, expert interviews and case study interviews. This method is used to gather an in-depth understanding of people's experiences, perspectives and impressions (Proverbs and Gameson 2008: 102). Unlike an online questionnaire or a survey with closed-ended questions, a face-to-face, a semi-structured interview has the ability to hear participants' opinions in their own words and understand how genuinely they feel about the topic. Open questions allow for freedom of expression. This way, participants can input into identified theoretical factors and potentially add new ideas. For those reasons, a face-to-face interview and questions that are open in nature are preferred for this study.

In this study, the expert-elite interviews are the core data for the research. As per Section 4.3, this is in accordance with Morse's (2010) guidelines on having a core and a supplemental study. The expert interviews can be used to explore relatively new topics, to acquire more data, or to build a theory (Flick 2009); which are all reasons to implement this method in this study. While literature makes some distinction between the terms, in this study, the 'expert interviews' are also 'elite interviews'. The elite interviewees are well-informed participants with significant roles and authorities in organisations or communities (Rose et al. 2015). In this study, participants are management professionals who have high or senior roles in the AEC organisations. There are some challenges to this method, such as participants' accessibility, time limitations and their ability to share the information. It is expected from the interviewees to reveal extensive information, and this could be challenging due to their role or their authority (Flick 2009, Rose et al. 2015). However, Bogner et al. (2009) mentioned several reasons why an expert would share their knowledge with the other experts, such as curiosity about the research, willingness to help and being in the same industry field. This study further addressed these challenges by allowing a year for the data collection, the interviewees could pick the time that suited them and the ethical agreements were also provided and signed which contained the details about the study, confidentiality of data and the ethics behind the study. There can also be a risk of subjective interpretation of questions by interviewees, but for this, Trinczek explains that this is the nature of the qualitative research in general and social science (2009). This disadvantage was reduced through a careful and structured data collection and data analysis design, a combination of FA and CA, where the same issue is investigated through multiple questions and different participants.

Expert interviews were chosen based on their 'elite' position in organisations and also due to their ability to reconstruct the knowledge about a phenomenon (Flick 2009), which is in this study BIM development process in organisations. The expert interview method is also an effective tool to quickly collect quality results (Bogner et al. 2009). Elite interviewing can also provide additional knowledge, broad, comprehensive perspectives and explain questions of 'why' and 'how' (Rose et al. 2015), which are vital benefits for this study. As a result, expert-elite interviews are the core of this research:

- To obtain in-depth findings on the current and best practice with BIM adoption, change, skill development and understand the vision of experienced professionals regarding the same topic;
- To gather different perspectives from construction professionals with different job roles, knowledge and experiences;
- As a tool to cover all the key topics identified from the literature on IM, KM and CM, to test those factors and elaborate on them;
- To get new ideas, insights and solutions from the experienced industry professionals.

4.4.2 Interview design approach

In accordance with the aim of the study, the interview consists of questions about BIM team development practice in the participants' current organisations or organisations they worked with, about training strategies and mechanisms to achieve the BIM change. The form is semi-structured, which is appropriate when the researcher wants to obtain answers about pre-investigated topics (Arsovska 2012). A semi-structured form is also appropriate for expert interviews (Arsovska 2012, Flick 2009, Saunders and Townsend 2016). The questions are flexible to allow participants to provide new ideas. A fully structured interview form would not enable that contribution and it would be challenging to clarify questions. According to Wilson and Sapsford (2006), most studies that investigate beliefs and perceptions do not suggest a structured approach. Allowing participants to freely speak about what they find the most important for the BIM team development helps the researcher identify the critical factors in practice. Having a flexible conversation with the participants is also more practical because the majority of participants have a high level of authority and years of experience in construction and having a fully structured questionnaire would seem like an interrogation, rather than a comfortable conversation with them. This is also in accordance with the guidance on ethical responsibilities by Rubin and Rubin (2012). They emphasise the importance of having a comfortable conversation flow, not forcing the answers and the importance of showing respect. Therefore, although the interview is not fully structured, it is also not unstructured. An unstructured form would make the analysis process more challenging, would not be aligned to principles of FA, this study follows, and it would be difficult for the researcher to cover all areas of interest.

The questions were prepared in advance, but the freedom was given to participants to express their opinions. The questions were designed in a way to fit both the case study of a construction company (senior management participants) and also expert industry participants so that the results could be compared more easily. Depending on who the participant was, questions were allowed to be modified to fit the conversation and to fit the participant's role, but the structure, schedule and the aim of the questions needed to remain the same, as suggested by Wilson and Sapsford (2006).

Whilst developing the questions, the researcher considered utilising an interview design which would follow the theoretical list of factors - one by one. Another option was to have a more flexible approach without necessarily discussing each factor separately, but asking various questions which would cover those topics. Firstly, the interview was designed using the first approach and the list of factors. This draft interview is presented in Appendix B3**.** This interview was semi-structured with a number of open questions, asking "how important is the certain factor?", "why is that the answer?", and "how is it achieved in the project team?". The researcher then designed a second draft, which later influenced the final interview questionnaire, presented in Appendix B1 and B2. This version included background questions and discussed challenges and initiatives in their teams. This was piloted and consultations were made with the supervisory team and other academics and it was established that the second approach is more suitable. During the pilot process, some of the background questions were moved to the end of the interview, so that the most important questions get more time and so that the conversation at the end becomes lighter.

To select the right approach, the researcher listed key opportunities and limitations for both questionnaires, presented in Table 4.1**.** Although the first draft has the ability to test each factor, the second, more unstructured draft, provides greater opportunities to also check if the construction professionals have different perspectives from the researcher and the theories. This allows the theory-testing, allows for the theoretical knowledge to be revised and also shows connections between theoretical factors (Table 4.1). Finding these connections between factors, challenges and solutions, processes of delivering BIM change and mechanisms, is one of the main contributions of this study. Investigating the connections, relationships between mechanisms and outcomes is also in accordance with the research philosophy of pragmatism, explained previously. Therefore, the study chose the second interview design option.

Table 4.1 Main characteristics of questionnaires: their weaknesses and opportunities

1*	**Main characteristics of interview Design 1 which follows a more structured approach - presented in Appendix B3**	weakness	opportunity
a	The researcher can ask a question on each factor without missing any.		
b	The researcher can test factors - check participants' opinions on each of them.		
c	It is easier to analyse, because questions are already grouped within topics.		
d	There are only a few open, general questions which provide opportunities to hear different perspectives.		
e	It covers all topics, all theoretical factors, equally.		
f	It is more theory-testing oriented.		
2*	**Main characteristics of interview Design 2 which follows a more open and less structured approach - final interview presented in Appendix B1, B2**	weakness	opportunity
a	It provides opportunities to see if participants have different perspectives.		
b	The researcher can cover all the topics – theoretical factors. It depends on participants how much emphasis they put on certain topics, and they can avoid topics if they want.		
c	The researcher can hear how other people experienced in this field explain the topics using their own words.		
d	Answers can show connections between solutions, connections between solutions and challenges and context.		
e	Fewer questions appear less demanding to respond, therefore more people would be likely to respond.		
f	The conversation during the interview will be less monotone.		
g	It is both "theory testing" and "theory building" oriented, therefore it is in accordance with the research aim and research approach.		
h	It is harder to analyse, it will be more challenging to code and connect responses.		

Description:
Interview research design: 1 - structured (Appendix B3), 2* semi-structured approach (Appendix B1 and B2)

Moderate impact	
High impact	

4.4.2.1 Designing an open semi-structured interview

Table 4.3 shows a matrix of relationships between interview questions and factors. The fields coloured light grey show the position of answers in terms of their potential to discuss the theoretical factors. As the matrix shows, most of the questions were designed in a way to be open. This allows the answers to contribute towards many theoretical factors and topics, or even add to the list of theoretical factors, which is shown in the right column of Table 4.3. For example, question 11b ("Should BIM implementation be radical or support the existing practices? May I ask why that is your opinion?"), seems specific to factor F18, however, it can also cover other topics. That can happen if participants, for example, mention that the change cannot be radical in certain teams because the management support is not sufficient for that to happen. Participants can also mention that other factors are required to deliver a radical, supportive, moderate or a minor change, such as communication strategy, clarity about the change, having a common vision, mandatory training and others.

The mark "x" shows that the question shall provide an answer to a specific theoretical factor and a topic. This way, during the interview design, it was assured that all topics (theoretical factors) are covered at least once. The interviewer was not allowed to lead an answer and it was up to interviewees to explain which factors are key to BIM team development process. However, with this matrix, the interviewer made sure that participants had an opportunity to talk about all factors and reveal their opinions about them. Some factors had an opportunity to be mentioned more, but that was not an issue, because this study is interpretive and what participants say about a factor is more important than the number of times a factor is mentioned (as per Section 4.4.5). Mentioning a factor even once, but explaining how important it is, would classify the factor as very important if other participants agree. Equally, people could mention a factor multiple times, but in a negative context or they could say that it is not that useful for BIM team development and therefore the factor would be excluded from the final list of factors. These results are presented in Chapter 6.

Appendices B1 and B2, show the final list of questions for all participants. Relationships to broader topics, such as KM and CM, are presented in Table 4.2 below. The questionnaire also includes background questions, questions on CM and KM and questions on challenges, because the study is investigating the practical mechanisms to deal with challenges of BIM team development. Depending on the professional roles of participants, two questions (7. and 11.), were made flexible to be able to fit different roles. There is an option for BIM managerial roles and those who do not have BIM managerial responsibilities. The study seeks to gather suggestions from participants and understand the overall, guiding principles in the AEC teams, therefore having different questions to fit the roles does not affect the results.

Table 4.2 Relations between questions and general topics

Topic	***Questions***
Background and their experience	*1, 2, 15, 16, 17*
Change Management and Knowledge Management	*3, 4, 5, 6, 7, 8, 9, 10*
Challenges and solutions to challenges	*11,12, 13,14*

Table 4.3 Matrix of relations between the interview questions and theoretical factors established in Section 3.5

No.	Interview questions / Theoretical factor category	Background question	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	Add into factors
1	Could you describe your current position in your organisation?	x																						
2	Please describe your experience with BIM projects briefly.	x																						
3	In your opinion, what are the key components to successful BIM implementation? (Additional) Could you give me an example of how was this achieved on one of your projects?																							
4	What was the greatest change for your team while you were adopting BIM practice?																							
5	a) Could you give me an example of some initiatives which helped BIM development process in your organisation and your project team?																							
	b) In your opinion, are there any other solutions which could help BIM team development?																							
6	What has been your most valuable learning experience relevant to BIM working practice?																							
7	a) (for managers) Which training approach did you use for the staff development? What other training solutions could benefit the BIM project team?				x															x				x
	b) (for non-managers) Which training did you attend to develop your BIM skills? Is there any other training you would like to attend?				x															x				x
	c) (for everyone) What is your opinion on the "trial-and-error" learning?																				x			
8	a) Could you describe the communication strategy on your BIM project? (Additional) How does communication occur in your team?								x	x	x													x
	b) Could you propose any other communication solutions which would help meeting your project BIM objectives?								x	x	x													x
	c) Does your team have open meetings to brainstorm what has been achieved and what could be improved?		x	x		x	x		x	x	x	x	x	x	x		x						x	x
9	a) In your opinion, which approach is the best route to BIM implementation, top-down or bottom-up?				x									x	x						x			
	b) Which approach was deployed in your organisation, top-down or bottom-up?				x									x	x						x			x
	c) What is your opinion on having a shared leadership or decision making on a project?													x	x									
10	Finally, in your opinion, how should an effective BIM project team look like? For example, in terms of culture, roles and responsibilities, team structure, skills, vision, leadership or control.		x	x			x	x				x	x	x	x	x	x	x						x
11	a) (for non-managers) How was BIM implementation achieved in your team, to support the existing practice or was it a radical change?																		x			x		x
	b) (for managers) Should BIM implementation be radical or support the existing practices? May I ask why that is your opinion?																		x			x		x
12	What challenges did you face during the BIM implementation?																							x
13	How did you overcome some of these challenges?																							x
14	There are a few other barriers I would like to discuss in-depth. What is your experience with and what could be a solution to: a) Lack of commitment;				x																			x
	b) Lack of clarity;		x	x		x																		x
	c) Lack of trust;						x					x												x
	d) Communication challenges;								x	x	x													x
	e) Resistance to change.				x																			x
15	Could you explain your organisational BIM objectives briefly?	x																						x
16	What elements of BIM are implemented on a project you are currently working on?	x																						
17	What are your BIM project objectives?	x																						x

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

4.4.3 Participants and sampling

This study used the purposive sampling. In expert interviews, the experts were those who had both practical knowledge and those who were able to reflect on their practice (Flick 2009). To ensure the credibility of responses, it was also crucial to interview those who had the knowledge and experience of BIM working practice. This is demonstrated in Table 4.4. This table shows the connections between the participants and the industry fields, shows their experience and knowledge and shows why their answers are helpful for this study. To gather a range of perspectives and compare them, the interview participants were people different in terms of their job roles, levels and experiences, while they were all management professionals.

The first step was to determine the number of participants. For the case study, a recommended number is to have at least three to five participants (Creswell 2007), but for the qualitative research involving semi-structured interviews, there are several different guidelines. There are various recommendations in the literature on organisational research, such as to have between 12 to 60 participants, to have 5 to 25, or even to have up to 15 (Saunders and Townsend 2016). Some authors recommend 4 to 12 for homogeneous and 12 to 20 for heterogeneous samples (Saunders et al. 2012, Kuzel 1992 in Saunders and Townsend 2016). A study by Saunders and Townsend (2016) investigates the interview studies within the organisational research and concludes that an optimum number is between 15 and 60 participants, however, it does recognise that depending on the study, this number can vary from a few interviews to hundreds. Another study by Patton finds that most dissertations include 20 to 30 interviews (2015). For these reasons, this study aimed to collect at least 15 responses, but the researcher was aware that the sample size could change throughout the data collection and the needed number could be reduced or extended (Patton 2015).

The optimum number of participants was also informed by the saturation and the quality of results. To ensure the population validity, the interviews were conducted until ideas had started to overlap and the data saturation had occurred, as per Saunders and Townsend (2016). In this study, the saturation occurred after having the first four interviews. This meant that the new codes emerged during the first interviews and these codes were repeated in the following interviews. Even if more people were interviewed, the answers would not add new codes into the findings, as overall the interview findings were largely overlapping. This is visible in matrixes – tables in findings (such as Table 6.1).

The quality was achieved by purposive sampling, in accordance with the pragmatic stance and interpretivist epistemology (Morgan 2014b, Bryant 2017). The purposive sampling is adopted in cases where the researcher needs to hear in-depth opinions, in this case, from the most knowledgeable people in the industry (Suri 2011, Guest et al. 2013). It also fits this study, because interviewing a high number of people would not be practically achievable and there is a limited number of experts in the UK who would be able to provide valuable answers. As a result, those who were interviewed were some of the most knowledgeable people in the UK about the topic, which can be seen in Table 4.4. They also had international experience (Table 4.4). A greater accuracy in the sample over the size is also recommended by Oppenheim (1992). Being a research that focuses on finding the common themes between participants, experienced BIM professionals, it is also recommended to have a smaller number of participants (Guest et al. 2013).

This study conducted a total of 20 interviews, 11 from BIM management experts and 9 from the case study that were senior management professionals involved in BIM management. The majority of the case study interviews, 8 out of 9, were rich in data regarding the BIM management which allowed them to be compared and discussed together with BIM management expert interviews in Chapter 6 (Figure 4.1). This was also enabled by having similar sets of questions and by having conversations not only about the context of the case study, but also their experiences in other projects and organisations in the UK and other countries.

Engaging participants

It is worth mentioning that techniques to engage participants were helpful in the data collection process. The researcher invested some time to read about how to encourage people to talk, body language and communication in general. This was found to be helpful to get people to share more. Particularly, it was helpful for the researcher being a non-native English speaker. During the interviews, the researcher also showed respect, appreciation for their work and engaged the participants by asking questions, which also made people more open and accessible. Upon their answers, the researcher shared some ideas relevant to the topic, not necessarily about the study, that also helped the conversation flow and helped to get more suggestions from the participants.

Table 4.4 Interview participants

Expert-elite interview participants from the AEC industry							
Interview code	**Month and approximate length of the interview**	**Professional field/ role**	**Type of work**	**Working for**	**Type of BIM projects**	**Project scale**	**Construction Sector**
I1	April 1h 40min	Internationally recognised BIM consultancy Strategic management	BIM and strategic consultancy	SME, UK Government-funded group	Supporting: construction organisations, client-side, design consultants with BIM strategic management; Private and public sector; Both UK and worldwide	Small and large (mostly large)	Building Infrastructure
I2	May 1h	Principal Engineer Responsible for piloting and implementing BIM in his organisation	Engineering and design management of infrastructure and energy projects	UK and multinational construction company	Design - engineering consultancy; Currently supporting the client-side UK based construction projects	Large	Infrastructure Energy
I3	May 1h	BIM management professional	BIM coordination and management	Regional Construction Company Academia	Construction projects	Small and large	Building
I4	July 2h	Regionally known BIM consultant and a director of an architectural company	BIM training and strategic consultancy Architecture	SME - Locally and regionally known Architectural studio and BIM consultant company	Supporting: construction organisations, client-side, design consultants with BIM strategic management; Design consultancy	Small and large	Building
I5	July 1h 30min	BIM manager for the organisation	BIM strategical and coordination management	SME - Locally and regionally known architectural studio who also provides project management consultancy	Design consultancy - architectural and planning	Small and large	Building
I6	July 1h 30min	Business manager and software consultant for BIM	Software strategic management	Worldwide known BIM analysis software company Construction Professional	BIM management consultancy for construction companies, client-side, design consultants	Small and large	Building Software

				Body			
I7	August 1h	Project director Responsible for BIM implementation	Construction project management Strategic BIM management	UK major construction company engaged also in civil engineering and facility management	Construction projects, Currently commercial projects	Large	Building
I8	August 50min	MEP BIM manager for the organisation	BIM strategical and coordination management	UK major design and engineering company involved in a wide range of projects: educational, commercial, transport, energy projects	Design consultancy – engineering and design for educational projects, healthcare	Small and large	Building Infrastructure
I9	August 1h 30min	BIM strategic manager for the organisation	Strategic BIM management	UK major design and engineering company involved in a wide range of projects: educational, commercial, transport, energy projects UK Government group	Design consultancy for large infrastructure transport projects, energy projects Design consultancy for buildings: administrative, educational, healthcare	Small and large (mainly large)	Building Infrastructure
I10	August 1h 40min	Strategic manager for the digital sector and BIM and development director	Strategic digital and BIM management	UK major and multinational construction company engaged in the delivery of range of projects and facility management UK Government	Range of construction projects and facility management projects for residential, healthcare, commercial, transport, education and leisure projects	Large	Building Infrastructure
I11	August 1h	BIM manager at property consultancy engaged in projects in the UK and worldwide	Strategic BIM management and coordination	UK and multinational property multi-disciplinary consultancy	Range of projects: residential, commercial, energy educational	Small and large	Building Infrastructure
	Total: 14h 40min						

Large AEC company – the case study participants (1C – 10C), the industry participants (I12 – I19)							
Interview code	**Month and approximate length of the interview**	**Professional field/ role *all involved in BIM team development**	**Type of work**	**Working for**	**Project type – case study**	**Project scale**	**Construction Sector**
I12-1C	July 1h	One of the main (leading) design managers	Design management	UK major construction company	Healthcare	Large	Building
I13-2C	August 1h	One of the main (leading) planners	Planning	UK major construction company	Healthcare	Large	Building
I14-3C	August 1h 10min	One of the leading M&E design managers	Design management	UK major engineering company	Healthcare	Large	Building
I15-4C	August 1h	One of the leading M&E planners	Planning	UK major engineering company	Healthcare	Large	Building
I16-5C	August 1h 10min	One of the leading M&E design managers	Design management	UK major engineering company	Healthcare	Large	Building
I17-7C	August 1h 10min	One of the main design managers	Design management	UK major construction company	Healthcare	Large	Building
I18-8C	August 1h	One of the main project managers	Project management	UK major construction company	Healthcare	Large	Building
I19-9C	August 1h	One of the main project managers	Project management	UK major engineering company	Healthcare	Large	Building
10C	August 40min	One of the main QS	Quantity surveying	UK major construction company	Healthcare	Large	Building
	Total: 9h 10min						

4.4.4 Data collection (interview) limitations

As previously discussed on the limitations of expert-elite interviews in Section 4.4.3, it can be difficult to obtain participants for this type of interview (Flick 2009, Rose et al. 2015). Face-to-face interviews are also time-consuming. Therefore, the interviewer negotiated for months with construction professionals and organisations. It was also challenging to obtain an opportunity to conduct a case study, as not all companies are open to this kind of collaboration with universities. The researcher waited several months and sent a project proposal to several companies together with the supervisory team. As a result, the data collection lasted a year.

Although the case study was arranged, to conduct the case study interviews, the researcher volunteered and helped the managers on a number of tasks and ultimately the interviews were arranged and finalised at the end of that period. This was time-consuming, but it helped the researcher acquire more practical knowledge about the topic. Arranging the interviewees from within the industry was also challenging. Potential industry interviewees were asked several times to help the study. To get their contacts, the interviewer relied on both private and professional networks.

To collect interviews, the interviewer visited different locations across the UK. The interviewer was open to different methods of arranging interviews, to arrange more quality interviews, therefore there was also one phone interview and one Skype interview. There were also face-to-face conversations with those participants. The interviewer was asked to share some of the findings and a few conclusions were shared with a promise that they would receive more information once the study was published. All the findings shared were only small insights from the study. This was found to be helpful because the participants were also willing to share more quality information, and therefore help the credibility of the results, as they knew that they would receive a useful material in the end. The offer to share results was not only beneficial to gather more participants, but also, according to Rubin and Rubin (2012), is ethically responsible and helpful to demonstrate the respect to participants.

To summarise, it was essential to interview only knowledgeable professionals who understand BIM team development process and working practice. This ensured the credibility of the results (Rubin and Rubin 2012). On the other hand, the limitation was that the number of people in the UK construction industry with such experience was very restricted in the year 2016 and 2017.

4.4.5 Data analysis

4.4.5.1 Framework Analysis

This study conducted the Framework Analysis (FA) and supportive Content Analysis (CA). The FA is a method that allows studies to apply deductive, inductive or combined reasoning or logic (Gale et al. 2013). Many authors explain that it is not connected to any epistemological stance (Ritchie and Spencer 1994, Gale et al. 2013, Parkinson et al. 2016) and that is a pragmatic approach. This method, similar to well-established thematic analysis, developed in the 1980s, is becoming more common in social and health sciences (Parkinson et al. 2016). There are very few guidelines in psychology, health and social science, but they provide details for other researchers to follow. In comparison to some other methods, such as grounded theory, it is used less in studies and there are fewer guidelines for ways to apply it (Oliver 2012). However, it fits the aim of the study, and it can enable a structured comparison between the theoretical and empirical data: which is the aim of this study. In addition to that, the FA is a relatively straightforward process to apply.

In this study, the idea of investigating factors from theories lead the researcher to FA, even before the researcher was aware of such a method in practice. The researcher applied a pragmatic approach to analysis and the analysis was not only conducted based on theories but also based on the available data and the nature of the study. Through a trial-and-error approach, the researcher investigated ways to analyse the data based on the first few interviews' findings using NVivo and this was later further developed using FA methods found in the literature. To enhance the quality of the analysis and findings, and enhance the validity of the methods, the researcher found a few studies in psychology, social and health research that provided a good description of the FA method. These were studies by Parkinson et al. (2016) and Gale et al. (2013).

It was found that FA is a suitable method to apply being (Parkinson et al. 2016, Gale et al. 2013):

- A pragmatic approach;
- Similar to thematic analysis;
- It allows the data to be compared with pre-defined theoretical topics (deduction process – Deductive Qualitative Analysis) and allows new topics to emerge;
- Helps with the data management and can deal with a large amount of data;
- It can evaluate factors – investigate what works and identify new theories or actions.

The work of Parkinson et al. (2016) was also found suitable as it has the same philosophical and epistemological stance. This study suggests implementing principles established by Ritchie and Spencer (1994), where FA includes: familiarisation, identifying a framework, indexing, charting, and mapping and interpretation (2016: 10). How these steps were implemented is presented in Table 4.5 below. An additional explanation is provided in the further text and directly within findings - Chapters 5 and 6.

Table 4.5 Steps of conducting FA

Principle - steps	Suggested by Parkinson et al. (2016), Gale et al. (2013) and Ritchie and Spencer (1994)	In this study
1. familiarisation	Immersion into the data: • Reading transcripts; • Discussing; • Familiarisation - listening to interviews.	• The same person is conducting interviews, transcribing, coding and analysing. • Taking notes during and after the interviews, noting key ideas. • Majority of interviews are coded both manually then again in NVivo. • Discussing the data with the supervisory team.
2. identifying a framework	Organising the data to be and to have: • Meaningful structure; • Manageable; • Categories come from the literature and data (pre-defined and open coding); • Categories are not the same as themes in thematic analysis; • Categories are broad ideas; • It is a trial-and-error process; • Data are not interpreted yet; • Piloting codes; • Developing a working analytical framework; • The list can be refined.	• Codes included all 21 theoretical factors; • Codes also included other relevant categories e.g.: challenges, benefits, training principles. • New codes emerged from the data; • Case study interviews were coded twice – for the case study findings and for the purpose of interviews. • The researcher piloted the first interview to test the codes. • The list of codes was established in the first few interviews as saturation occurred; • Coding and interpretation were discussed with the supervisory team; • Clarity was achieved by checking previously coded text and by adding a description of code in NVivo.
3. indexing	Coding the transcripts of each interview. Adding numbers to codes. If appropriate data are coded into multiple codes. Add the category "other" for the data that cannot be indexed.	Dragged and dropped into pre-defined codes in NVivo. Each code has a number. In this study multiple coding of the data is allowed and this shows relations between codes. Adding emerging codes and the "other" category.
4. charting	Organising the data. Summarising perspectives of participants.	This principle was implemented by creating a summary of results – for each factor for each participant. This is discussed in Chapter 5.
5. mapping and interpretation	Making sense and understanding: drawing relationships, describing codes, practical conclusions and other points.	This was achieved in Chapter 6: each factor is described, it was shown how important it was, there are also maps that show relations and the researcher identified practical ways of achieving the factor in practice that can help both the industry and academics.

In this study, the data were interpreted early with the pre-established codes, as per FA; while new emerging categories and codes were interpreted, merged and mapped in the later stage, as in Parkinson et al. (2016), to revise the initial theoretical concept. A difference between this study approach and Parkinson et al. (2016) was that they had a bigger set of data and a whole team conducting the study. Another difference was that they established a lower number of broad categories (around 10), while this study included both theoretical factors (21 factor – codes), broad categories and potential, new factors. The analysis by Parkinson's et al. (2016) was more suitable for the number of interviews they had which was 77, while the method in this study is more suitable when there is more time, fewer interviews and the researcher wants to go in-depth with the data and go through the data multiple times (Parkinson et al. 2016).

4.4.5.2 Content Analysis

A conceptual content analysis was also conducted to support FA. It is a quantitative method used to analyse the qualitative data (Denzin and Lincoln 2011, Wilkinson and Birmingham 2003). It is a systematic, practical tool used best in combination with other methods (Allen 2017, Rose et al. 2015). Whilst the method can start both deductively and inductively, this study applies a deductive coding that "commences with prior establishment of categories and codes based upon a theory and bringing them in connection with the text" (Kulatunga et al. 2007: 503). In combination with FA, this allowed for pre-established codes (critical factors) established in Chapter 3 to be tested against their occurrences in the interviews. This quantitative element of the findings was also supported by the pragmatic, pluralist stance of the research, as discussed in Section 4.2. and Section 4.3. The study assigned relevant parts of the text (interview transcript) to pre-defined codes, which is part of FA, then the CA, a quantitative step, analyses the frequencies (Wilkinson and Birmingham 2003).

Regarding the statistical information that was established from NVivo through CA, the researcher agrees with Patton (2002) that this can only partly contribute towards a better understanding of the data. However, the information about numbers and frequency of codes were useful to graphically present and visualise the data, and this is used in the findings presented in Chapter 6, through tables which show the presence of each factor in the interviews and in the case study. As a result, CA complements FA, reveals the frequency of concepts and allows for the visualisation of the data.

4.4.5.3 The analysis process

The analysis used a CAQDAS software – NVivo 10 and NVivo 11. The researcher used NVivo software to help the analysis process by providing the storage, structure, control and digital way of working with the data. In studies previously identified as guiding studies for FM, by Parkinson et al. (2016) and Gale et al. (2013), NVivo was also identified as a useful and portable tool that could increase the transparency and control of findings.

To understand the data, and write the analysis chapters presented in Chapter 5 and Chapter 6, besides NVivo support, the researcher relied on multiple readings of transcripts, reflection and an in-depth understanding of the interview data. The interviewer also took notes during and after interviews to note key ideas, additional points, observations and the context of the interview, to enable better interpretation later, as suggested in Flick (2009).

The process of drawing conclusions, the process of synthesis, is a creative process which comes from the researcher (Patton 2002). It is a process that includes going back and forth with the data to summarise the key findings (Patton 2002). As per the FA methodology and Deductive Qualitative Analysis (DQA) by Gilgun (2013), whilst the overall approach was deductive, as the work started from the pre-defined set of codes (critical factors), when new topics emerged from the data, as suggested in FA, the researcher went back to previous transcripts to search for the matching quotes and identify if they were present. For example, when the researcher noticed an emerging topic in the Interview 4 (I4), this also meant going back to previous Interviews 1, 2 and 3 to code any matching ideas in those transcripts. Most new codes emerged within the first four interviews and therefore the saturation was reached early in the study. New ideas that emerged further helped to revise the initial theoretical concept (set of factors), as recommended in FA and DQA. While topics and saturation emerged early, fuller, richer data was acquired by having more interviews. BIM expert interviews where a source for all new topics and codes, whilst the non-BIM management professional interviews enabled for a deeper understanding of codes – critical factors. The perspectives of different professionals, BIM and non-BIM management professionals, helped to provide a more holistic way of perceiving and examining the data, as suggested in Patton (2002).

4.4.5.4 Limitations

This study agrees with Parkinson et al. (2016) that the final interpretation stage is challenging and time-consuming. In Parkinson et al. (2016) it was discussed how challenging it is to understand the data and draw conclusions from them. In this study, this issue occurred less, but the main challenge was time. While it was not difficult to understand the data and to draw conclusions, it was challenging for the researcher to physically read the data and to write findings with all timestamps. These timestamps were later removed from Chapter 6 and kept only in quotations, but the researcher kept a copy that could be used to validate the results. As in Parkinson et al. (2016), coding an hour of an interview usually required half a day. Writing preliminary findings (phase charting in Chapter 5 and writing the final analysis in Chapter 6) took almost a year. The biggest challenge was transcribing, where the quickest transcription took three hours (for an hour of an interview) and the longest took five days. In future research to improve this process, step 4 could be simplified and interviews could be more structured. Future research in a similar field could be quicker, particularly the reading and transcribing phase, as the researcher becomes more proficient with specific English terms and vocabulary. Discussing results was also time-consuming due to the complexity and the scope of the topic, as this study integrates knowledge from many different disciplines. However, this is an important, unique and innovative aspect of the study.

4.5 Case study

4.5.1 Case study methodology

A single, longitudinal case study method is appropriate for this study, as it enables a detailed examination of a real-life scenario, which is in this study BIM team development process in a construction project team (Flyvbjerg 2006). A single case study method provides an opportunity for researchers to be closely involved in the study and this can help to obtain in-depth insights about how the process of BIM team development occurs and about its challenges (Flyvbjerg 2006, Noor 2008). As a result, a single case study provides an enhanced understanding of BIM team development both for the academia and industry professionals and responds to research objectives, as per Chapter 5 and Figure 5.1. The practical knowledge acquired in this case study also demonstrates potentials of applying CM and IM theories (Figure 5.5). Currently, there are not many studies that explain BIM implementation in-depth and focus on KM, CM, IM and people management; therefore, as a tool to understand a scenario that is theoretically not well-known, the case study can help that (Yin 1989).

The case study and the pragmatic stance of this study have the ability to provide a discussion that holistically shows events and explains practical mechanisms that lead the team to results (Mills et al. 2010). Due to the pragmatic nature of this research, the case study combines different data and methods and emphasises results that incorporate practical guidelines for other academics and industry practitioners to achieve a software adoption and BIM team development. A case study also has the ability to capture the change and flow of processes, which is important for the aim of this study and CM investigations. As a result, a longitudinal, in-depth, single case study is the chosen method to obtain in-depth data about the process of BIM change and team development (Proverbs and Gameson 2008).

The case study in this research is dominantly idiographic and partly nomothetic. The main aim is to present and explore the phenomenon of BIM team development in a project team context, but also to interpret reality (real-life events in regard to BIM team development) by making connections with existing theories. As a result, the case study demonstrates how applying CM, IM and KM theories can benefit other AEC teams with BIM team development. As per Mills et al. (2010), most social research is between the two ends of idiographic and nomothetic research. Being partly nomothetic, this case study was purposively chosen to have "most-likely" characteristics (Eckstein 1992), to be able to generalise for other organisations (Windelband in Mills et al. 2010). The case study team is similar to many other large project teams that include various construction disciplines, deliver government's projects and aim to deliver BIM Level 2. In comparison with the work of Yin, this study is a 'revelatory study' which means that it provides an opportunity to investigate the phenomenon in-depth (Yin 1994 in Eisenhardt and Graebner 2007). From Lijphart's (1971) perspective, it is interpretative, theory-confirming and theory-guiding, as it interprets issues and findings through existing theories and helps to develop them further.

Its idiographic (interpretive and theory-guided) and qualitative nature was a strength for contributing the most to the body of knowledge, and even more with the combination of qualitative FA analysis and content analysis (Levy 2008: 2). Being a theory-guided, exploratory and explanatory study, it interpreted BIM team development processes and challenges within one team by comparing them to theories of IM, KM and CM. This was achieved through a thematic Framework Analysis (FA) and partly with the help of conceptual Content Analysis (CA), which created quantitative findings to contribute the qualitative discussions. Theory-informed FA provided a better understanding of events, as Levy (2008) suggested. As a result, findings were compared to existing pre-established codes in FA and due to pragmatist stance, new findings emerged from the data about challenges and mechanisms in practice. Being pragmatic, some results are presented in a descriptive manner to help other researchers and practitioners with BIM software and practice development of their teams.

Being a part of the more extensive research study and being a supplement study (Morse 2010), designed to address Objective 1, the case study had time limitations. However, the single case study has an advantage over the larger number of studies, as it enables the researcher to be more focussed, reveal more details and relations and to be more persuasive (Siggelkow 2007 in Eisenhardt and Graebner 2007). From Yin's stance, a single case study is usually a choice for unusually revelatory cases, which is the case with this case study, being a project of well-known, successful construction and design organisations in the UK and the researcher was able to conduct in-depth, close investigations of the team (Eisenhardt and Graebner 2007).

The case study is a common method in management research and the AEC literature. There are many studies in management research, such as recent studies by Lindgren et al. (2018), Wang et al. (2017), Bygballe et al. (2018), Peansupap and Walker (2006), Schröpfer and Kurul (2017), Eriksson et al. (2009) and Robinson et al. (2005), that use a single or a few case studies. Some of these articles are also close to the domain of this research, as they investigate the technology adoption, innovation and KM. They also conclude that more in-depth case studies shall be provided, as discussed in Chapter 1. A case study is a useful tool because it provides contextually dependent results that are essentially more practical and more valuable (Flyvbjerg 2006: 224). Particularly in social sciences, the case study is an appropriate and common method (Noor 2008). Being a standard and practical method for investigating social and learning processes, commonly used in management research, the case study method can contribute to this study. However, as a precaution, it should be acknowledged that the findings could be 'contextually dependent', not to mislead the generalisability of the results.

This case study applies qualitative methods for the data collection, including weekly observations, interviews and insights into documents. The contemporary studies on research methodologies and previous discussions in Section 4.2.5 stress the need to combine methods to get the richness of the data and to allow new perspectives to emerge into the body of research. The construction management research is not diverse in terms of methods and it mainly follows principles of positivism and quantitative research; while those studies which implemented a qualitative approach are uniformed and mainly solely use the interview technique for the data collection (Dainty 2008: 6). There is a need for a 'multi methodology' to get rich, complementary data and develop a fuller perspective regarding the investigated topic (Dainty 2008). As per Morse (2010) and pragmatic nature of the study, work of Flyberg (2006) and Thomas (1998), combining different qualitative research methods and different levels of analysis can enable case studies to reach its potential and fulfil the aim of this study: to explain relations between events and contribute towards the theory development.

4.5.2 Process

In accordance with Proverbs and Gameson (2008) guidelines, the case study started by defining boundaries for the study and the unit of analysis. These were 'BIM skill development and change management implementation' and the core construction project team was the unit of analysis. The timeframe was nine months. Previously defined aim of the study, objectives and conceptualised theoretical evidence were applied to focus the study both during the data collection and for the analysis. The case study addresses specifically Objective 1. The case study process is illustrated in Figure 4.3 below and in Chapter 5 in Figures 5.1 and 5.5. The model presented in Figure 4.3 was developed in accordance with the work of Noor (2008).

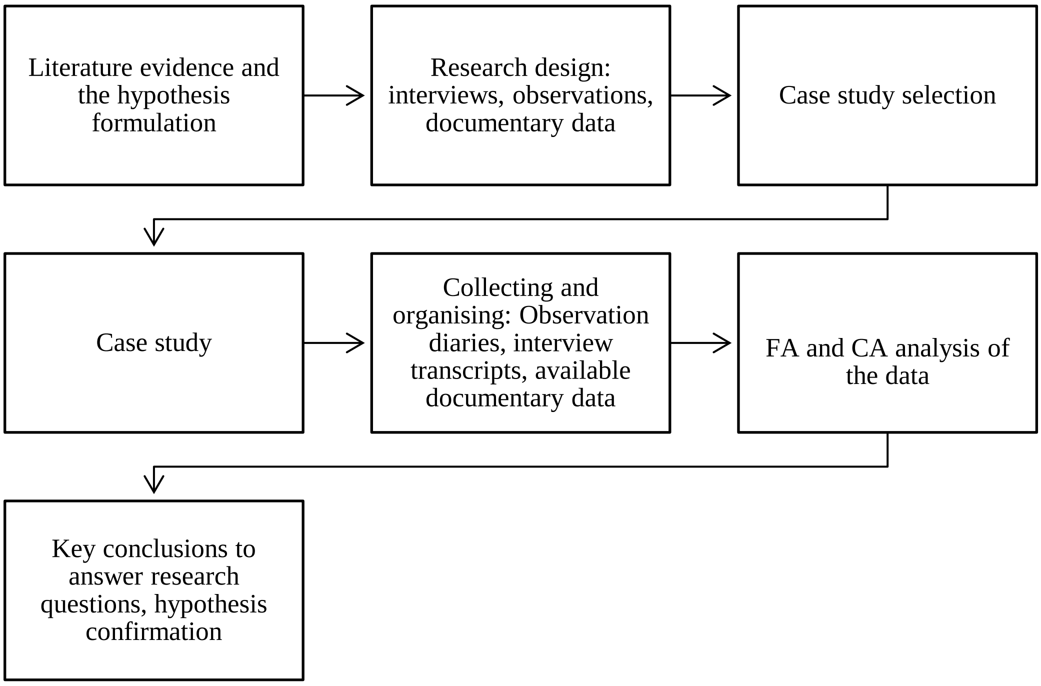

Figure 4.3 Case study research project process

4.5.3 Interviews data collection

The previous section, Section 4.4, describes the design of all the interviews in-detail. Here this is summarised to explain the case study interviews. Additional details relevant only for the case study are provided. According to Proverbs and Gameson (2008) and Dainty (2008) an open-ended question interview is a common practice for a qualitative data collection in construction management, and it is a usual practice for case studies.

As per Section 4.4, the sampling for the interviews is purposive. Participants are senior managers, chosen based on their experience, authority, knowledge about BIM, involvement on the project and diversity of their professional backgrounds, as presented in Table 4.4. At the time they were appointed by two different, large, construction organisations. Most of the participants had experience in delivering BIM projects prior to the case study project in previous organisations. Nine participants came from five different managerial teams. From these nine, eight were chosen to be compared with the interviews of BIM management professionals. This was due to their extensive understanding of BIM practice and because they were willing to share their experience from other projects and organisations too. The last one had less of an understanding of solutions; and therefore, this interview was excluded from discussions in Chapter 6; however, it did contribute to the case study. To make the process clear, the eight interviews were coded twice – once with the case study codes and again as other elite-expert interviews.

This data was examined through a framework analysis (FA): where results were compared to a pre-defined list of topics emerging from the literature using NVivo. The second level of analysis was CA. More about FA and this process is in Section 4.4. The final codes were established based on pre-defined codes, and by adding new emerging codes and codes specifically relevant to the case study. In content analysis, most codes were pre-defined, whilst the other set of codes (such as some challenges within the AEC team) emerged from the data (Rose et al. 2015). The frequency of codes - provided by CA - provided an additional level of understanding about the project challenges. This is presented in Chapter 5.

4.5.4 Observations

The observation was the second method of data collection with the purpose to understand the real behaviours and processes in the team. Combining different perspectives of interviews and observations, having the data collection from different sources is also suggested in pragmatism (Johnson and Onwuegbuzie 2004) and qualitative mixed methods (Morse 2010). As per Morse (2016: 10) both mixed and multi-methods allow for the triangulation, which in turn enhances the validity of the study (Morse 2016, Morgan 2014b, Noor 2008). As suggested in Johnson and Turner (2003), combining different methods allow a study to achieve Maxwell's (1992) dimensions of validity for a qualitative research, descriptive validity and interpretive validity. Descriptive validity means ensuring the accuracy of the data, while interpretive means ensuring that the interpretation of the data and that what participants explained is correct (Johnason and Turner 2003). This is similar to the concepts of validity defined by Guba and Lincoln (1981 in Ali and Yusof 2011): credibility and confirmability. The concept of validity is explained further in Section 4.6. Therefore, combining observations with other data help researchers to understand the real picture that might vary from the way participants presented themselves in, for example, interviews.

According to Proverbs and Gameson (2008), the participant observation is a tool that allows the researcher to become a part of the team, acquire an in-depth understanding and collect the qualitative data. Unlike detached observations, this method has a risk of being biased (Proverbs and Gameson 2008), therefore the researcher in the team followed a pre-defined strategy, was aware of potential subjectivity and validated the data through triangulation and different methods of analysis, FA and CA. The strategy was to record the processes in the organisation in the form of a pre-structured diary - in the form of an expanded FA. The idea was to create a system that can be compared to interviews and pre-defined codes. This type of observational research is called a more-structured observation (Sapsford and Jupp 2006). Observational records also contain an introduction segment that describes general activities of the team and a table of comments for each of the twenty-one theoretical factors on BIM team development from Chapter 3. For example, it was noted how the team made decisions, about their vision development, learning mechanisms and other points. After the completion of the case study and observations, to analyse the data the researcher created a summary for each factor. This analysis was extensive, but helped the researcher to integrate the data. This part of this analysis is presented in Appendix E.

4.5.5 Documentary data

The researcher also had the ability to review some of the project documents relevant to BIM adoption on the project, which further enhanced the validity of interview and observational findings. The researcher also had access to the intranet, cloud-based material relevant to BIM adoption and the results of the company's surveys. The review of the cloud-based material revealed the approach that the company was implementing to train the staff, whilst the company's surveys were attitudinal surveys towards BIM implementation, which revealed the interest towards BIM within the wider internal team. The first survey was on the company level, while the second survey was on the project team level. The documentary data revealed the level of certainty about the BIM practice and the ability to achieve BIM Level 2 at that stage in time. Due to confidentiality, it is not possible to present the documentary data or discuss them in detail. However, this data enabled the researcher to acquire a greater understanding which helped to conduct interview conversations and write the observational findings.

4.6 The integrity of study - ensuring validity and reliability

To ensure the quality and integrity of the study, the researcher must ensure validity and reliability in their studies. Ensuring validity means that the findings are presented accurately, that there is integrity in methods (Ritchie et al. 2014). The concept of the reliability is about the replicability of the findings (Ritchie et al. 2014). There are some discussions in the literature on whether the reliability should be discussed in the qualitative research, and the main advice is to explain the research methodology and design and show how findings would be repeated with another sample (Ali and Yusof 2011, Ritchie et al. 2014). Validity and reliability have different criteria for qualitative and mixed-method research; and therefore, these are discussed separately. Firstly, it is explained for the qualitative study – elite, expert interviews, then for the case study as a whole.

Qualitative survey – elite interviews

For the qualitative aspect of the study, this study follows the well-known work of Lincoln and Guba developed in 1985, and the four criteria to achieve trustworthiness of a study: credibility, transferability, dependability and confirmability (Lincoln and Guba 1985, Ali and Yusof 2011). The credibility is the most important and it confirms the significance of a study (Flick 2009). Table 4.7 describes how each of these criteria is achieved in this study.

Table 4.6 Ensuring validity

Ensuring validity - trustworthiness	In accordance with guidelines from Lincoln and Guba (1985), Patton (2015), Flick (2009), Ritchie et al. (2014), Ali and Yusof (2011) and Morse (2016)
Credibility	Showing how confident are findings: • Purposeful sampling; • Triangulation – different methods of analysis – FA analysis and additional CA; • Demonstrating and describing the analysis process for each study separately – chapter 4 and findings chapters 5 and 6; • Each quote or statement in analysis has a reference – time when it was mentioned in the interview; • Once summarised, findings were presented to interview participants – respondent validation with 4 participants. Participants agreed with findings and asked for future publications or results; • The findings were presented as conference proceedings and conference presentations and the feedback was positive – non-member validation. The feedback was mostly about how findings are practical for their organisations and how they would like to get more details, current and future publications. Feedback occurred in QA after the presentations and some feedback arrived in emails after; • “Peer debriefing” with the supervisory team and presenting the work to other students; • All interviews were recorded and securely stored; all participant information sheets were signed and securely stored.
Transferability	Showing how findings can be used in another context: • Purposeful sampling; • Interview participants worked for different AEC organisations and they had different roles – this is visible in the table of participants; • The majority of participants were involved in policy-making and consultancy with a range of organisations and projects; • They have authority in the field; • Detailed presentation of findings with quotes.
Dependability -	Showing how study can be repeated, showing that the research was systematic and

reliability	documented: • Recording interviews; transcribing interviews, having an audit of the data; • The interview questionnaire created and presented; • Audit trail – a documented process of research design and choices made.
Confirmability	Showing how conclusions emerged from the data, how they were not a product of subjective interpretation of the researcher: • Demonstrating a structured approach to interviewing and analysis; • Audit trail – showing the process of analysis and data collection in detail; • Content Analysis (presence of factors in interviews) to support Framework Analysis.

Case study

The pragmatic stance is achieved not only by describing, but also by adopting different ways of evaluating and interpreting the data, which increases the validity of the study. Pragmatism and mixed-methods suggest the triangulation to increase the validity of the study's findings (Morgan 2014b, Morse 2016, Bryman 2016). This was previously discussed within the section on participant observations – Section 4.5.4. While discussing benefits of mixed methods, Johnson and Onwuegbuzie (2004: 18) explained that "if findings are corroborated across different approaches then greater confidence can be held in the singular conclusion". Particularly in the case study, combining multiple techniques to collect the data is the recommended approach to help the validity of the data (Noor 2008).

Being qualitative, this study relies on qualitative measures of validity, established by Hesse-Biber (2010) and demonstrated in Table 4.8. These methods are developed in the 1990s by Kvale and presented in Hesse-Biber (2010). As per Hesse-Biber (2010), these are the methods that apply to qualitative research or mixed-method qualitative research. This is important to consider for this study, as the study employs the pragmatic stance, it combines different methods of data collection and different approaches to analysis, both qualitative and quantitative. Table 4.8 presents these criteria and shows how they are achieved in this study.

Table 4.7 Validity of the case study

Adopted from Kvale (1996) in Hesse-Biber (2010)	Question to respond (Hesse-Biber 2010)	In this study
Validity as the quality of craftsmanship	How well methods fit together and respond research question? Showing credibility. Showing reflexivity.	All methods have the common aim to describe the processes relevant to BIM development in the project team. Credibility and integrity are also discussed separately for each method. How methods fit together is demonstrated in Chapter 5. Reflexivity is present by identifying limitations in the study.
Validity as communication	How is the study transferred to the research community	All phases of the study and decisions were discussed with the supervisory team. This study is presented to the community in multiple ways: reports in the case study organisation to show key findings, conference papers, presentations, teaching at the university. This showed member and non-member validation. Their feedback had an impact on the way the research was conducted and results were written.
Pragmatic validity as action	What is the practical impact?	Helping organisations and the AEC practitioners to achieve more effective BIM team development. Summarising lessons learnt from the practice. Showing the value and implementation of theories.

In addition, this study collected interview audits, detailed transcriptions, interviews were double coded manually and in NVivo, follow-up discussions with the case study participants and senior members of the research team to verify the data were conducted (Guest et al. 2013, Lindgren et al. 2018). All interviews were validated through the same process as BIM elite-expert interviews in Table 4.7.

4.7 Ethical considerations

This study was conducted in accordance with the Coventry University ethics procedures. To gather the data, the researcher applied for and obtained ethical approvals. These approvals are referenced with codes: P53162, P48040 and P73060. To obtain these certificates the researcher provided an explanation of how the process was going to be conducted, storage of the data, any risks involved, examples of questionnaires and other relevant details. For both interviews and the case study, participants were provided with an Information Sheet document that included the aim and brief of the study, the confidentiality clause, information about recording and the use of data and information on how it could be beneficial for both for the study and them. Each interviewee signed a consent form too. Ensuring that participants see the benefits of the study contribute to the quality of their participation and their trust.

This study adopted guidelines by Thomas and Hodges (2010). The first principle of truthfulness is being established by presenting the raw data, quotes, through a number of tests and triangulation of the data. For the second principle - conflict of interest - the researcher declares that she has no hidden interests regarding the way the data or theories were presented. Regarding the third, there is no scientific standards and bias, as the research presents different perspectives and theories throughout the study. The next concept is on plagiarism. For this the researcher referenced each idea, fact or statement that was being taken from another source. The list of references is also provided. The study went through Turnitin, a plagiarism checking tool, and a report was presented to the supervisory team. The welfare of the study's participants is guaranteed by having a study which does not reveal at any point participants' details. The final concept is the safety of the support staff and this is achieved by making sure that the research procedures were not posing any risks to the supportive research community and the researcher's team.

4.8 Systematic review methodology and systematic review protocol

The Systematic Review (SR) is used as a method to collect and summarise all the evidence in the literature within a specific subject area. This study uses this method to understand what has been done in the area of BIM implementation strategies and bring the first conclusions from it. This aids to this study by summarising the literature research and organises results.

According to Petticrew and Roberts (2006), SR is beneficial when there has been a lot of research regarding a particular topic, but there are still some crucial unanswered questions. It could be particularly useful for a research in a domain of BIM which is currently facing challenges regarding the team development and implementation processes, such as time and cost effort, lack of resources, coordination and leadership challenges (Azhar 2011, Bataw 2013). For this study, SR helped to find and investigate gaps and weak points that needed further research. SR also enabled the mapping of crucial steps that affect BIM team development process.

4.8.1 Principles underpinning the systematic review

Before explaining SR in detail, there is a need to explain the philosophical approach that stands behind it. The researcher's stance is the pragmatist perspective, as explained in the research design. It has also been explained how this study is influenced by CR. According to Gough, Oliver and Thomas (2012: 41) critical realism believes that "our knowledge of reality is mediated by our perceptions and beliefs". This affects the research process and the way researchers understand and analyse the data, therefore the researcher wanted to apply a systematic, structured way to review both the data and the literature. The 'realist synthesis' is an approach - or a logic of enquiry - developed from critical realism and used to collect and synthesise the evidence. This approach fits this study for a number of reasons (Rycroft-Malone et al. 2012, Pawson 2006):

- It helps to understand and explain the topic, not only summarise it;
- It helps to identify "what works for whom in what circumstances and in what respect" (Pawson 2006: 74);
- There is a gradual building of knowledge regarding the processes we are investigating. This can later be transformed into a theory or a model, which is the aim of the study.

The realist synthesis follows the logic of configuration, which means that different findings from a number of studies are gathered to develop a model or a theory (Sandelowski et al. 2012). It explains correlations that exist in the processes of interest and can show a bigger picture. The configurative synthesis is a process of reasoning which leads to an assumption or the beginning of a theory (Sandelowski et al. 2012); and the role of such reasoning was also discussed at the beginning of the chapter as a logic applied in pragmatic studies. Although the final assumption or theory might not be correct, it can explain the processes presented in the literature; and later this can be tested in empirical studies.

A number of authors (Gough, Oliver and Thomas 2012, Sandelowski et al. 2012, Rycroft-Malone et al. 2012) suggest the work of Pawson (2006) who provides the guidance for executing SR. Pawson (2016) and other authors (Denyer and Tranfield 2009, Kelly 2015, Rycroft-Malone et al. 2012) suggest that 'traditional' SR must be modified to be used for qualitative studies and further modified for socially-oriented or management studies. This was because the 'traditional' form used in the medical research followed a rigid research process that might not be appropriate for social sciences due to its rigid structure (Rycroft-Malone et al. 2012, Denyer and Tranfield 2009). Therefore, the protocol for this research follows principles of executing a systematic review made by Gough, Oliver, Thomas (2012) and Pawson (2006), for care and social sciences, and Denyer and Tranfield (2009) who created a set of guidelines for the management studies.

4.8.2 Defining systematic review

The systematic literature review is a method which leads to “unbiased, complete, reproducible reviews” (Boel and Cecez-Kecmanovic 2010: 130). The data collection must be done as a primary data collection, following “principles of quality, rigour and accountability” (Gough, Oliver and Thomas 2012). According to Denyer and Tranfield (2009), systematic reviews need to be transparent, inclusive, explanatory and heuristic.

The ‘transparency’ means to be open about the review and to explain the research process. This principle asks for a recorded and organised study. Therefore, this study explains how the data was selected, the leading questions and explains the processes of systematisation and analysis. Any change in the process shall be documented as well. This also increases the validity of the study.

The ‘inclusivity’ means primarily choosing the evidence that is fit for the purpose and that adds some relevant information, therefore not necessarily including all the evidence (Denyer and Tranfield 671: 2009). SR guidelines explain that there should be eligibility criteria regarding the evidence (Higgins and Green 2008), and Denyer and Tranfield added that there is also an importance to have a range of evidence to help the understanding of the topic and provide a bigger picture. This means that the range of evidence should be flexible and the literature should be investigated until the research questions are answered. This research study might include relevant websites, as a current and “live” source of information, but might not include all research articles on BIM from selected databases if an adequate data saturation and explanation is achieved. This principle was particularly implemented in the literature review (Chapter 3), while in the systematic review, the scope is to investigate only the academic papers.

The ‘explanatory’ principle explains the need for the study to be interpretive and to code and synthesise the data from various studies. The data shall be firstly organised in tables, which helps with the first conclusions. Then attributes of the studies (for example, ‘key topics assessed in studies’) are compared between the studies, which provides the final data synthesis. The data is also compared using the CIMO logic, explained in Section 4.8.4.

The fourth principle, regarding having a ‘heuristic’ review, explains that there might not be a universal solution to a problem, but conclusions from the systematic review could provide suggestions and guidelines. This is previously explained and mentioned in discussions on configurative synthesis (Section 4.8.1). This flexibility and hypothesising in the research are needed because solutions depend highly on the context and there cannot be one solution to all organisational management issues. As a result, the study's findings help to discover which mechanisms work in which context (Pawson 2006).

4.8.3 Systematic review protocol

This protocol follows guidelines suggested by Pawson (2006), Tranfield, Denyer and Smart (2003) and Denyer and Tranfield (2009). Pawson structured the process into the following categories (2006: 79):

1) Identifying review questions;
2) Searching for primary studies (interested in their results);
3) Quality appraisal of the evidence;
4) Data extraction;
5) Synthesising findings;
6) Dissemination.

These steps are used in SRs that follow meta-analysis principles, but Pawson re-defined each phase to be suitable for flexible, socially-oriented studies. These suggestions were therefore incorporated in the protocol and explained in the study. The process was non-linear and some modifications could have been made later during the study (Pawson 2006:82).

4.8.4 Systematic review strategy and questions to be addressed – question formulation

This protocol is built to achieve the first objective of the study. This is:

> "To identify challenges and development strategies for BIM implementation in the AEC industry."

This is achieved by reviewing the literature on BIM adoption, implementation and development in the AEC organisations. To achieve this objective, there are the following research questions presented below in Table 4.8.

Table 4.8 Objective 1 and research questions

Objective 1	research questions
	1. What are the current implementation and development practices for BIM in the AEC industry? Which strategies were implemented to achieve BIM development in organisations? 2. What is a good practice that can be implemented in other organisations? 3. What research topics (questions) have been addressed in studies on BIM implementation and training? 4. What are the challenges regarding BIM implementation and team development?

The study uses the CIMO logic as suggested by Denyer, Tranfield and Aken (2008) and research questions developed from Table 4.8.

The CIMO logic structure is defined in Table 4.9. This model is developed from the 'realist synthesis' CMO (context, mechanisms, outcome configurations) model made by Pawson (2006). According to Gough, Oliver and Thomas, the purpose of this model is to investigate causation links, where the researcher needs to recognise different contexts in which different mechanisms works (2012: 43). The final goal is to develop a model which explains what works under which conditions (Pawson 2006).

Table 4.9 CIMO logic and questions development

Component	Questions
Context - C	**The population of interest?** AEC organisations. **Which interpersonal relationships are of interest?** Group and individual learning dynamics. Change. Development. **Which aspects of the wider infrastructural system are of interest?** AEC industry.
Interventions - I	**What is the intervention of the interest?** Training, development, initiatives.
Mechanisms - M	**What are mechanisms of the interest?** A strategy that can influence BIM team development; e.g. greater software knowledge, teambuilding, improving information management flow, improving communication flow, encouragement.

Outcomes - O	**What are the relevant outcomes?** What outcomes are relevant for organisations? BIM project performance; Control, coordination, collaboration with external parties. **What are the secondary outcomes?** Development of employees: Process understanding, software skills, coordinated teamwork, greater communication, problem-solving skills, decision-making skills. **How will the outcomes be measured?** Measuring BIM learning efficiency, understanding the feasibility of investment, employees' motivation and attitudes and other relevant factors.

The CIMO logic and research questions helped in defining the keywords for the search. The key databases identified are presented in Table 4.10. The aim of the search is to connect the keywords derived from the CIMO logic: to connect Context words (C) with Interventions (I) in order to achieve Outcomes (O) through Mechanisms (M) and find the most relevant literature.

The search was:
"((Construction OR Architectural OR AEC)) AND ((company OR organization OR firm)) AND ((Building AND Information AND modelling)) AND ((development OR implementation OR adoption OR training))".

4.8.5 The search strategy and the population sample

The list below, in Table 4.10, presents some of the most relevant databases for the purpose of this study, according to Coventry University and a few other British universities. Each database has been searched multiple times for keywords and the search showed that there are a number of papers in these databases that could be beneficial for this research. The research included peer-reviewed academic journal papers, whilst the conference papers were considered.

Table 4.10 List of databases and their description

Database	Description
ECONLIT	Worldwide economic literature. Covers over 600 journals, books, dissertations and working papers.
Emerald, Emerald Engineering and Emerald Management Peer	Reviewed journals published by Emerald covering built environment, management, economics and other sciences.
Science Direct	Database that covers sciences, business, economic and social sciences.
EBSCO database	Includes 'Academic Search Complete' database.

4.8.6 The criteria for inclusion and exclusion of studies

The first, pre-selection, eligibility criteria was for the selected research papers to belong to one of the databases defined in Table 4.10 and contain relevant material to questions presented in Table 4.8. There is a need for studies to be in the context (C) as presented in Table 4.10 and preferably located in the UK. However, as at the end of the process, the research found many studies outside the UK that were highly beneficial for the research. Studies were from peer-reviewed journals and the timeframe was between 2006 and 2016.

4.8.7 Evaluation of data and sources

It is important to be clear on why some sources have been excluded or included. For this the researcher considered the following information (adapted by Denyer and Tranfield 2009):

1) general information (reference);
2) reason to read,
3) study aim and research questions (key topics and questions),
4) study context,
5) study research design; empirical, conceptual or multi-method
6) key findings,
7) how relevant is to research,
8) how reliable is,
9) representative to the context we are interested,
10) conclusions from this study.

This information is presented in Table 2.2, while the SR results are presented in Chapter 2.

Chapter 5. Research findings and analysis

This chapter presents methods of conducting the analysis in this study. Different sets of results are presented separately – the longitudinal case study in Section 5.1 and expert interviews in Section 5.2. According to Morse (2010), in multimethod studies, it is necessary to discuss the findings separately for each study before discussing them together. Section 5.1 presents a single case study of a large construction project team. The case study investigates Objective 1 (Figure 5.1). The connections with Chapter 2 and the position of the case study are presented in Section 5.1.7. The expert-elite interviews purposively sampled to be with management professionals are preliminary analysed in Section 5.3 and they investigate the Objective 3 and 4.

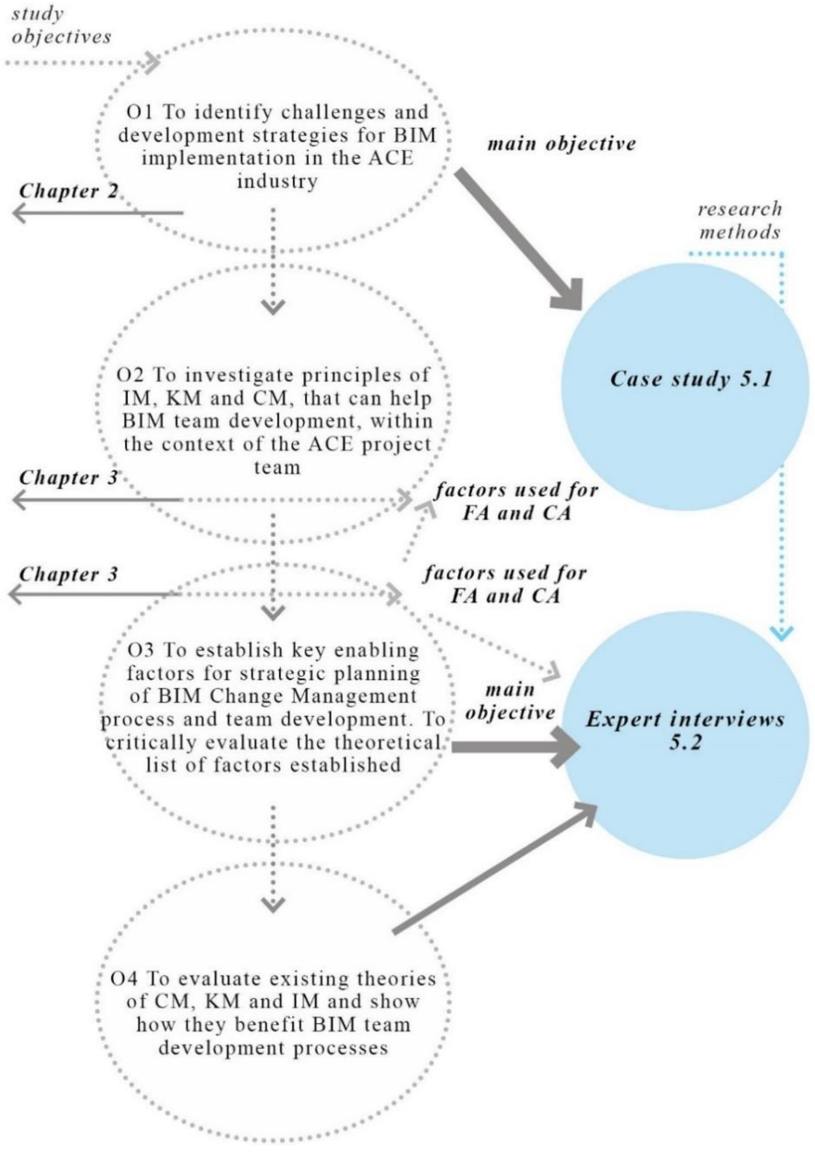

Figure 5.1 Study objectives and how they relate to Chapter 5

5.1 Exploratory case study - research findings and analysis

5.1.1 Introduction and background of the study

The case study discusses the experience of a large construction organisation in dealing with BIM team development and change. This longitudinal case study follows the nine months practice of a construction team, as illustrated in Figure 5.2. This large project, worth over 500 million pounds, was based in the UK and had multiple parties involved. The project team had a goal to reach BIM Level 2 and potentially use BIM for the facility management. As explained in the methodology, Chapter 4, the researcher developed a conceptual framework to perform FA of the data and applied it to qualitative data collected as observations and interview findings. Upon FA, CA was also applied as the second level of analysis. To further check and support the observational findings and interview discussions, documentary data were also collected and analysed. Details about conducting the case study method, data collection and analysis are discussed in Chapter 4. Results show that improvements in management support, communication, team's vision and knowledge management are among mechanisms that could help this team manage their challenges with BIM team development. Upon the analysis, as one of the conclusions and contributions of this study, it emerged that KM, IM and CM could positively impact the case study project team and help the BIM team adoption and development.

5.1.2 Gradual adoption of BIM in an AEC team

According to interviews, the documentary data and observational findings, in terms of BIM practice there was a weekly model sharing between the core team parties to create a federated model, which strengthened the communication and the quality of exchanged information between parties. Architectural, structural and building services designs were all modelled. While design information was being created and shared regularly, it was not determined how the as-built model would be created, by which party and to what level of detail. The project team was certain that they were supposed to deliver Level 2, but they were not sure what that meant and what requirements were expected from them.

According to interviews, the project team was already delivering a certain level of BIM practice, as per Figure 5.2. They were also using 3D federated models to visualise design, coordination, project schedule - 4D practice, change management, do some 'technical checks' and clash detection. However, one of the interviewees explained that for a more advanced BIM practice "there's not a lot of embedded information in there at the moment for us to work with". It was said that the model did not have the right level of information to be interrogated (interviewees mentioned points such as - “to determine what the airflow rates are, what the ductwork material is” or to conduct energy calculations). BIM was used mostly for the graphical representation or visualisation, but as they explained, the ‘actual engineering’ was in 2D format (Figure 5.2).

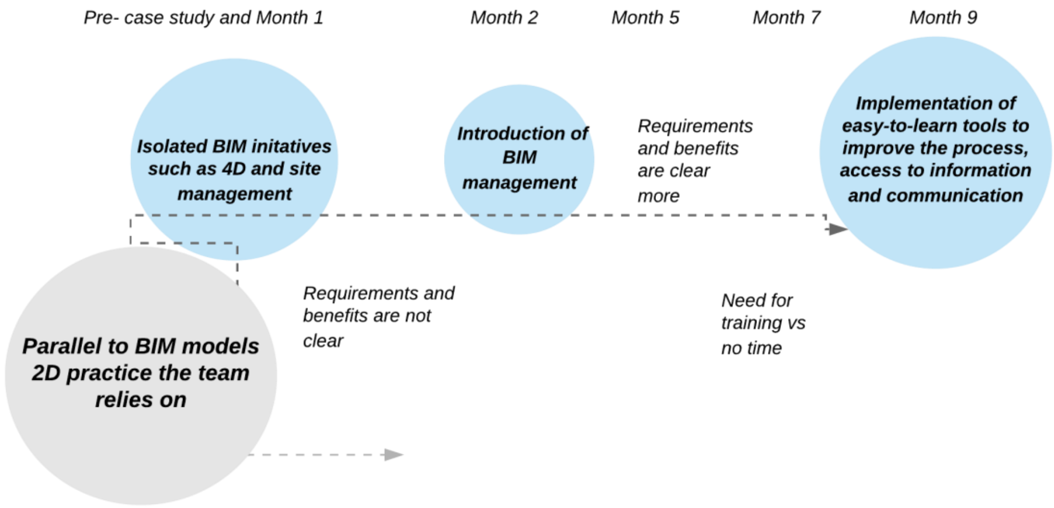

Figure 5.2 The case study process

The overall change and development within the team was slow and moderate, which was determined by the management team and several challenges. At the time BIM models were mostly used as a ‘reference point’ and supportive practice, rather than the central tool. The change was gradual, and it was there to support the non-BIM, standard practice and the Government requirements. This study investigated the reasons behind the slow adoption of BIM in this team and from all sets of data, it emerged that one of the reasons was the lack of clarity of the client’s requirements.

The team spent many months, before and during the case study, exploring ways to achieve ‘BIM Level 2’ that was requested by the client. A few months after introducing a dedicated project BIM management and months of in-house discussions and negotiations, the team was hoping to implement BIM more on-site, to create an as-built model, to connect information collected from the site with the as-built model and to use the model for the future facility management of the building. They hoped to achieve an as-built model with the ‘Level 2’ level of information attached to it. Overall, the team was exploring how to achieve BIM Level 2, but also to benefit the project-specific needs not only the client and Government requirements. However, new BIM initiatives were facing several challenges (Section 5.1.4).

Firstly, in observations and interviews, it was found that the ‘BIM Level 2’ objective and BIM management efforts were not greatly appreciated by the wider project team. There were significant time and budget constraints. It was also not clear what needed to be delivered and who was responsible for each BIM tasks. Whilst the management professionals, in interviews and observations, recognised several BIM benefits such as visualisation, particularly for the sign-off, coordination, a more efficient site delivery, 4D, construction sequence and planning processes; these efforts were not well-shared and recognised within the wider, less-experienced project team. The findings demonstrated that the middle and top-management appreciated the benefits of BIM practice and implemented a certain level of BIM practice to meet their individual project needs. Still, the change on the whole-team level was very incremental and difficult to achieve because the other members of the team were not sharing the same knowledge, experience and commitment. This study explored the rationale behind this resistance and the lack of enthusiasm and other challenges by using the knowledge from IM, KM and CM theories and FA.

5.1.3 Framework Analysis (FA) of the case study results

FA of observations and interviews enabled the researcher to acquire in-depth insights into team dynamics, collaboration in the team and how these had an impact on the BIM team development. Because the codes in FA emerged from KM, CM and IM, this allowed the case study findings to be more quickly compared to these concepts and for events within the case study to be explained through theories of KM, CM and IM. This chapter presents the main findings that emerged from the case study data, whilst the discussion chapter, Chapter 7, provides a further comparison between these findings and CM, IM and KM literature.

The key findings of the case study are separately discussed within five dimensions presented below – A to E. These findings emerged from both observations and interview data. For additional clarity, Table 5.1 separately presents only the observational results. As a result of FA, it was established that the key improvements in the project team could be achieved by focusing more on:

- A Top support
- B Communication
- C Vision and clarity
- D Knowledge Management
- E Involving people to tackle resistance to change, motivation.

Table 5.1 FA of observational reports, details are presented in Appendix D

	Key concept	*Key finding or concepts related to it*	*Additional conclusions*	*Importance for BIM development*
A	**Top support**	There was a BIM mandate but not precise requirements. Although there was a BIM mandate, some team members believed that it was "too late".	Management needed to establish requirements and technical and human resources.	Highly important
B	**Communication: exchange, access, control**	The team discussed everyone's needs. The team discussed different experiences with software tools. The wider communication established with CDE and application of PAS1192. Interoperability was important. The choice of software is determined by the ability to provide access to the right information for the project team needs. The software needed to be portable, accessible, without downloading, without additional licensing. It was essential to establish data management responsibilities and rules. It was not clear if the digital environment helps the culture of openness. The team attempted to hear about the opinions of everyone through emails, forum and several surveys. Implementing CDE was to support existing good practice. It was a very gradual change, but this was the only way because the project was in the middle of the construction stage.	Enhanced communication and discussing everyone's needs helped to achieve greater understanding within the team. Communication occurred mostly within the same discipline. Guidelines and technical support helped. The licensing was commercially challenging even for this large construction team. All deficiencies in team integration affected communication negatively. This also affected the planning process negatively. Enhanced digital communication was beneficial to have up-to-date and more consistent information sharing between parties. The management showed efforts to communicate within the wider team, but also there was a resistance of the team to be open members and there was some blame culture.	Highly important
C	**Vision and clarity**	There was no clarity on BIM project objectives. The vision was defined but not understood, described as "not - tangible". It was difficult to clarify for the whole team what needed to be achieved when the management was still discussing it. On the higher levels, within the management, the clarity improved during the case study.	It was not clear how to define goals, objectives, vision and who needed to be involved in the process of determining the vision and objectives. There needs to be more explanation than saying "deliver BIM"	Highly important
D	**Knowledge management**	The organised training consisted of: • E-modules; • BIM awareness sessions.	The management discussed the topic of training significantly in comparison with other issues. The training was organised by in-house management.	Highly important

		• Training initiatives: in-house software training sessions. There was not much reflection on the existing practice; most of the brainstorming was done through informal conversations. Time is negatively affecting the process and the team was on the pressure to learn tools quickly.	There were resource issues. Having an open, honest culture supported the training arrangements.	
E	**Involving the team in the change**	Key decisions regarding the adoption of new software were made as a team, but mostly between middle managers. For a complex and large project, it was difficult to involve more people in the process of deciding and planning. There is a team culture due to the long-term collaboration of team members on this and previous projects. It was noticed that not all team members were open to new ideas. This was due to time limitations.	Deciding together supports the collaborative culture, ensures the right decisions. It was slow, with more members. It was found essential for members to be open, to make the decisions quicker and accept the change.	Important

The categories A-E match previously defined critical factors (in Section 3.5) and helped to establish the connections between them: A (factors - F3, F20), B (F7, F8, F9, F5), C (F1, F2, F4), D (F18, F19, F14), E (F2, F5, F8, F12, F13, F21). This further shows how the case study findings feedback into Objective 2, 3 and 4, by discussing factors that emerged from theories of IM, CM and KM. This is the additional contribution as per the study design, the case study addresses Objective 1. The interviews were conducted towards the end of the research and they provide the most abundant source of data for the case study. Additional details on observational and interview results are presented in Appendices – B2 and D, but this chapter makes a summary and provides a connection of these findings.

5.1.3.1 A - Top-management support and control

The results showed that the team was aiming to adopt a more effective working practice and achieve the client's BIM Level 2 requirements, being a publicly procured project. There was top-management support from the start of the project to accomplish that and a push from the top, however, the results showed that the support was not efficient or adequate. In observations and the documentary data it was found that the team was less willing to apply BIM due to the lack of support from the top management, which manifested in lack of clarity about the requirements, lack of time and lack of equipment. Understanding these issues enabled this study to explain the required level of support, and this is one of the practical implications and contributions of this study that can be used in future by other AEC organisations as a lesson learned.

Initially, it was observed that the change was mandated by the management and the Government and the project team needed to adapt to deliver that. However, during the case study, it was found that the actual BIM adoption in this team was mostly organised bottom-up and middle-ground. The BIM change was implemented by the middle management and by a few disciplines, rather than as an organised change that comes from the top and spreads across the whole team equally. The middle management in the team already had some knowledge and experience with BIM projects, from their previous projects, and they implemented a few BIM 'satellite' initiatives for the benefits of their own smaller teams, not necessarily only to achieve the BIM project mandate. A few participants explained that this might have occurred because the BIM mandate was not clear to their teams. One of them told that there was no early BIM management support, therefore, within the construction team, a group of people developed a BIM practice on their own, but this wasn't shared and implemented on the whole, project team level. From interviews it also emerged, as in the systematic review findings (Chapter 2), that for the successful BIM implementation, there is a need for both top-down and bottom-up involvement within the team; and within this team, there was a certain level of initiative and support from both sides. However, the interviewees explained that the top-down plan was a ‘wish list’ or what would be beneficial to achieve, but this was not considered rigorously until the management appointed a BIM manager more than a year into the construction project. There were no precise requirements or clear steps from the beginning of the project on how to implement BIM.

The second finding is regarding the resources. Providing the top support in the form of equipment was found very important in the data, and this has been rarely discussed within the literature. Some people in the team had the needed resources, software and equipment but not the whole team. One of the interviewees explained that some managers had their licenses and they were contributing to BIM practice, but this was not open or shared with everyone. This practice improved in the following months, by providing more access to software, purchasing and adopting new software tools and providing the team with more access to the current model information.

5.1.3.2 B - Communication in the team

The literature on IM, KM and CM established the importance to investigate the aspects of communication within the team, open culture in the team, digital communication and face-to-face communication. This was translated into both interview questions and the structure of the observational diaries. Firstly, it was found that it was difficult to establish how open was the culture in the team, but the first observational insights were that the members of the team were approachable, regardless of their status and open to each other. Overall the team seemed open and communication between the team members occurred regularly and promptly. The only point of improvement found was that some project team members were not fully aware of each other’s knowledge and experiences which could have benefited the project. This was discovered during observations and confirmed in interviews. Being more aware of knowledge and responsibilities of others would help the team, as they would know where to ask for help and that would possibly reduce the resistance, by providing a sense of security.

In terms of digital communication and open culture, it was found that this had its challenges, such as the limited access to information online. Still, there was a practice of exchanging the advice within the company’s portals and forum. In terms of the digital information exchange, they found solutions in using an interoperable, capable and fast software, Wi-Fi access, implementing BIM standards and software licenses. The team had a weekly model exchange between design and construction teams via CDE, as suggested in standards, and this established more reliability in their communication. However, incompatible applications were a reason they had to purchase new software and train more people. This was particularly the issue with transferring the information they collected from the construction site into the as-built model for facility management (FM). Another problem they had regarding the capabilities of software was the challenge of tracking changes, sharing that information across the team and integrating it into the as-built model.

All key meetings around BIM development were organised face-to-face where different representatives had a chance to ask questions or present their point of view. However, it was also found that while being physically in the same location, not all members were part of conversations around BIM. This caused a few challenges, particularly when defining the requirements and understanding how to achieve the BIM FM model. This showed that physical proximity and face-to-face communication while being helpful were not enough to help the BIM adoption process without other mechanisms.

5.1.3.3 C - Vision in the team and clarity

The first insights were that there were opportunities to integrate the team both internally and externally, to achieve a BIM vision; however, this was not fully realised until the end of the case study. The team was defining the vision during the project, instead of setting it up in the early phase. This potentially caused number of challenges such as having diverse goals within the same team and parties being focused mostly on their role, needs and priorities rather than on a common goal. It was also found that the wider team did not clearly see the values of BIM practice, which could have been changed if the vision and benefits were communicated earlier.

They did understand that they must adapt to BIM change, but there was no clarity on what the exact vision was and what were the project objectives. According to interviews and observations, it was not clear to the team what Level 2 meant, who would create the as-built model, what data needed to be included within the design stage and what data within the as-built model. The lack of clarity about these issues could have emerged from the way the project was set and procured. It was not clear what were the exact requirements to achieve the FM and the team was trying to establish this by understanding what is technically and practically possible to deliver. The interviewees did not appreciate the lack of clarity about the responsibilities and lack of clarity about the deliverables and this influenced other issues, such as commitment in the team and motivation in the wider team.

This established the necessity to have a clear vision and goals about the BIM change from the start. It is essential to clarify what is going to be changed and why. The project team members were sceptical about getting involved with BIM aspect of the project as they did not understand what the change meant for their roles. Those that did, such as some of the experienced interviewees, did want to involve more people, asked for more licences, suggested that the main limit was time or resources, rather than the lack of skills or commitment. This shows a direct, positive correlation between the clarity about the change, and having the knowledge and experience, with the willingness to expand the change and desire to include the whole team. From these findings, it emerged that the clarity about the change is highly important to support the BIM adoption process.

The results show that it is vital to explain BIM objectives and to show that the change affects people personally, that is useful for their personal development. This finding was also established in Section 5.1.3.1 when investigating the top-management support and when investigating the role of vision and clarity. Among the teams who implemented the 'satellite' BIM initiatives was the team who realised the 4D practice. This team had a positive experience with the same software tools on their previous projects, therefore, they implemented the same methods on this project, although this specific practice was not mandated. They also convinced others within their teams who were less experienced to join them and trained them. This shows a relation between understanding the benefits of BIM practice and willingness to involve others and the desire to apply the new method without being asked to do so by the management. The experienced interviewees also expressed that the progress in the team could have been achieved more quickly if more people were involved and they recognised the benefits of engaging others and learning as a team.

These suggestions on improving the clarity about the BIM change, explaining and clarifying the vision and requirements, explaining the benefits to help the process of the change are all some of the key principles of CM and critical factors identified in Chapter 3, Section 3.5. The case study confirmed that these enhance the openness towards the change and towards learning about BIM, as the experienced professionals were the most open towards the change and interested in learning more about other tools and BIM practice. These concepts, also to an extent present in IM and KM, is further discussed in Chapter 6 and Chapter 7.

5.1.3.4 D - Managing knowledge and development

The study also explored the aspect of education and development of the project team. It was found that the lack of clarity about the objectives and the vision had a negative influence on planning the training sessions. It was not clear what needed to be delivered and it was difficult to establish a skill gap. Due to the time limitations on the project, it was difficult for even experienced individuals to use their experience to benefit the BIM practice. In observations and interviews, it was found that it became difficult to establish who needed training and experience and who was merely resistant due to the time and other limitations. There was also a lack of time and resources to send people on training; and technical problems, such as equipment and licensing emphasised those problems. The management organised training sessions to raise the BIM awareness and establish at least a minimum use of specific BIM tools. The attempt was to spread the use of visualisation, clash detection and project communication through BIM software and the team achieved these improvements within eight months.

The mid-management in interviews was also asked about training and learning experience in their teams. They explained that the solutions that worked for them were bottom-up, self-initiatives rather than a company initiative. Very few mentioned previous training they had at the company or other companies or projects. They provided examples of trying software tools within their smaller teams, of a very few people, throughout this project and previous projects and explained that this improved their knowledge about BIM tools and practice. For example, the team who achieved the 4D modelling established what needed to be achieved, their goals and vision and they worked and learned together to achieve these. The successful learning was learning through experience, trials and errors and shared learning– within the team, in small groups, they were learning from each other and showing each other how to use the software.

In terms of the overall willingness to learn about the BIM practice, the findings were positive. The investigations into company surveys, company portals, forums, observation findings all showed that the majority within the team were willing to learn about BIM. It was other reasons that negatively impacted the overall commitment. It is also found, as explained previously in Section 5.1.3.3, that it was those who already saw BIM benefits, who tried the tools and had some knowledge of how it would benefit their specific needs that were the ones eager to learn the most about it. The results show that to motivate people, there was a necessity to demonstrate how to fit BIM for the project-specific needs. This was achieved through training sessions, where the management was explaining and showing the practice that others can apply. In discussions, it was made by talking about examples that are specifically relevant to the project and discussing practical ways of achieving them. All this showed the role of knowledge sharing and training to positively impact the commitment to change and support the change.

5.1.3.5 E - Involving team in the change

Within the team, there was a shared leadership as well as 'active involvement of all key parties' in decision-making. The project management team often gathered to plan the BIM development process, discuss the implications of the current BIM practice and to make further decisions (Table 5.1). These meetings helped to decide between a few software and to implement the solutions that were the most suitable for the team, suitable for their resources, previous experience, current project needs and time limitations. It was found that involving a wider team can help to understand the software capabilities and to establish the right direction for the team. This finding also relates to discussions about the vision in Section 5.1.3.2. It shows that defining the vision and goals does not only depend on client's needs, BIM manager's needs, but also it depends on the project-specific needs, project members' needs and also software capabilities and interoperability within the current system.

The investigations on planning, deciding as a team, involving more people in the process of BIM change, revealed a level of resistance within the team. There was a resistance of a few members, as they preferred the familiar equipment. The new equipment was promising better performance, more access to people and fewer problems in terms of the data transfer from construction to FM phase, however, the management did not have trust in it. The management was also being aware that the process of decision-making takes time and the deficiency of time on this project further enhanced the resistance. Due to the time limitations, it was also challenging for the management to involve all key parties when making the decisions. This is understandable because the findings also showed that a slow process of deciding future actions was also reducing the team's perceptions about BIM benefits. Time constraints on the project had a negative impact on the ability of people to accept the change and be open to new ideas (Table 5.1). This, with Section 5.1.3.3. discussion (about defining the vision), demonstrate how the lack of time also caused a lack of clarity about the BIM objectives. These results recommend the importance of providing enough time for the team to adapt, to provide clarity and to reduce the resistance to change.

BIM managers did involve several key parties in the planning process but explained that this was not easy. When being asked about the involvement of some other project team parties, particularly those outside the core construction team, such as design and FM, the management showed some resistance. It explained that it was not easy and clear how to bring the whole team together (Table 5.1). Regarding the involvement of external parties, subcontractors and suppliers, this was highly-recommended by all interviewees and this was one of the leading suggestions when being asked about BIM team development. Interviewees explained that the external parties they worked with, were willing to share their models and that was very helpful for the construction team as it improved the precision of the design work.

Based on observations and interviews, everyone supported the idea to include more people in the BIM process by providing access to software to more people than before. At the start of the case study, it was mostly the senior management who had access to software, while the majority in the team had not. This was due to a limited number of software licenses. Towards the end of the case study, the team purchased software that enabled better access. As a result, more people were able to view the model, run the clash detection, send comments, do mark-ups, all via the cloud-based software. Therefore, more people were included in the BIM practice. During the interviews, the respondents expressed that they were happy about this new potential to involve more people in the process. At the end of the case study, there was also a short training, for each software tools, to show the essential functions of those tools, and team members expressed great interest in it.

5.1.4 Identifying challenges to BIM team development

The study followed the change in people's knowledge and attitudes towards the BIM during the nine months of the case study. Technically, the team improved in terms of adopting standards, BIM practice and implemented new BIM tools. For example, in observations, it was noted that the project team had:

- Several brainstorming sessions about software tools, for the key management personnel;
- A few presentations from software providers for the project managers;
- A certain level of technical change - they changed the software and hardware to implement new, easy-to-use software, that was able to collect the data from the site and transfer to FM team, unlike the previous tools the team was using;
- Everyone in the team received more guidelines on how to use the CDE and tools.

However, in terms of the attitudes, during the nine months of the case study, from observations and the documentary data, it was difficult to establish if the team became more confident with the practice, if the resistance decreased and if the interest increased. The management was more certain about what needed to be delivered and they established how this was going to be delivered. However, due to time, equipment and other process limitations, there was little that could have been achieved to improve the knowledge and the commitment quickly.

It is also important to note that the team was overall interested to learn more about BIM. This was found in the observational data, interviews and documentary data including the two company surveys and company's forum discussions. Both the project team in this case study and the wider company team were happy to learn more about BIM and interested in BIM team development. The management professionals in interviews expressed that they wanted to learn more about specific software tools and use 'more of BIM' on their projects. All management professionals recognised BIM benefits and found it useful for their practice. However, on the project level, it was clear that the enthusiasm towards implementing the BIM change was lacking and this study investigates the rationale behind this resistance and commitment, by establishing the connections with the lack of clarity about the requirements, support and many other factors. This study also identified other challenges from the observational data and interviews discussed below.

5.1.4.1 Interview data

Interviewees discussed several challenges, which further explain the results of observations and the documentary data findings. Firstly, when asked about the initiatives that helped BIM development, some responses were "I cannot think of anything that we have used and to help the BIM development". There was no consensus on this, as other interviewees reported a few initiatives within the team that helped their BIM team development. This shows that there were not many initiatives to support BIM development or that efforts were not distributed equally across the whole project team. The interviewees recognised a few barriers to BIM change and this explained why the change needed to be slow and gradual. These challenges are graphically presented in Figure 5.3 and Figure 5.4 and summarised in Table 5.2 and Table 5.3 below.

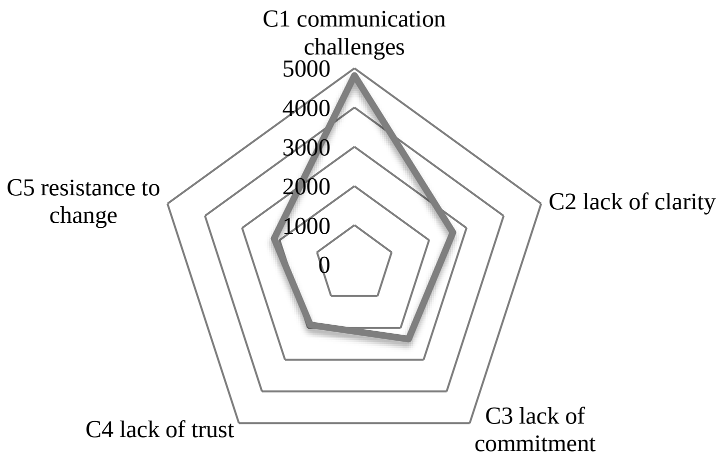

Figure 5.3 Challenges asked during interviews

From diagrams (Figure 5.3 and Figure 5.4), it can be observed that communication was the most discussed problem. There were also other challenges, including the lack of clarity, commitment, trust and resistance, that were all confirmed to be present to an extent. These were specific challenges mentioned in the semi-structured interview questions. There were also other challenges that the interview questions did not specifically ask about, but the interviewees suggested them. From these emerging challenges, the most significant were, as per Figure 5.4:

- Communication - particularly the data exchange and coordination challenges,
- Late BIM introduction,
- Lack of knowledge in the team,
- Inability to track design changes and frequent changes in the design,
- Clarity of BIM requirements,
- Lack of experience of consultants and
- Equipment problems.

Other challenges identified are presented in Figure 5.4, Table 5.2 and Table 5.3. Table 5.2 presents relations between challenges established in interviews and challenges identified in observational reports, to show that some challenges were confirmed in different sets of data. From this it can be confirmed that unclear requirements, communication, coordination, clarity about the process and the lack of knowledge are some of the most significant problems. To summarise the findings, the insights on these key challenges are further discussed in Table 5.3. The data in these tables, Table 5.2 and Table 5.3, confirmed that the key areas to be addressed are factors suggested in IM, KM and CM literature, particularly on establishing top-support, communication improvements, vision and clarity about the BIM practice, involving more people in the process of discussing and deciding and KM.

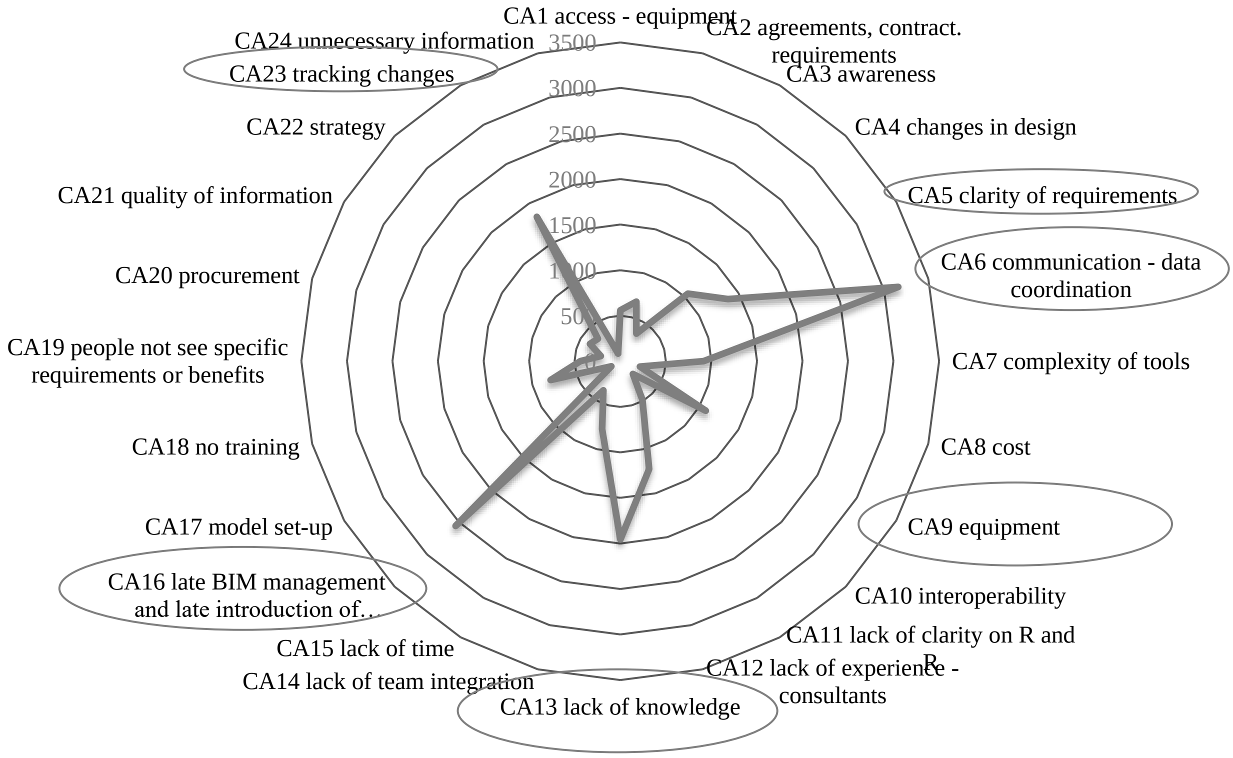

Figure 5.4 Challenges that emerged from case study interviews

5.1.4.2 Summary of findings about the key challenges

Table 5.2 BIM development challenges in the team – NVivo interview data cross-referenced to observational findings

Challenges **Challenges that emerged from the interview data:**	**Number of words in interviews**	**Confirmed in observations**	**Solutions** (based on chapter findings)
CA24 unnecessary information	89		C
CA17 model set-up	111		A
CA10 interoperability	196	×	A, E
CA20 procurement	222		A
CA8 cost	224	×	A
CA22 strategy	348		A, E
CA3 awareness	352		C, D, E
CA15 lack of time	369	×	A
CA21 quality of information	385		A, B
CA19 people do not see specific requirements or benefits	437	×	C
CA11 lack of clarity on roles and responsibilities	488		C
CA1 access - equipment	558	×	A
CA2 agreements, contract. requirements	679		A
CA14 lack of team integration	770	×	A
CA18 no training	793	×	D
CA7 complexity of tools	915	×	D, E
CA4 changes in design	1048		A, B
CA9 equipment	1084	×	A
CA12 lack of experience of consultants	1223		A+D
CA5 clarity of requirements	1363	×	A, C
CA23 tracking changes	1831		A, B
CA13 lack of knowledge	1958	×	D, C, A, E
CA16 late BIM management and late introduction of requirements	2556		A+C
CA6 communication - data coordination	3160		A, B
Challenges asked:			
C4 lack of trust	1901		A, B, C
C5 resistance to change	2145		C, E, A
C3 lack of commitment	2350	*×	A, C, D
C2 lack of clarity	2639	×	A, C, E
C1 communication challenges	4816	×	A, B, E

Description: x means confirmed in observations; * means not the same challenge, but there is a connection with; solutions written were based on findings written in the chapter including Table 7.6 below; A Top-management support and control, B Communication in the team, C Vision in the team and clarity, D Managing knowledge and development, E Involving team in the change

There is an overlap in findings of different sets of data as shown in Table 5.2 above, but also it can be seen that some findings were only established through interviews. This is because interviews provided an opportunity to have longer, face-to-face conversations with team members which enabled to get more insights and understand the process with more depth. Participants were also more open in interviews. On the other hand, observations were useful to follow the process of change and track the initiatives within the team. The documentary data were there to provide additional evidence. As a result, in-depth data on critical challenges are presented in Table 5.3 below. The table shows the most commonly mentioned challenges and participants' opinions on them.

Table 5.3 Summary of findings about key challenges

Challenge code	Challenge	Findings
CA9	Equipment:	• They were not satisfied with the performance of current on-site BIM tools. • As mentioned in observations, participants confirmed that limited software licensing caused challenges and disabled the access to get the right information.
C5	Resistance to change	• "There are still people who do not see any relevance to it, and they are so busy doing their day job, that they see no benefit in stopping to learn it, or stopping to use it, when they feel they can do it quicker and better without it". • The resistance came from the lack of understanding in the team on what BIM could do for them and lack of clarity. • The resistance was enhanced with time and cost limitations.
C3	Lack of commitment	• The lack of commitment was due to little benefit or value of what parties would get from the BIM; If benefits were explained, there would be commitment. • It was found that clarifying requirements would help the commitment. • People did not appreciate efforts about the modelling of as-built information. • There was no commitment from the start of the project, as there was no one responsible for ensuring BIM requirements were delivered when the project started. • The commitment could have been improved with training. • Other things had priority because the project was late.
CA5, C2	Lack of clarity about requirements and vision	• There was a lack of clarity as to what BIM Level 2 was and what was needed to be delivered. • The lack of clarity improved with the introduction of BIM management. • Participants wanted clarity as to how they were using the model and what they were aiming to achieve.
CA13	Knowledge	• It was suggested that everyone should have been able to know how

		to open the BIM model and find the information they need. • There was a noticeable lack of skills, as even some experienced engineers only had a basic understanding of the software. • One of the key elements to BIM implementation was investing in training. • They also recognised that “the learning curve” was higher for the design consultants they worked with, compared to their team as the contractors. • For most people, this was the first time they used something else other than 2D information. • Some people lacked any training, but they learned how to use the software on their own or with the help of others within the team. • There were e-modules, but they found them ineffective and impersonal, they preferred in-house training or support.
CA6	Communica-tion	• A participant recommended that communication could have been improved with more effective decision-making - “someone able to say “yes” or to say “no”. • There were many parties involved during the project and participants suggested that the solution was to involve the right people at the right time to communicate and make the right decisions. • Tracking change and revisions of the design information were significant challenges. Participants explained, “That model might have moved on since then, even though it has got the same revision number on it, it still might have moved on, might have been developed within a week”. It was challenging to understand what version to review and how to match drawings to the model. It was difficult and essential to keep the control of information. Overall, the reliability of information needed to be improved by the ability to track the information in the model. • Communication could have been improved with more control – administration and tracking changes. They suggested having a “status report of the model”, implementing a different system for “noting up drawings that come from models” than systems they had. The exchange of information needed to be regulated, and it was improved by introducing the BIM manager.
C4	Trust	• Trust was not found to be a significant issue. • However, it was mentioned that it existed in communication with external companies, such as design parties. • They suggested explaining how the information would be used to reduce the issue. Having a clear strategy and requirements from the beginning, the right level of design and realistic timelines would reduce the issues of trust in the wider team. • They also suggested that trust would be improved by ensuring the reliability of model information and tracking – reporting changes and model development.

5.1.5 Key recommendations on establishing BIM processes in this construction team that emerged from the interviews

In interviews, participants were asked for recommendations. The researcher coded and analysed all points where participants discussed their needs and suggestions to summarise these recommendations. The conclusions were written as they emerged from the data, then suggestions were incorporated into emerged categories A – E (Section 5.1.3). A few recommendations were also presented in previously discussed challenges – Section 5.1.4. The connection between these categories A – E and theories of KM, CM and KM demonstrated that these theories would positively impact the case study project team and BIM team development.

The lack of knowledge was a significant problem and introducing BIM late emphasised this and other challenges. Therefore, in terms of their future needs, they firstly identified a need for training, particularly specialised training. As mentioned previously, learning was mostly happening within smaller teams and it was experiential learning and shared learning. In terms of knowledge, they recognised that they needed specific training sessions for the part of the work they were delivering. The participants positively reacted to an idea to have workshops or facilitated sessions where everyone could ask questions and try software. They suggested those groups to be ideally smaller, with up to ten people. Participants in interviews also added that they would like to see some more and specific real-life examples which would further explain benefits of BIM and why were they implementing the new practice, why were they trying to create an as-built model for FM. A few examples of case studies were distributed via emails in July 2017, however possibly a better way to distribute this information would be through meetings or workshops, rather than a written word. This all confirmed how important it is for managers to establish a 'knowledge and development' strategy, previously discussed in part D, as part of BIM change.

Other discussions were on requirements – part C. They repeatedly mentioned how it was not clear what needed to be included in the final model and what were the client's requirements. Therefore, a lack of clarity was a second-mentioned issue. The team needed to be clear with what was supposed to be achieved with the model. They later had a few sessions where BIM managers explained that BIM model is more than a 3D model, however, the process of adoption was prolonged, as the introduction into the BIM processes and explanations were arriving very late into the project, when the project was already in the middle of construction. A few interviewees did not recognise the value of general sessions they had about BIM – specifically a session they had about the BIM implementation plan, being too much about BIM management, not about their own matters, as they said. However, they also recognised that they did not know what a model could do for them, or that was not very clear. Instead, they wanted to understand the benefits for each specific discipline. It was also found that it was not clear why are they using different tools, why are they changing tools and the entire BIM process as a whole. Therefore, explaining the vision of the entire BIM initiative would be helpful for the team, including explaining the specific project-related benefits and specific requirements the team needed to deliver.

It was largely suggested that the communication aspect, discussed in part B, Section 5.1.3.2, needed improvements. It could be that regular meetings and face-to-face communication were not enough for effective communication. One of the interviewees suggested that they had enough meetings, both face-to-face and online meetings, therefore, the lack of meetings was not an issue. Instead, issues in communication could have been due to the lack of team integration, lack of open culture (based on observations, interviews e.g. S4), lack of trust (to less extent) and not having the reliable information in models received from designers. In terms of the team integration and lack of communication, one of the participants mentioned that most BIM communication issues were solely handled by BIM management, although, him/her as a design manager also wanted to be included. The participant added, “I do not get involved in the monitoring and recording of the flow of information, unfortunately” (S3: 00:18:35). Here the connection was also made with the importance to involve more people, a topic discussed in part E, Section 5.1.3.5. Another connection with ‘E’ was also made when participants were asked about the potential of facilitated open meetings. They reacted positively on those suggestions and mentioned that they wanted to include other teams more, such as project design teams, as they wanted to hear where they were with the models. In terms of the reliability of the information, they suggested the importance of tracking changes, and the emphasis on tracking changes as a challenge shows this even more (Table 5.2 and Table 5.3).

The interview participants were recommending the management to involve more people in the process of BIM change – Section 5.1.3.5, aspect E. Most of interview participants showed a desire to be more included in the BIM process. This was regardless of their age. This was also confirmed in the documentary data findings. They showed a desire not only to use BIM for visualisation, but for other purposes. They particularly showed interest in energy calculations, automated quantities, tracking changes, getting more information from the model such as materials, creating asset register, facility management purposes and others. During the case study, this was improved by the use of new cloud-based tools which enabled the team to be more involved and have the most current versions of the project. Also, they discussed licensing problems and suggested that having more software licenses would enable access to the right information and more inclusivity of project team members. However, in terms of being included in the process of deciding a software tool, a few mentioned that it did not have to be a shared decision.

Other suggestions were that:

- They needed strong leadership and knowledgeable people to make decisions and to have competent external parties to work with. The top-management needed to provide this (aspect A)
- They added that information needed to be added gradually to create an as-built model. Again, this is something that needed to be organised and supported by the leadership (aspect A) and integrated into the team as a vision (aspect C).
- The resistance came from not understanding benefits, therefore, these needed to be explained to the team to a greater extent, as discussed in aspect C, Section 5.1.3.3. Also to visualise the benefits and the whole BIM process they suggested that it would be better to be included longer on the project, which is often not the case and could only be achieved by the way the projects were organised by the top-management (aspect A).
- Overall, interviewees agreed that it would be good to conduct reflection sessions and lessons learnt. These would help knowledge management in the team, previously discussed in aspect D, Section 5.1.3.4.

5.1.6 Methodology limitations and solutions

The researcher was new to the case study team and this created some limitations. Not all processes in the company were clear to the researcher, which was mentioned in observational findings and observation diaries (Appendix D). This limitation was solved through interviews where the researcher obtained more insights into the team dynamics by asking different questions and by creating a friendly and open conversation with participants. Participants were aware of the independent work of the researcher and therefore, aware that they can freely express their opinions. In that sense, it was useful to be an external party for the team. As a result, interviews were a helpful method to understand the challenges (Table 5.2). Participants were open during the interview sessions and willing to share more information and knowledge than in their daily practice, documented in observations.

5.1.7 Exploratory case study position in the study and concluding remarks

5.1.7.1 Case study concluding remarks

The case study had the aim to investigate the Objective 1, as per Figure 5.1. It was designed to understand the development strategies or initiatives within the case study project team and identify challenges within the team. The evidence from the case study suggests that A – E categories can address the challenges identified in the case study and this is discussed in Section 5.1.3 and presented in Table 5.2. These categories, A – E, are in alignment with the critical factors identified in Section 3.5 which emerged from theories of IM, KM and CM: A (F3, F20), B (F7, F8, F9, F5), C (F1, F2, F4), D (F18, F19, F14) and E (F2, F5, F8, F12, F13, F21). This shows how case study findings also feedback into Objective 2 and 3. This further shows that KM, IM and CM could positively impact the case study project team and help the BIM team adoption and development, which is another contribution of the study.

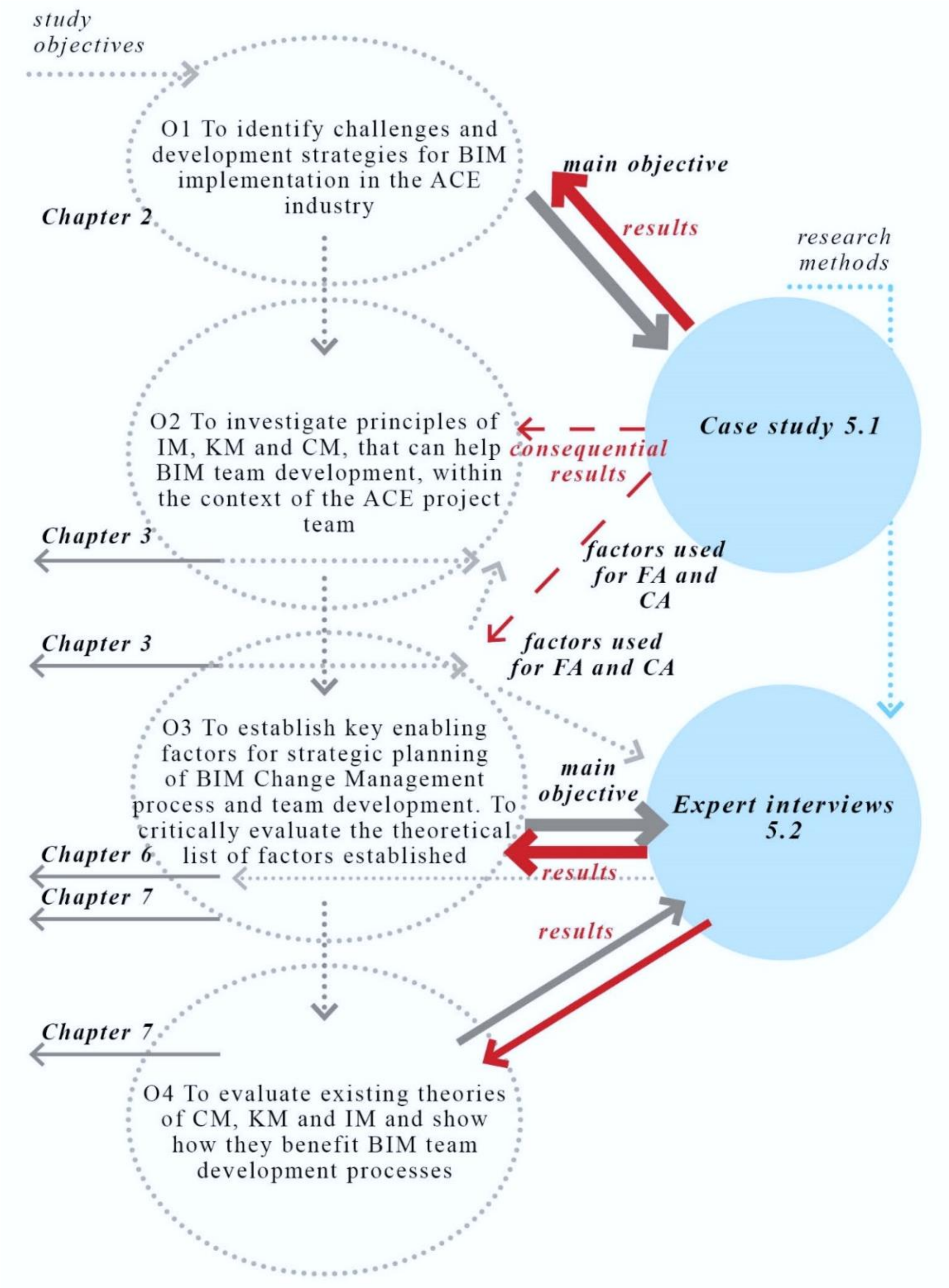

Figure 5.5 Relations between case study and objectives

5.1.7.2 Case study results and the systematic review

In this study, Objective 1 is addressed by the case study presented in Chapter 5.1 and also addressed in the systematic review – Chapter 2. This section shows the connection between the systematic review and the case study. The key findings from Section 5.1 and Chapter 2 are, however integrated into the discussion, Chapter 7, which shows the most relevant arguments from the data and literature to achieve the aim of the study.

Challenges identified in the case study are previously discussed in different studies in the systematic review (Table 5.4). However, the case study enabled a more in-depth understanding of context, mechanisms and explanations of why these challenges occur (Table 5.4). This in-depth investigation led to the results that confirmed the potential of KM, CM and IM theories.

Table 5.4 List of key challenges - case study and systematic review

Challenges that emerged from the interviews	Key findings and comparison with challenges from Table 2.2
CA4 changes in design	This is rarely discussed in studies. An example which recognises it is Chien et al. (2014). The case study discusses a practical problem in the industry (design changes) and the inability of software tools to help, which further enhances the resistance.
CA9 equipment	Cost of equipment is mentioned in several studies when discussed investment issues, such as Arayici et al. (2011a). The case study further shows how the lack of equipment causes resistance in the team and the lack of commitment.
CA12 lack of experience of consultants	Lack of experience in the industry is discussed in studies, such as Succar et al. (2012). The case study shows how the team worked together with suppliers to enhance their skills. The case study also shows how the lack of experience from some other teams caused several technical challenges, resistance in the construction team, lack of clarity about the requirements, lack of vision in the project and to an extent lack of trust (See Table 5.3).
CA5 clarity of requirements	Clarity of requirements is mentioned in studies, such as Dossick et al. (2010). The case study provides an in-depth understanding of how important it is to have precise requirements and vision from the beginning of the project (Section 5.1.3.1).
CA23 tracking changes	As previously mentioned in CA4, this is rarely discussed in studies.
CA13 lack of knowledge	Lack of BIM skills is present in the industry and acknowledged by the studies. This case study further shows how the lack of minimum awareness or knowledge negatively influences the commitment in the team. The contribution of this study is in finding solutions to address this challenge, by implementing critical factors (Table 6.29).
CA16 late BIM management and late introduction of requirements	Late introduction of BIM into the project is rarely discussed in studies. This study shows the role of time and how the lack of time negatively impacts the BIM adoption.

CA6 communication - data coordination	This is discussed in studies but usually recognised as a benefit of BIM technology rather than a challenge (such as Ahn et al. 2016). This study shows difficulties in coordinating the large team without the clear requirements and vision.
Challenges specially asked	
C4 lack of trust	A few studies discuss the lack of trust about the model information, such as Mahalingam et al. (2015). This case study confirms this issue (Table 5.3), but it shows that this was not as challenging as other issues.
C5 resistance to change	This is mentioned in many studies, such as Won et al. (2013). This case study shows how this occurs due to lack of vision, clarity, time, knowledge and it shows a potential of IM, KM and CM to address these.
C3 lack of commitment	This is mentioned in studies, such as Mahalingam et al. (2015). This case study shows how this challenge occurs when BIM is established late on the project and not prioritised by the management.
C2 lack of clarity	This is mentioned in studies, such as Mahalingam et al. (2015) – there is a lack of clarity about the benefits. This case study discusses this in-depth and also shows that it needs to be clarified to the team what the change is for their roles, what requirements are, what is the vision and what are the benefits.
C1 communication challenges	This is mentioned in studies such as Won et al. (2013). This case study shows how communication could be improved with several technological measures, but also that it would be further improved with more leadership and control. This further confirms some of the factors identified in Chapter 3, in particular, F9.

The case study presents an AEC project team that adopted a middle-ground approach to BIM adoption, an approach suggested by the systematic review. It started as a top-down initiative, however, the team was facing several challenges, as per Section 5.1.4, which inhibited the BIM adoption and negatively impacted the commitment in the team. When the BIM adoption became a middle-ground initiative, it lacked the overall project vision, clear requirements and top-down support, which shows the importance to have both sides, top-support and bottom-up involvement to cooperate to deliver BIM change. The results align with the conclusion of the systematic review, but findings also show the importance of having a strong management support.

According to the systematic review, there have been a few recommendations in current studies that show the importance to manage people's perception, the sense of usefulness and tool compatibility and the case study shows the manifestation of these challenges in practice. Therefore, and in-depth understanding of these challenges is one of the outputs of this study. Secondly, identifying that IM, KM and CM can manage some of these challenges is the further contribution of this study.

The study findings agreed with the systematic review (middle-ground and bottom-up studies, TAM models and studies on BIM adoption factors) that it is vital to take care of matters such as motivation, resistance to change and knowledge to achieve more sustainable BIM change. It, therefore, agrees that it is important to apply the knowledge from KM and CM to achieve that. Overall points made in the systematic review align with the case study, whilst the case study shows more in-depth perspective towards the BIM implementation and IM, KM and CM potentials.

5.2 Preliminary research findings

This section describes how is the analysis conducted with expert-elite interviews to achieve Objective 3, as per Figure 5.1. Firstly, this section discusses the analysis process for the expert-elite interviews in 5.2.1; then it presents the preliminary results in Section 5.2.2. These results are the summary of the first analysis presented in Appendix C. The complete main results are presented and discussed in Chapter 6.

5.2.1 Interview analysis – analysis process

The analysis follows the Framework Analysis (FA) principles as explained in Chapter 4. This approach enables the researcher to leave an audit on how the analysis was conducted and how conclusions were developed. Unlike the content analysis, FA enables the frame of codes to be expanded and for new topics to emerge. Unlike the typical thematic analysis, it starts with the preliminary framework and pre-defined codes, which emerged from theories on CM, IM and KM. The coding structure is then modified per data and findings. The saturation occurred early after the first four interviews, which enabled the researcher to use the first few interviews, while waiting for the rest of the data, to create a system and process that suits both the emerging data and pre-established theoretical factors - codes. Based on the pragmatic research stance, research aim and design explained in Chapter 4, the following process of analysis was established (graphically presented in Figure 5.6) (further details were presented in Chapter 4):

1. Interview transcriptions. This included dividing the text into paragraphs and adding the time references.
2. Preparing the coding system using the conceptual list of factors for BIM team development defined in Section 3.5, where each factor has a number. The researcher also added a few more codes such as “BIM experience”, “background”, “challenges”. This included a stage of experimenting with the data and coding and making the analysis process logical and practical. An example of a coding list, for the first five interviews, is

presented in Table 5.6.

3. The transcripts were coded using NVivo software and manually coded onto the paper. Paper coding was done prior to NVivo, at least a day before. This helped to double-check the data and check if the emerging ideas would overlap. Sometimes the paper coding would produce one set of codes and NVivo coding would complete that. Having the same ideas twice ensured validity and reliability as well.
4. After the coding system was developed, the researcher created a spreadsheet with a summary report for each interview. The reports included the main findings for each factor for each interview. This contained main findings, conclusions about how important the factor is based on the qualitative data - colour code, few representative quotes or information that there was no relevant data in that interview. The importance of the factor based on the qualitative data was compared with the quantitative data from the software – frequency and percentages. This is later used to graphically present the data in Chapter 6, as 'tables of presence' for each factor, for example, Table 6.1.
5. The next step was the creation of a few pages on 'factor summary' for each interview (e.g. I1: F1, F2 …Fn), the researcher integrated these findings into one by organising them per factor. Figure 5.6 below shows the steps of analysis. Due to the size of the file, a part of it is presented in Appendix C: Expert interviews framework analysis - example. There is no need to present this in full detail because the key findings are presented in Chapter 6. Chapter 6 emerged from this preliminary factor analysis for each interview and by rechecking these findings by going through NVivo codes and transcripts.
6. The researcher continuously compared the findings from the first interviews, then again, when the data collection and coding were completed, to clean the emerging codes and understand which new factors are more important. The method is conceptually presented below in Table 5.5. Conclusions were written directly in the preliminary list of factors, presented in Appendix C. This helped to understand the importance of existing and new potential factors. It helped to group new emerging codes with existing and form new factors.
7. Throughout the process, in NVivo, the researcher also reviewed the pre-defined codes, new emerging codes, merged codes that were covering the same topic, changed the way they were named, cleaned unnecessary codes.
8. The final process was comparing preliminary FA findings (Appendix C) with NVivo notes and quotations. Checking the codes, quotes, going through the data again, noting quotation timings, all to ensure the validity of conclusions. As a result, factor per factor, the analysis was written and presented in Chapter 6.

Table 5.5 Summary of factors from the first four interviews – step 5.

Factor Colour represents the importance, as the average value of individual factors	Interview 1 White means “Excluded”	**~~Title~~** X No-evidence about the importance of this factor, therefore excluded. Explanation: This factor is not seen as important according to the interview data. It will be excluded.
	Interview 2 Green means “Little important”	**Title** Conclusions and comments.
	Interview 3 Orange means “Important factor”	**~~Title~~** Conclusions and comments. Explanation: This factor is seen as important, but findings were transferred into another factor, therefore, its title is crossed.
	Interview n Red means “Very important factor”	**Title** Conclusions and comments.

Description: ~~Title~~ – the factor is excluded as a result of findings

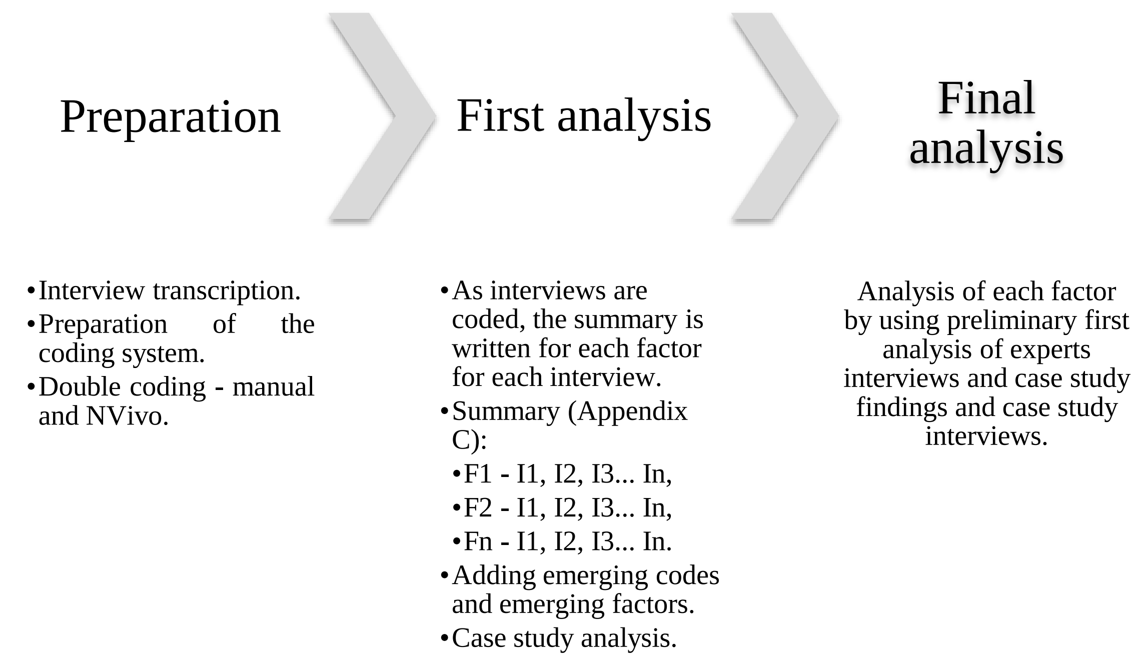

Figure 5.6 Process of analysis and coding the data: steps 1-5

Table 5.6 Table of nodes extracted from NVivo, used in interviews 1-5

Name of code	Type	Created On
01. Aligning vision	critical factor	07/05/2017
02. Planning future actions as a team	critical factor	07/05/2017
03. Establishing top-support	critical factor	07/05/2017
04. Clarity about the change process	critical factor	07/05/2017
Aligning vision - but not together		13/06/2017
05. Ensuring an open culture	critical factor	07/05/2017
06. Diversity in the team (skills, roles)	critical factor	07/05/2017
07. Communication 1 - inf. exchange	critical factor	07/05/2017
BIM coordination		09/07/2017
Communication face to face		11/06/2017
Communication regularly		11/06/2017
Model sharing and validation		12/06/2017
08. Communication 2 - inf. access	critical factor	07/05/2017
09. Communication 3 - inf. reliability	critical factor	07/05/2017
10. The culture of trust and respect	critical factor	07/05/2017
11. Team building	critical factor	07/05/2017
12. Shared decision making	critical factor	07/05/2017
13. Shared leadership	critical factor	07/05/2017
14. Flexibility 1 - Adaptability	critical factor	07/05/2017
Flexibility to share skills		12/06/2017
15. Flexibility 2 - Openness to new ideas	critical factor	07/05/2017
16. Flexibility 3 - Flexible team	critical factor	07/05/2017
17. BIM Implementation to support good existing practice	critical factor	07/05/2017
18. Structured organised training	critical factor	07/05/2017
19. Experiential learning	critical factor	07/05/2017
20. Creative pressure	critical factor	07/05/2017
21. Opportunity for reflection (confusion, brainstorming, positive deviance, deep reflection)	critical factor	07/05/2017
BIM benefits	other impacting topics	12/06/2017
Their importance in the process		13/06/2017
Understanding others		12/06/2017
Visualisation		12/06/2017

BIM experience	background of participants	07/05/2017
BIM nature	other impacting topics	12/06/2017
Bottom-up implementation	interventions / strategies	07/05/2017
Challenges	other impacting topics	07/05/2017
Communication challenges		13/06/2017
Lack of clarity		13/06/2017
Lack of commitment		13/06/2017
Lack of trust		13/06/2017
Pressure during the project delivery		13/06/2017
Resistance to change		13/06/2017
Changes with BIM	other impacting topics	07/05/2017
Clarity about R&R	potential new factor	07/05/2017
Clarity about requirements	potential new factor	07/05/2017
Collaborative team	potential new factor	12/06/2017
Teamwork		12/06/2017
Engaging people	potential new factor	09/07/2017
Experience	background of participants	07/05/2017
Importance of soft skills	other impacting topics	12/06/2017
Initiative to use or implement BIM practice	initiatives/mechanisms	10/06/2017
Helping the client		10/06/2017
Pre-required for bidding		12/06/2017
Integrated team	potential new factor	07/05/2017
Middle ground approach	interventions / strategies	12/06/2017
Position	background of participants	07/05/2017
Safe environment	potential new factor	07/05/2017
Shared experience	potential new factor	07/05/2017
Shared learning		12/06/2017
Showing benefits	potential new factor	09/07/2017
Skills	potential new factor	12/06/2017
Equipment		13/06/2017
Supportive processes	initiatives/ mechanisms	07/05/2017
Team set-up - team structure	potential new factor	09/07/2017

5.2.2 Preliminary analysis of expert interviews and case study results

Table 5.7 below summarises the first results of experts' interview analysis which was presented in more detail in Appendix C. Table 5.7 is a product of all conclusions of the first analysis of what each participant said independently for each factor and emerging factors. These conclusions were made after the process of coding, as explained in Section 5.2.1. The emerging codes were new specific ideas that were repeated multiple times by several participants. Based on the text written in the case study findings (Section 5.1), the table was extended to include these findings – to show which factors have been found beneficial during the case study. This table will be used further for developing the final list in the next Chapter 6.

It was found that the case study confirmed most factors, including the ones that emerged from the interviews. There were three excluded: F6, F11 and F16. In terms of F11, it was found that more clear relations exist between the 'team integration' and BIM implementation. In terms of F6 and F16, there was not enough evidence on benefits. This was concluded during observations (Appendix D) and there was no more evidence in interviews or the documentary data. In comparison with interviews, F11 and F16 were also not found significant in interview findings, while F6 was found valuable. The case study emphasised benefits of groups of factors A-E, which included A (F3, F20), B (F7, F8, F9, F5), C (F1, F2, F4), D (F18, F19, F14) and E (F2, F5, F8, F12, F13, F21). When investigating F20, it was found that there should be more pressure in terms of responsibility, but time pressures negatively impacted adoption, as concluded in Section 5.1.7. Other factors confirmed in the case study were F10, F15, F17 and emerging factors.

Table 5.7 Summary of experts' interviews conclusions and case study findings

n	Preliminary factor Variable – Area of improvement	Interview findings ✓ means confirmed by results	Conclusion options: • Found very important by the majority; • Found important; • Found less important; • Not found important. Key comments. *Naming in the process of analysis*	Case study findings
1	**Aligning vision** **(agreeing a common vision)**	✓	Found very important by the majority. *Clear, Common Vision;* *Aligning vision, clear outcomes;* *Understanding the vision and requirements;* *Clear long-term vision and requirements;* *Establishing a common shared vision and clear requirements;* *Understanding the vision, direction as a team;* *Aligning the vision with the wider team context, top-down;* *Aligning and understanding the vision, the vision is developed top-down;* *Aligning and understanding vision as a wider team.*	✓
2	**Planning future actions as a team**	✓	Found important. Could be integrated with 12 and 13. *Collaborative planning of future actions;* *Planning future actions - but top-down;* *Planning future actions;* *Planning future actions – top management team and relevant supporting teams;* *Planning future actions – mostly top-down.*	✓
3	**Establishing top-support** **sub-topics: structure, empowerment, rewards, innovation champions, knowledge portals, leadership**	✓	Found very important by the majority. There is a new factor about the providing structure, skills and resources that might add to this factor. *Ensuring top-down support and structure;* *Ensuring top-down support;* *Ensuring top-down support and setting up a structure;* *Ensuring top-down support, structure and controlling processes;*	✓
4	**Clarity about the change process**	✓	Found important. It can be merged with F1. It was not mentioned by all interviewees. *Clarity about change.*	✓
5	**Ensuring an open culture**	✓	Found very important by the majority. *Ensuring the culture of openness, trust and respect;* *Ensuring the culture of openness – wider team.*	✓
6	**Diversity in the team (e.g. skills, roles)**	✓	Found important. Can be a part of 14. Can be part of a new factor F27. *Diversity;* *Diversity in terms of skills;* *Diversity of skills – diversity in understanding;* *Diversity in skills.*	

7	**Communication digital and non-digital information exchange** **(regular meetings, face-to-face meetings, discussions)**	✓	Found very important by the majority. *Communication – Information exchange;* *Communication 1 – establishing an effective information exchange.*	✓
8	**Enabling access to information** **(interconnectivity of team members, ability to get information)**	✓	Found very important by the majority. Can be merged with F7. *Communication – Access to information;* *Communication – Enabling access to information.*	✓
9	**Ensuring reliability of information** **(a transparent flow of information, ensuring up-to-date information)**	✓	Found very important by the majority. *Communication – Information reliability.*	✓
10	**The culture of trust and respect**	✓	Found important. It can be merged with F5. *Safe environment, trust and respect;* *Trust and respect;* *Trust and respect – Understanding and respecting each other's role and responsibility;* *Trust and respect – enabled by leadership.*	✓
11	**Team building**		Not found important. No-evidence about the importance of this factor, therefore excluded in some cases. Mentioned a few times indirectly.	
12	**Shared decision making** **(shared problem resolution process, everything understood by all members)**	✓	Found important. Can be incorporated with F2. *Shared decision making – shared within the internal and external team, but limited;* *Shared decision making – limited;* *Shared decision making – only top management;* *Shared decision making – mostly top-down with suggestions.*	✓
13	**Shared leadership**	✓	Found less important. To be discussed. Not as important as F12. *Shared leadership – present but limited;* *Shared leadership – pro and against;* *Shared leadership – top only.*	✓

14	**Flexibility 1 – Adaptability of the team** **(adaptable to equipment changes or changes within the team structure)**	✓	Found important. *Versatile team;* *Flexibility 1 – sharing skills;* *Flexibility 1 – the ability to learn from each other and help each other;* *Flexibility 1 – the ability to learn from each other, flexible with tool changes, understanding each other and having flexibility in skills;* *Flexibility – a skill to have flexibility when a tool changes;* *Flexibility 1 – adaptability, knowing principles;* *Flexibility 1 – shared learning.*	✓
15	**Flexibility 2 - Openness to new ideas**	✓	Found very important by the majority. *Flexibility – openness;* *Flexibility 2 - open to new ideas.*	✓
16	**Flexibility 3 – Flexible team** **(the team is not a fixed structure, it should be modified when there is a need for it)**		Not found important. No-evidence about the importance of this factor, therefore excluded. *Flexibility 3 – the team is not a fixed structure;* *Flexibility 3 – pro and against in terms of adding resources.*	
17	**BIM implementation to support good existing practice**	✓	Found very important by the majority. *BIM Implementation to support good existing practice.*	✓
18	**Structured organised training** **(Training as an assignment)**	✓	Found very important by the majority. *Training as an assignment;* *Training, education, awareness, customised, fit to the company (not assigned);* *Providing an opportunity for structured training, awareness;* *Training – structured, mixed approach, people specific training;* *Training – important;* *Training as an assignment but a mixed approach;* *Organised training – internal and external (help for the wider team).*	✓
19	**Experiential learning** **(learning through active participation or learning by doing)**	✓	Found very important by the majority. *Active participation - learning by doing;* *Learning by doing – pilot projects, initiatives, accepting the investment and risk for the long-term benefits;* *Learning by doing – mixed approach;* *Learning by doing – the most effective way – real project;* *Learning by doing with support (real project, mixed approach);* *Learning by doing – real project;* *Learning by doing – pilot project, little project.*	✓
20	**Creative pressure** **(competitions, time limitations, mandate)**	✓	Found important / Found less important. Divided opinions. To be discussed. *Adding creative pressure;* *Adding creative pressure – disruption appropriate to the team;* *Adding pressure – industry pressure, mandatory, deadlines, live projects, "something tangible".*	✓

21	**Opportunity for reflection** **(confusion, brainstorming, positive deviance, deep reflection)**	✓	Found very important by the majority. *Opportunity for reflection (confusion, brainstorming, positive deviance, deep reflection);* *Reflection opportunities – open discussions.*	✓
New	**Emerging factors**			
22	**Clear roles and responsibilities**	✓	Found important. Integrated as advice into other factors.	✓
23	**Structure and control and measure**	✓	Found important. It is integrated into other factors, such as F3. *Structure in place;* *Structure;* *Structure and control and measure.*	✓
24	**Shared learning**	✓	Found very important by the majority. *Shared experience;* *Shared learning.*	✓
25	**Collaborative team**	✓	Found very important by the majority. *Team collaboration and teamwork;* *Team collaboration;* *Team collaboration – multidisciplinary team;* *Team collaboration and teamwork – useful but not all levels.*	✓
26	**Integrated team**	✓	Found very important by the majority. *Integrated team.*	✓
27	**Support for skills and resources**	✓	Found very important by the majority. It can be integrated with F3 and others. *Skills and set-up;* *Support for skills and resources;* *Support for skills and resources and set-up;* *Skills and support.*	✓
28	**Easy to use**	✓	Found important. It will be integrated with others as advice.	✓
29	**Showing benefits**	✓	Found very important by the majority. *Showing benefits – the importance of recognising benefits;* *Showing benefits.*	✓

Chapter 6. Interview findings

This chapter discusses each factor from the preliminary, theoretical list of factors established in Section 3.5. These are factors F1-F21. In addition, the study also presents new concepts that emerged from interviews – F24-F27 factors, that helped to refine the initial theoretical list of factors (see Section 6.26.2). Each factor is presented firstly with a rationale and explanation about why it is important. The second level of findings are mechanisms, suggestions and enablers - how factors can be achieved according to the interview data. All statements presented in this chapter are written based on interviews with BIM management experts (I1-I11) and senior management in the AEC organisations (I12-I19), as explained in Chapter 4. Diagrams presented in this chapter are produced as a result of these findings. Tables of presence, such as Table 6.1, present the results of content analysis and present the expert-interviews data, to support the qualitative findings. Results of these findings and a summary of conclusions are presented in Section 6.26.

6.1 Factor 1 - Vision

Having a clear and common vision in the team was found to be an important factor in adopting BIM processes, according to the majority of participants (Table 6.1). This factor can address challenges such as 'lack of commitment', 'lack of understanding in the team', 'lack of understanding from the client', 'lack of clarity about the purpose of the model', 'resistance to change', 'lack of clarity about the requirements' and 'lack of trust'. Participants also mentioned other benefits of 'vision' such as:

- Helps to understand the outcome and "where you are trying to get to" as a team (I15 00:36:10);
- Helps to create a positive view in the wider team – for all stakeholders, which was mentioned as the key component to BIM implementation;
- Helps in managing expectations;
- Helps in managing the motivation - "If they had a part in planning, setting it up in the first instance, then, they cannot complain "no one asked me" or "it does not do what it needs for me" (I19 00:42:25).
- Vision motivates people to attend training and to feel part of the team;
- Helps everyone to buy-into the change and puts the wider team into the same direction;
- Helps organisations to align their data strategies, making organisations more agile.

The majority of participants agreed that F1 needs to be established early in the project or before the project starts. Everyone in the team needs to be aware and have an understanding. By ‘everyone’, interviewees explained that it needs to be internal and the wider project team. Parties should influence each other and reach a common understanding; and because this statement follows the same principles as F25 and F26, it was also coded as other factors - ‘collaborative team’ F25 and ‘integrated project practice’ F26. This is an example of a connection between F1 and other factors. According to Table 6.1, a table extracted from the interview data, there are also possible connections with F3, F7, F2, F12, F5, F18 and others.

Table 6.1 Presence of F1

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	22	14	10	10	11	0	5	5	4	0	2	10	9	0	6	0	5	0	2	2	0
I2	6	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0
I3	3	0	3	1	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0
I4	13	3	3	1	1	1	3	1	1	0	0	1	1	1	0	2	1	2	0	0	2
I5	9	1	3	0	1	0	1	1	1	0	0	1	0	0	1	0	0	2	1	0	0
I6	12	1	2	0	1	0	6	0	0	1	0	1	0	0	1	0	0	2	0	0	0
I7	13	4	3	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
I8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	15	4	9	1	6	0	9	4	1	0	0	2	3	0	0	1	1	3	0	1	0
I11	10	1	5	0	0	0	2	0	0	0	0	1	0	0	0	0	0	2	0	1	0
I12	12	0	5	2	0	0	1	1	0	0	0	0	0	1	1	0	1	1	1	0	0
I13	12	0	2	1	1	1	5	2	1	0	0	1	2	0	1	0	0	0	0	0	3
I14	10	2	2	0	0	0	2	0	0	0	0	3	2	0	0	0	0	2	0	0	1
I15	14	5	1	0	0	0	2	0	1	0	0	4	2	0	0	0	0	0	0	0	0
I16	20	3	6	0	1	0	3	1	1	0	0	0	0	0	0	0	0	1	0	0	2
I17	11	1	3	0	0	0	1	0	1	0	0	1	0	0	0	0	0	4	0	0	0
I18	7	0	5	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0
I19	5	2	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1
F1	199	41	64	16	23	2	44	15	11	3	2	29	20	2	11	3	8	21	4	6	10

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Suggestions

The main principle for F1 is to clarify the process of change for the team by explaining “why are we doing this”, “what are the benefits” and “what are the outcomes” (I1 00:10:25, I6 01:04:58, I15 00:12:40, I16 00:12:25). ‘Showing benefits’ is a suggestion mentioned by all of the participants and it is identified as a sub-factor. Another recommendation about defining and distributing the vision is to answer, “what is BIM for them” and “how will the company achieve it” (I5 00:03:09, I13 00:49:26, I15 00:12:40). Answering these questions creates a clear and tangible vision and helps to address ‘lack of clarity’. The vision also must be relevant, not too abstract, realistic, but aspirational.

Other enablers of F1 (Figure 6.1) recognised in interviews are:

- Brainstorming as a team – discussing the common goal and ways to achieve it or reviewing the initial plan and vision (a connection with factors ‘planning as a team’ F2 and ‘reflection’ F21; further in the text all identified connections with other factors will be presented solely stated as ‘Fn’);
- The vision should be developed by people who understand the entire project process;
- An effective communication strategy is needed to distribute the vision, with the emphasis on face-to-face communication, but other levels of communication are also beneficial (F7).
- Having BIM champions and supportive groups, with authority, is a recommended mechanism to distribute the vision.
- Having clear requirements defined early with the client helps F1. For example, I11 explained that the vision comes from the client’s EIRs;
- Training is another mechanism for raising awareness (F18);
- Seeing examples of good practice helps to distribute and support F1;
- The vision should be included in the entire project lifecycle;
- A supportive procurement strategy enables F1.

Differences in perspective

Who decides the vision is one of the most debatable findings according to expert interviews. Some interviewees suggested that top-management needs inputs, knowledge and feedback from other team members and that the vision needs to be defined as a team, rather than solely by the management. There should be some input from the wider team, including, for example, the FM team as one BIM manager mentioned. Others proposed for the decision-making process to be top-down oriented, but even those interviewees agreed that there should be opportunities for everyone to have an input. For these interviewees, the main rationale behind ‘defining the vision as a team’ is to motivate people, but also to make people accountable, “if they start to fail in delivering what they said they were going to offer” (I7 00:23:29). The common solution is middle-ground, where the message is ultimately distributed from the top to get people to buy into, but it is defined as a team and with the input of people who know about the BIM process. There is more discussion on this topic within the factor F12 'shared decision making'. As a result of all data and findings, Figure 6.1 presents the enablers and benefits of F1.

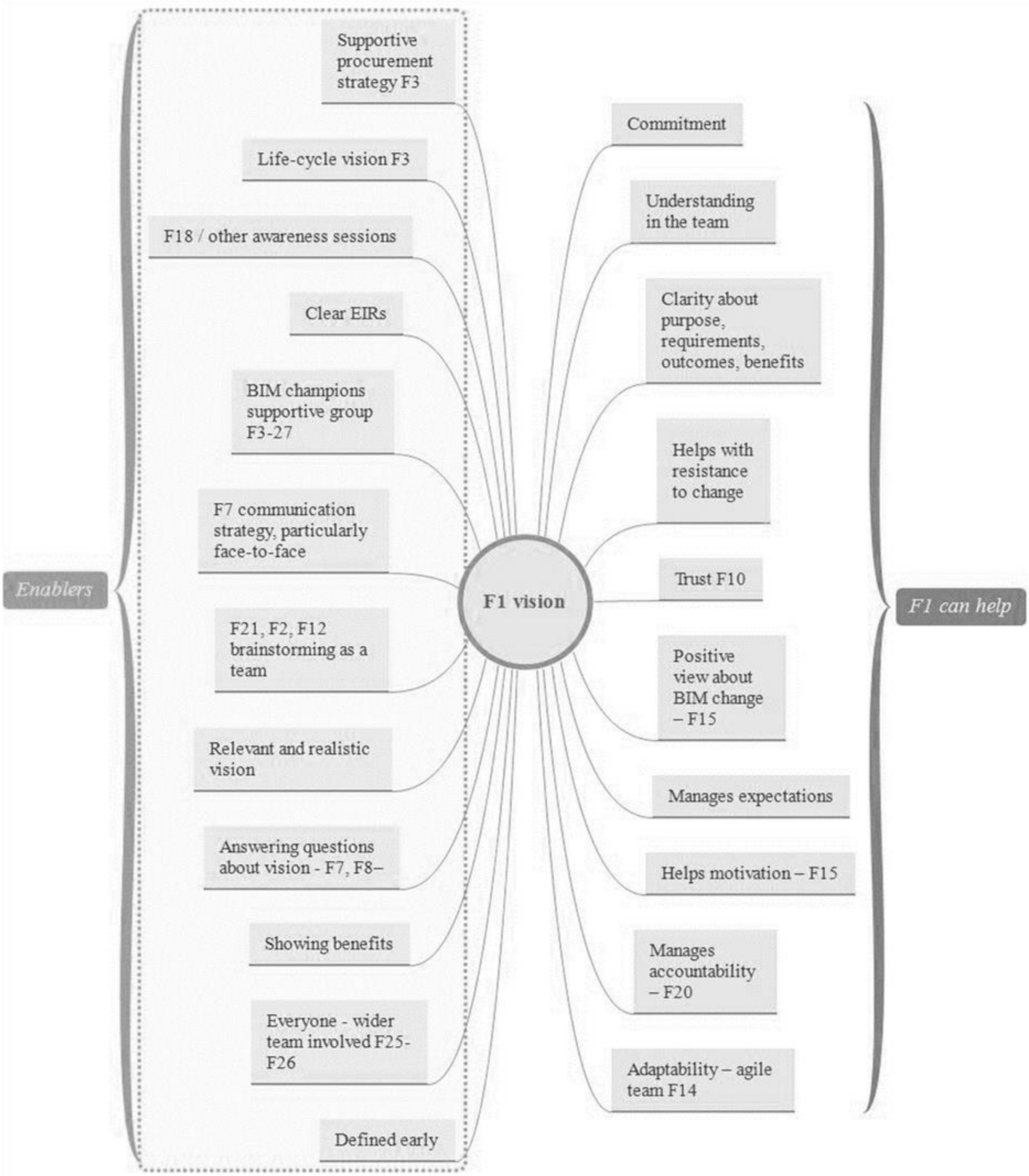

Figure 6.1 Enablers and benefits of F1

6.2 Factor 2 - Planning future actions as a team

Participants explained that planning as a team is beneficial for BIM team development. This can include planning requirements, future actions on the project and overall BIM adoption process. Main benefits of F2 recognised in interviews show the importance of this factor. These are:

- Gathering knowledge, as the leaders might not necessarily have the knowledge and experience;
- Gathering ideas;
- Solving issues early;
- Achieving a shared understanding;
- Understanding people's needs;
- Motivating people by asking for their input.

On the other hand, participants I3, I5, I9, recommended less engagement of the entire team and decisions to be made mostly by the management.

Integration into other factors

Suggestions made for this factor F2 are often present in other factors, particularly factor F12 'shared decision-making' and F26 'integrated team'. This is apparent in tables of presence –Table 6.2 and Table 6.28. For those reasons, recommendations that emerged for F2 are integrated within F12 and F26 to avoid duplication. As a result, this factor F2 is merged with factor F12, as the final Table 6.29 shows. For those reasons, the following Section 6.3 discusses factor F12.

Table 6.2 Presence of F2

	F2	F1	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	2*
I1	16	14	11	5	14	1	7	4	4	1	2	10	11	1	7	0	3	0	2	1	0	0
I2	2	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0
I3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	4	3	2	0	1	0	2	0	1	1	0	1	1	0	1	0	1	1	0	0	3	0
I5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	4	1	0	0	0	0	4	2	0	0	0	1	0	0	0	0	0	0	0	0	2	0
I7	8	4	1	0	0	0	2	1	1	0	0	2	0	0	0	0	0	0	0	0	2	0
I8	4	0	0	0	2	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0
I9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I10	9	4	7	1	1	0	5	2	1	0	0	5	4	0	1	1	1	3	1	0	2	0
I11	3	1	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
I12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	2	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0
I14	2	2	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
I15	6	5	0	0	0	0	0	0	0	0	0	4	2	0	0	0	1	1	0	0	0	0
I16	3	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
I17	11	1	3	0	5	3	3	0	0	0	1	2	2	0	0	0	0	0	0	0	6	2
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	4	2	2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0
F2	80	41	32	6	24	4	29	13	7	2	3	33	21	1	9	1	6	5	5	1	20	3

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, 2* - arguments opposite or against F2 in some way

6.3 Factor 12 - Planning and decision making in the team with contributions from all team members

The main rationale for enabling more people to contribute to the development of the strategy and planning of actions is to motivate people to accept new decisions and the change. Table 6.3 shows a high presence of F12 in interviews, which also confirms its importance. Fifteen participants recognised the benefits of this factor. I12, I17 and I18 did not recognise it as useful and I16 was against it. As a result, the majority agreed that all team members should be able to contribute and express their ideas, suggestions and needs. Overall, participants recommended greater involvement of all team members. However, they explained that not everyone in the team should be able to decide, but more people should be engaged in the process of defining BIM strategy.

The majority of participants recommended that decision-making should be limited to management and those who are knowledgeable about BIM processes. On the other hand, four participants, I2, I7, I15 and I19, each with different backgrounds, suggested that the whole team should be consulted. They explained that it is essential to provide people with opportunities to contribute because:

- The management does not have all the knowledge;
- To incorporate other people's needs (F10);
- To learn as a team (F24) and help with the lack of experience and knowledge.

Other benefits of F12 recognised by participants are:

- Involving people helps to get their buy-in (F15);
- It tackles lack of commitment;
- It tackles resistance to change;
- Helps to understand everyone's views;
- Helps communication processes – helps to decide what communication practice is the most effective;
- Helps managing expectations;
- Helps to get feedback (F21);
- Helps managing capabilities;
- It enables decision-making when some members are absent (F14).

Table 6.3 Presence of F12

	F12	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F13	F14	F15	F16	F17	F18	F19	F20	F21	F12*
I1	11	10	10	9	3	13	0	5	3	3	0	2	9	0	5	0	2	0	1	0	0	0
I2	4	1	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0
I3	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I4	6	1	1	2	0	0	0	0	0	0	0	0	2	0	1	0	1	0	0	0	1	2
I5	3	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I6	4	1	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1
I7	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
I9	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1
I10	8	2	5	5	0	0	0	2	2	0	1	0	5	0	1	0	0	2	1	0	1	2
I11	2	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	3	1	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
I14	5	3	1	1	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	1	4
I15	4	4	4	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
I16	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I17	4	1	2	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
I18	5	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
I19	3	1	2	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	1	0
F12	71	29	33	24	3	14	2	11	5	4	2	2	35	0	7	0	3	2	3	0	5	15

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F12* - arguments possibly against F12

Mechanisms

It was found that the enablers of collaborative decision-making are:

- Shared leadership (F13);
- Top-support (F3) - to give people the freedom to make decisions;
- Certain procurement strategies (F26) that enable a long-term collaboration between parties. This allows for ‘planning’ and ‘defining requirements’ to be consensus and team’s tasks;
- Workshops or brainstorming sessions (F21);
- Trust (F10) in the team.

Within the organisation

BIM managers explained that F12 is used to:

- Decide what needs to be done;
- Develop a plan on how to achieve project requirements;
- Develop the design on the project;
- Define educational strategy;
- Define organisational capabilities.

However, F12 is not recommended for deciding about the software tools. As per one of the BIM consultants, suggestions from the team, about the choice of tools can be incorporated if those can be accommodated. However, one of the strategic BIM managers made an argument against by saying that only management makes those choices. That way, the management ensures that the team uses the same tools across the organisation and they "make it easier for people to get the support" (I9 00:46:11).

In the wider team

"Meeting different people across organisations was very helpful in defining the strategy and decision-making process (I10 01:20:39). This makes the connection with the new factor F26 on having an integrated team. Interviewees suggested that the following members of the wider project team should be involved in collaborative decision-making:

- Client;
- Sub-contractor;
- FM team - to develop the data requirements.

Engaging a wider team was used to understand and decide about:

- Common goals and requirements with the client to achieve a "consistent understanding within the team" (I1 00:16:49, I7 00:46:49);
- The communication strategy with the wider team;
- The data requirements;
- Capabilities of suppliers.

According to the majority, some aspects of strategy and plans should not be open to everyone to decide, but rather set by the management. There should be clarity on what is fixed and where everyone can contribute. A rationale for this is that enabling everyone to decide would not be time or cost-efficient, people would expect their suggestions to be incorporated and sharing decisions could enable people to avoid liability. As a result of interviews, a summary of all benefits and mechanisms is presented below in Figure 6.2.

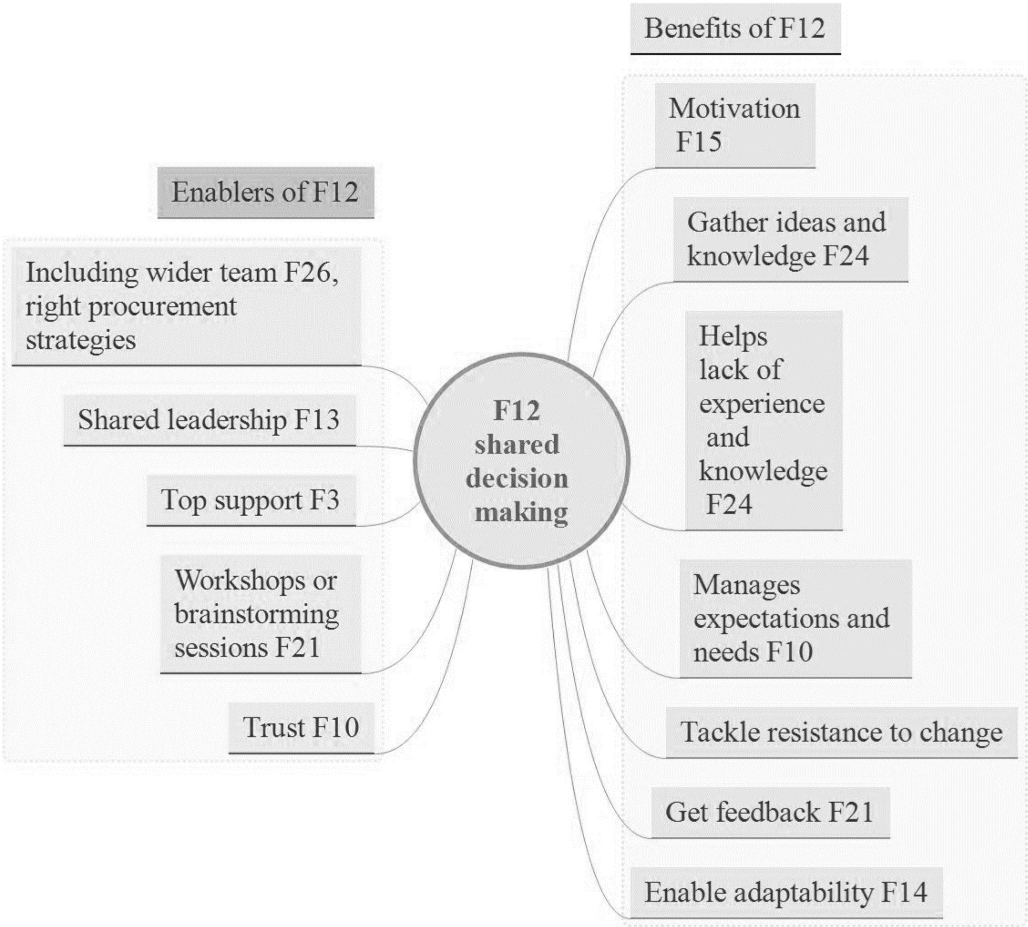

Figure 6.2 Benefits and enablers of F12

6.4 Factor 13 – Shared leadership - shared roles and responsibilities

Some participants, mostly BIM consultants and managers, recognised the value of the factor (Table 6.4). However, there is not enough evidence to enable this factor to stand independently. When recognised as beneficial in the data, it was discussed in connection with 'shared decision-making' (F12). As a result, some principles of it were integrated with F12, as per Figure 6.29.

Table 6.4 Presence of F13

	F13	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F14	F15	F16	F17	F18	F19	F20	F21	F13*
I1	12	9	11	8	2	10	1	4	3	3	1	2	9	1	4	0	1	0	2	1	0	0
I2	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I3	2	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	0	0	0	1	0
I4	2	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	1	0
I5	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I6	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
I7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
I8	4	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
I9	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
I10	6	3	4	5	0	0	0	0	1	0	0	0	5	0	0	0	0	3	0	0	0	1
I11	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
I12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	2	2	0	1	0	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0
I14	4	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
I15	3	2	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
I16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	2	0	2	1	0	0	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
I18	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
I19	2	0	1	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0
F13	52	20	21	15	2	12	5	6	4	4	3	3	35	1	6	0	2	3	2	1	4	7

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F13* - opposite codes

F13 is already in the nature of BIM projects:

> *All the responsibilities are shared. The person who produces information, the person who gives information, the person who checks information, it is all one big family. So, it is all shared responsibility* (I5 01:12:00).

Both strategic and BIM management professionals agreed. They recommended all key disciplines to be involved from the start and to be given support. However, there is no evidence to discuss this further.

Other ideas in relation to F13 were:

- F13 is valuable, but needs to be constrained and limited so that it is possible to move forward with the project (equal suggestion provided in F12);
- F13 is useful because leaders need an input (F12);
- F13 is useful while setting the organisational capability to change (F12);
- If present, shared roles and responsibilities “need to be defined early, so people understand them” (I11 00:29:37).

In interviews I4, I9, I12, I13, I18 there is no evidence. One of the arguments against was, “if you have a shared problem, you have a shared responsibility. That means no party ever really takes liability seriously” (I6 00:57:32). Similarly, I7 said that roles and responsibilities need to be clear and “that it is important that everyone is accountable for their area” (I7 00:48:18). I10 recognised that F13 could bring a value when defining the strategy, but because of liabilities, I10 suggested that it is difficult to have that in the industry, “we might talk consensus, but ultimately someone has to take responsibility” (I10 01:08:33). Other arguments ‘against’ were in I14 and I16.

The majority of participants agreed that it would be difficult to enhance F13 in practice due to the reasons above. It was found that F12 can achieve similar benefits and would be easier to apply and for those reasons, F13 is removed (Table 6.29). This is further discussed in Section 7.5.2 to avoid the extensive discussion in this chapter.

This section will only note a few other recommendations that emerged from F13 data that could be beneficial for practitioners and that can be incorporated into other factors:

- BIM ‘contribution’ or ‘responsibility’ should be added into the key existing roles (F20);
- Clear roles and responsibilities should be established (F1, F4);
- Skills should be duplicated (F16);
- There should be an understanding of each other’s roles (F1, F4).

6.5 Factor 4 – Clarity about the change process

The presence of F4 is shown in Table 6.5. Seven interviewees recognised the value of this factor. I1, I3, I5 and I12, made multiple references and found it more important. Although many participants did not comment on this factor, some mentioned that the way we introduce the change is "a key element" (I1 01:15:37).

Participants suggested that clarifying the change can help with:

- Resistance to change – they said that uncertainty causes the resistance to change;
- Lack of commitment;
- Lack of clarity and fear of change, "we try to demystify the change, so it does not seem as big and intimidating" (I1 01:19:48).
- Lack of clarity for the whole team – participants said that it is unclear what different people need to do, due to the change;
- Lack of trust;
- Enabling other factors such as F12 and F13.

Being "open about the process and sharing resources and updates" further helps managers to gain trust from the employees (I3 00:30:15) (F5 and F10). Once people are informed "about the change and benefits that they will gain" it also helps with the resistance to change (F1) (I3 00:30:15). The whole team should also know what barriers they might face, which increases openness about the processes (F15).

Suggestions

The main recommendation that emerged from the interviews is that it would be useful for people to know how BIM change impacts their role and other roles in the team. It is essential to:

> *Clearly understand what is expected of me in my role and how, and what can I expect of everybody else* (I1 00:10:25).

This is important to establish as BIM roles might be different from their usual roles and they also might be different on different projects. Therefore, it was suggested to:

> *Teach people and inform them about their BIM roles* (I3 00:24:55).

That will help them to understand the change.

Table 6.5 Presence of F4

	F4	F1	F2	F3	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	13	10	5	2	3	0	0	2	0	0	0	3	2	0	3	0	5	0	0	1	0
I2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	5	1	0	2	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
I4	1	1	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
I5	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
I6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
I11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F4	29	16	6	8	5	0	2	3	1	0	0	3	2	0	3	1	6	3	0	1	1

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Non-BIM managerial participants, I12 and I13, mentioned that the problem they had on their projects was that they were not explained how to do BIM, “how will they get there” (I13 00:49:26). I12 said that it would have been useful to hear the plan and practical examples of how it was achieved on some other projects:

> *The solution is not to instruct anyone until you have a clear idea of what you want to do and do not waste anyone’s time* (I2 00:49:40).

A BIM consultant said that to achieve that they defined strategy fist, set deliverables, then created a scheduling tool. They also made the plan and the strategy visible. Therefore, once the vision and strategy are defined, the plan about the BIM change should be explained to all team members. These recommendations are aligned with F1.

Within the management team

When defining the strategy, it needs to be clarified what is the change the team aspires to, to gain the correct, required capabilities (F1, F3). In the change programme, links between capabilities and benefits need to be clear:

> *This is the benefit that we want, and this is the capability that we need in order to get that benefit. This is the change that we have to implement in order to get that capability established. So, that change might be staff training, implementing the common data environment et cetera* (I1 01:33:09).

Within the wider team, it is recommended to explain to a client the process of change – "make them aware of the process that is going to happen" (I3 00:03:50) and explain what needs to be done, another BIM consultant added (I5).

Relations with other factors and conclusions

Interviewees suggested that the wider internal team can be involved in the decision-making process and they can be part of the leadership, to motivate them to accept the change. However, it is essential to clarify "what aspects of the change are fixed and what aspects of the change can everybody contribute ideas to" (I1 01:03:57). This is recommended for both organisational and project level (I1 01:03:57). Therefore, clarifying what is certain or clear (F4) and where others can contribute, supports other factors F12, F13 and BIM change.

This factor was found valuable by a few participants and beneficial against a few important challenges. The diagram for F4, a summary of previous conclusions, is in Figure 6.3. However, this factor presents similar suggestions to other factors, particularly factor F1. For example, F1 also explains the importance of achieving a clear understanding. In conclusion, it is established that this factor will be incorporated into F1 – presented in Table 6.29.

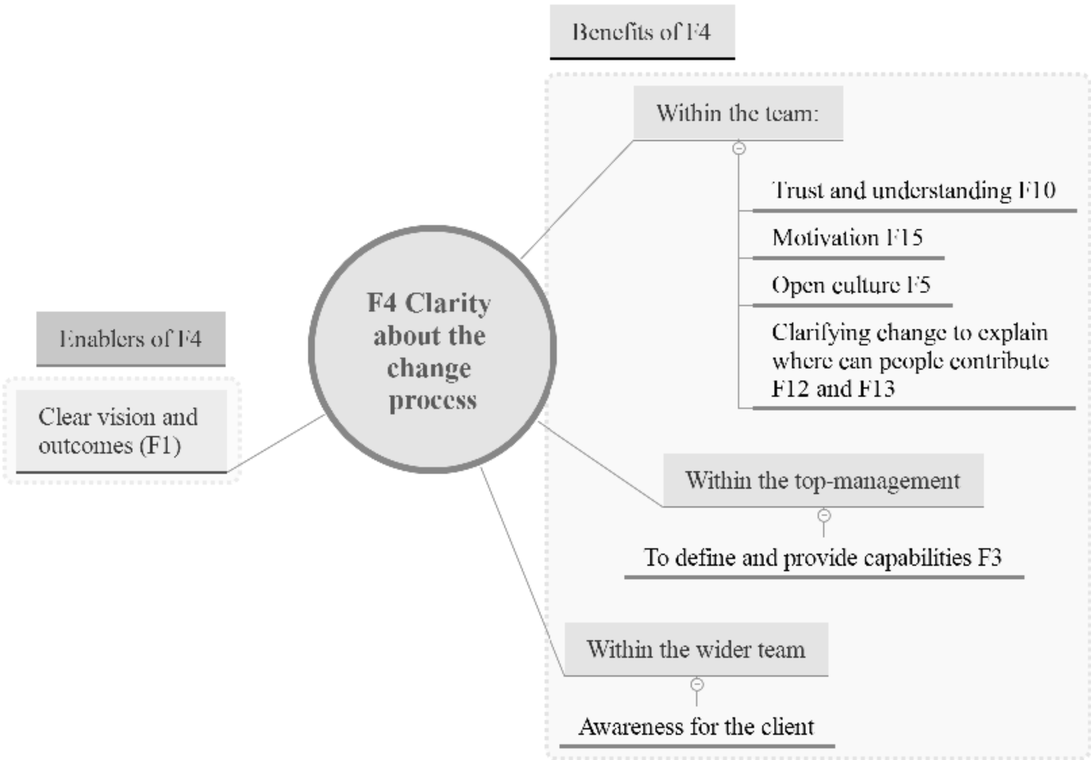

Figure 6.3 Enabler and benefits of F4

6.6 Factor 5 - Ensuring an open culture and culture of collaboration

Table 6.6 shows the presence of this factor. This factor can be defined as ‘providing an opportunity for people to share their ideas and views’. The difference between this and factors F12 and F13, is that in F5 project team members are not involved in the decision-making process. However, they have the freedom to speak, express opinions and contribute in that way. Most participants, 18 of 19, recognised that the culture should be open and collaborative. Some experts specifically said that BIM is about having a culture of openness and collaboration; and a few added that there should be an open culture regardless of BIM being present on projects.

This factor is crucial as it helps with:

- Communication challenges (F7);
- Lack of trust (F10);
- Lack of commitment;
- Lack of clarity;
- Enabling knowledge sharing in the team (recognised by many) (F24);
- Managing everyone’s needs;
- Defining requirements;
- Solving challenges;
- Enables F2 and F12 - planning and decision-making;
- Effective learning (F18, F19 and F24) - enables asking questions and asking for training.

What emerged from the data is that managers need to ensure a ‘no blame culture’. I2 explained: “it should be fine to make a mistake” (I2 00:27:44) and “you should not be afraid to say what you think” (I2 00:42:46) and to raise if something is wrong on time (I2 00:27:44). Others added:

> *A right mindset in the team, willingness to try new things, to trust each other and to try not to maintain a culture of blame* (I4 00:02:15).

Participants further mentioned a ‘culture of collaboration’. It was said that a non-collaborative, silo-way of working would cause problems for the dynamic BIM environment.

Table 6.6 Presence of F5

	F5	F1	F2	F3	F4	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	27	11	14	13	3	1	9	4	5	5	6	13	10	1	8	0	3	1	2	0	1
I2	7	0	0	2	0	0	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0
I3	6	0	0	1	1	0	2	0	0	1	0	0	1	0	3	0	0	0	0	0	2
I4	7	1	1	1	1	0	3	1	2	4	0	0	0	0	3	0	0	0	0	0	1
I5	4	1	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0
I6	5	1	0	0	0	0	5	1	0	1	0	0	0	0	0	0	0	0	0	0	1
I7	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I8	1	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
I9	5	0	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	1
I10	12	6	1	8	0	0	11	6	0	0	0	0	0	0	0	0	1	1	0	0	3
I11	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	4	0	0	4	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
I13	4	1	0	3	0	1	2	0	0	0	0	1	1	0	2	0	0	1	0	0	1
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	5	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	2	1	0	5
I16	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	8	0	5	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	6
I18	4	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	3
I19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F5	104	23	24	36	5	2	53	16	8	15	6	14	12	2	17	0	4	7	4	1	26

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Enablers within the wider team

There is a lack of trust within wider teams, which inhibits information sharing and open culture (F10). For example, it was mentioned by managers that design consultants were not willing to share the work before the deadline; and this could have been improved by the way contracts and programme were structured. Clear roles and responsibilities and non-adversarial forms of contracts would address this, reduce conflicts and enable F5. To enable F5, it was also suggested to define BIM requirements as a team (F1, F2) and to organise team workshops to share good practice (F7, F21, F24).

Mechanisms

Open meetings in the team (F7, F21) help to achieve F5. I3 suggested having open meetings every two months where people could make suggestions, provide feedback and share opinions. I8 suggested fortnightly open meeting for both internal and wider team to discuss concerns. Others explained that regular design team meetings where people would be safe to share the information are enough. To support open culture and communication, team members should also meet to discuss what did not work and lessons learnt (F21). It is important to ensure that during those meetings, everyone contributes. For example, to make people share more information I18 suggested that each party should bring at least three points to discuss.

When asked about having open meetings, some said that it is enough to be in the same physical location. Having all disciplines in one place and talking with each other was found very beneficial and it can “become an issue if you do not have face-to-face meetings” (I9 00:35:58). I17 said that suggestions should be raised in everyday conversations. I7 explained that there is not a need for specific ‘open’ meetings, but he/she recognised that this is possibly due to the small team size they have of less than twenty people.

Having the right leadership approach is another enabler of F5. The management shall be open about the processes and create a positive corporate culture. They should share updates and share resources, which would further help to win the employees’ trust. They should share challenges and discuss what are the risks for all roles involved. Another suggestion is for managers to ask for feedback throughout the project (F21). Other ways to increase openness (F5) is to provide access to those who create a strategy. Recommendations for this are:

- Increase face-to-face communication, organise workshops and enhance informal communication (F7);
- Establish online portals or forums for people to ask questions (F7, F8);
- Create steering groups, based on disciplines, as a safe place to talk and find information.

Those suggestions also enable F7 and F8. There were other comments in relation to open culture, such as providing access to the BIM model for more people in the team (F8). However, these will be discussed within factors F7, F8 and F9. Figure 6.4 summarises these findings.

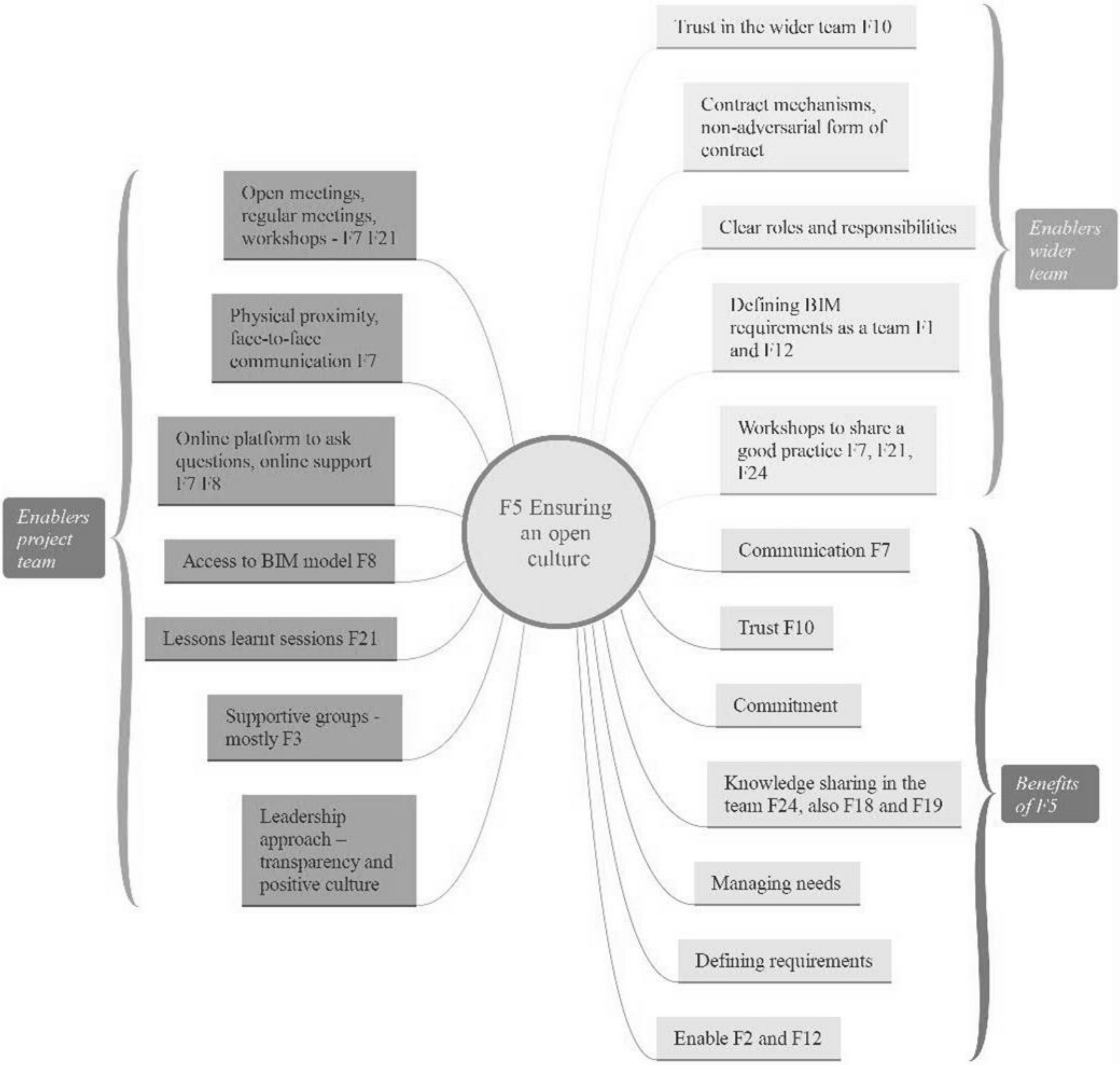

Figure 6.4 Benefits and enablers of F5

6.7 Factor 6 – Diversity in the team

F6 is coded in the majority of interviews except in I10, I16, I18, I19 (Table 6.7). Most participants said that diversity in the team is beneficial and they mostly focused on diversity in terms of skills and experiences. There is a relation between this factor and F14 ‘flexibility to adapt’, F10 ‘trust and respect’ and ‘skills and setup of the team’ within F27.

Table 6.7 Presence of F6

	F6	F1	F2	F3	F4	F5	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	5	0	1	1	0	1	0	0	0	1	0	0	1	3	1	0	1	0	0	0	0
I2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	2	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
I4	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
I5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	4	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0
I8	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
I9	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
I10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
I13	2	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
I14	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	5	0	3	1	0	0	0	0	0	0	2	1	3	0	0	0	0	1	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F6	34	2	4	3	0	2	0	1	1	4	2	2	5	6	6	1	1	2	0	0	0

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Participants recommended to improve diversity in skills, to have:

- A “cross-section of roles and abilities” (I13 00:35:47);
- “Multi-skilled people” (I14 00:41:50);
- “Technically competent people” and those who are “process-driven”, while everyone should appreciate both sides and have some understanding about each (I7 00:47:50), “at least some knowledge of what everyone else is doing” (I8 00:44:00).

It was stated that a diverse consultant team, helps to establish shared understanding on the project level, enhances adaptability and collaboration within the project team (F14, F25). Diversity also enables F2, F12 and F13. When asked about decision-making and shared leadership, participants explained that it is beneficial to have different disciplines involved and to have someone with BIM knowledge within each.

Diversity in terms of culture or nationalities emerged in one interview. A participant explained that such diversity "brings something different to the table and it impacts your efficiency and innovation" (I2 00:41:57). He suggests that it positively impacts companies and projects. However, this was the only reference for this level of diversity.

Another level of diversity recommended is to have a variety of experiences within the team. A participant explained that BIM proficient staff, even if not experienced as the AEC professionals, would benefit an experienced team. Both BIM knowledge and experience and engineering proficiency are necessary to deliver BIM projects. When discussed how F6 enables reliability of design information, participants said that having diverse experiences makes the team also adaptable and flexible (I4 01:01:02) (F14), as less experienced staff are willing to learn (Figure 6.5). A team diverse in terms of experiences and skills is adaptable to different project needs (F14) (Figure 6.5). Professionals with diverse skills further support adaptability and resourcing (I8 00:44:00) (F14).

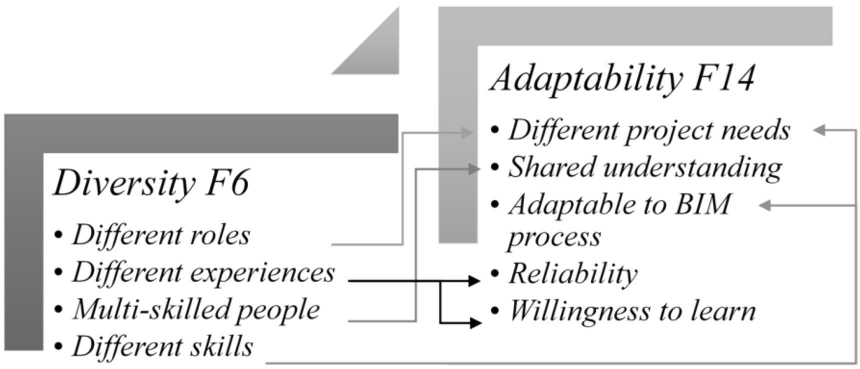

Figure 6.5 Relation between F6 diversity and F14 adaptability

To summarise, Figure 6.6 shows how can F6 help the BIM team development. It summarises all key points from the previous text.

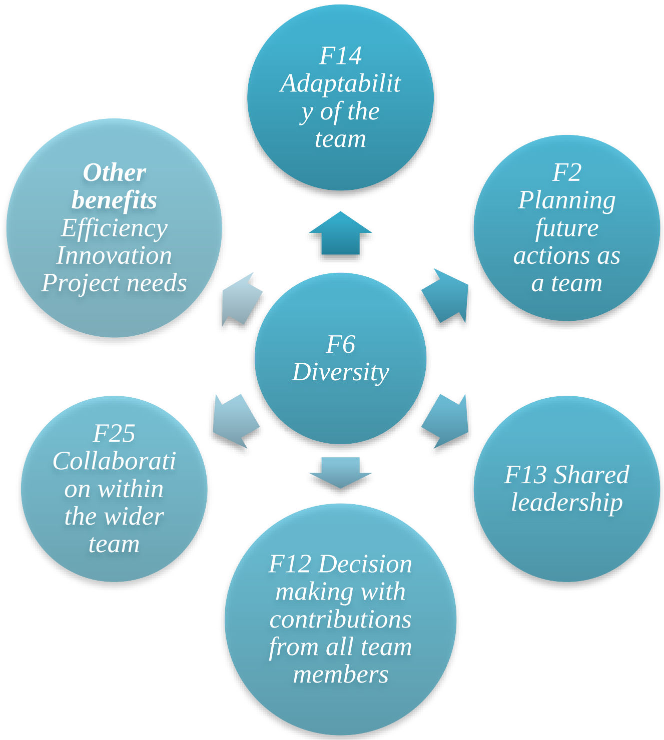

Figure 6.6 Relations between F6 and other factors and other benefits

6.8 Factor 7 - Communication digital and non-digital information exchange

This is the most coded factor, with 320 references (Table 6.8). For the majority of participants, this topic is within the most five discussed factors. During the process of coding, other sub-codes were emerging such as: ‘BIM coordination’ which is about the digital exchange of information, ‘communication face-to-face’, ‘communication regularly’, ‘model sharing and validation’. Participants explained that “BIM is about exchanging the data” (I4 00:16:00), which further confirms the importance.

Table 6.8 Presence of F7

	F7	F1	F2	F3	F4	F5	F6	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	20	5	7	6	0	9	0	10	10	2	4	5	4	0	6	0	5	1	3	2	1
I2	16	1	1	1	0	5	0	4	5	2	0	1	0	0	0	0	0	0	0	0	2
I3	11	2	0	4	1	2	0	2	1	1	0	0	1	0	1	0	0	6	0	0	2
I4	20	3	2	1	1	3	0	7	8	2	0	0	0	0	1	0	2	2	0	0	2
I5	12	1	0	2	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
I6	31	6	4	1	0	5	0	5	0	3	0	1	0	0	2	0	0	2	0	0	3
I7	20	0	2	3	0	0	0	5	6	2	0	0	0	0	0	0	0	0	0	0	6
I8	14	0	3	0	0	1	0	1	3	1	0	0	0	0	0	0	0	0	0	0	1
I9	27	0	0	3	0	3	0	13	4	0	0	1	0	0	0	0	0	1	1	0	3
I10	24	9	5	11	0	11	0	4	2	1	0	2	0	0	2	0	3	0	2	1	3
I11	21	2	0	3	0	1	0	4	1	1	0	0	0	0	0	0	0	0	0	0	2
I12	11	1	0	2	0	0	0	7	2	0	0	0	0	1	0	1	3	1	1	1	1
I13	11	5	0	2	0	2	0	2	3	0	0	0	1	1	2	0	0	1	1	0	1
I14	8	2	1	2	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	1
I15	17	2	0	1	0	4	0	4	8	3	0	0	0	0	0	0	0	1	0	0	5
I16	18	3	1	1	0	0	0	4	5	1	0	0	0	0	0	0	0	0	1	0	1
I17	17	1	3	3	0	4	0	0	3	0	0	0	0	0	0	0	0	1	0	1	3
I18	10	1	0	2	0	3	0	1	1	1	0	0	0	0	0	0	0	0	0	1	4
I19	12	0	0	4	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
F7	320	44	29	52	2	53	0	80	67	21	4	11	6	2	14	1	13	16	9	6	43

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support and structure, F4 - Clarity about the change process, F5 - Ensuring open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information, exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Planning and implementing effective communication solutions help many other vital aspects of BIM project delivery and BIM team development (see also Figure 6.7):

- Learning process (Table 6.7– Training);
- Stakeholder engagement;
- Design validation within the team;
- Clarity;
- Trust;
- Resistance to change and commitment.

In terms of challenges to information exchange, participants mentioned the following:

- Unnecessary information, such as too many emails or extensive documents;
- Lack of clarity on what kind of information is needed from the clients;
- Different team locations;
- Different cultures;
- Resistance to change;
- A fear to raise a different opinion (F5);
- Complex nature of the industry with many disciplines and parties - "a whole line of communication that can break at any point" (I4 00:39:42);
- Interoperability issues;
- Lack of trust (F10) – people are afraid to share the information while the work is in progress. It needs to be clearly stated how the information is going to be used and explained that it is only 'work-in-progress' information (I7 00:59:29, I19 00:50:52) (Figure 6.8) allow the information exchange.

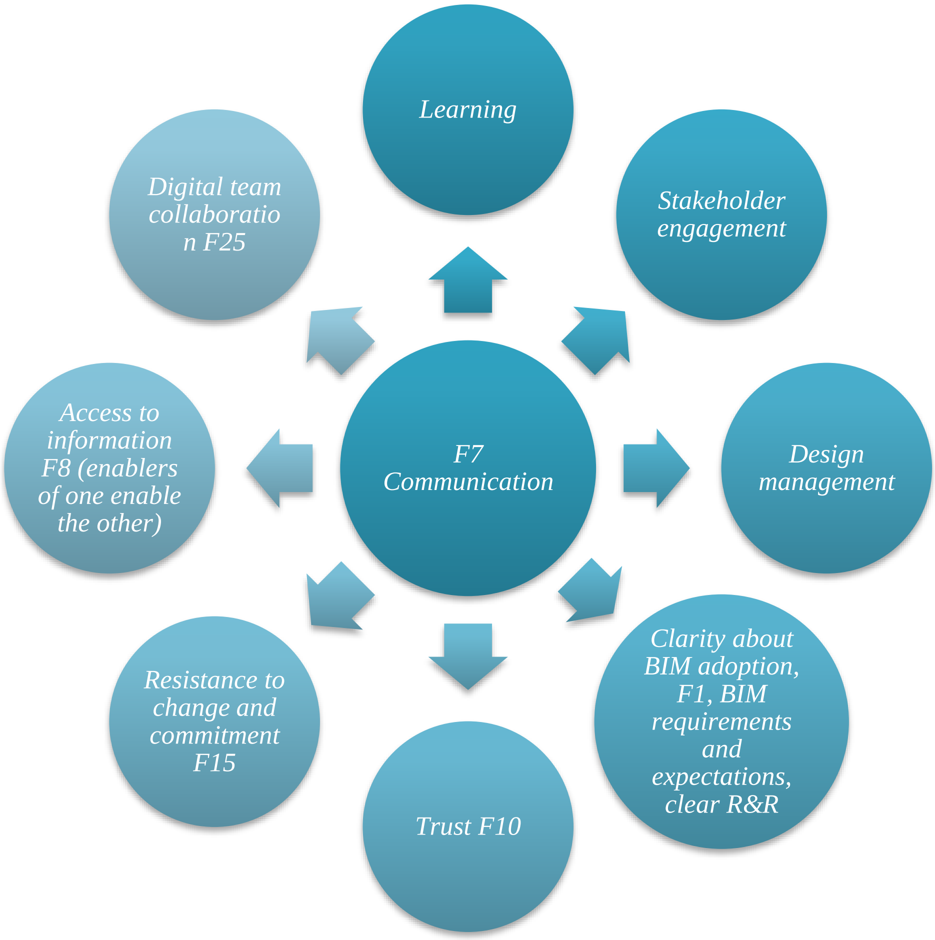

Figure 6.7 Benefits of enabling F7

Digital formal and informal communication

When asked about communication and BIM implementation, participants mostly talked about the effective CDE and information management system to support the exchange of data digitally between all parties. Participants recommend an automated information exchange and avoiding the transfer of information through emails. They recommend storing information in one place. The assigned Information Manager within the team can support that - "look after the data" and "establish the same language" through standard methods and procedures, use of standards and libraries (I5 00:43:21). It was also found that the main enablers of digital communication are the infrastructure and BIM management support, which are both top-down mechanisms (F3, F9, F27). There were more discussions about this aspect of BIM implementation, but as the focus of this study is on CM, IM and KM management, only the key points about digital communication are discussed.

Participants recommended simplifying the process and providing access for more people within both the internal and wider project team to model information – which is another factor F8. The new solutions participants mentioned, such as open formats, enable the wider team to be involved. For example, they recommended BIM tools that enable those without technical knowledge to view the model and documentation (I4 00:35:29). It was also found that teams still need and prefer printed material rather than digital formats. Simplifying the process and automatisation is also recommended to avoid the "double handling" of the data which causes waste of time and interpretation errors (I9 00:49:27). This is further discussed within the factor F8 on access to information.

Other aspects of digital communication mentioned were:

- Forums and social media – these enable F8 (access to information) and virtual collaboration within the team (F25);
- Better data visualisation techniques;
- Easier access through mobile applications (F8).

BIM management participants explained that the process of defining digital communication strategy is a learning process for the wider project team. Some participants established pilot projects to define the strategy, practice and test information exchange (F19). I11 mentioned how it was challenging for him as a BIM manager to define the strategy and also for people to accept it: "it takes people months to get their head around a new system. Because people hate change, everyone does" (I11 00:02:04). The process of defining the data exchange can also be challenging because it needs to include ideas about the future use of the data, to make sure that the data are accessible and usable in future. Defining the digital communication processes early also helps teams with expectations, clarity, clear roles and responsibilities and address the resistance to change. Therefore, defining rules about communication should occur early in the process of defining BIM team development strategy.

Non-digital formal and informal communication

Participants recommended different types of meetings to support the process. For the early phase, or adoption, I1, I4, I11 and I15 suggested workshops or whole day meetings, to discuss the best route for the company (F21, F2, F12). I2, I14 and I19 talked about meetings weekly to discuss issues and see what they can do as a team to develop the BIM design and improve BIM team development (F19, F2, F12). It is essential to make sure that everyone who attends these project meetings contributes to these meetings, not only attend (F20).

It was recommended that BIM project meetings should not only be about the use of software but also the process should be discussed. For the later phase, I3, I6, I9 and I13 suggested departmental meetings every two months to discuss what can be improved, which can enable people to share opinions, share methods, provide feedback and discuss lessons learnt. This is also recommended within the wider team, to stop issues manifesting in the first place (F26). This is another factor F21 and it is discussed more later in Section 6.22.

Other ways to enable effective non-digital communication are:

- Awareness sessions: workshops and conferences to cover different levels of the organisation;
- Groups and champions to distribute the information, I10 mentioned that this helped as it made a significant change in perception and helped to create a safe place to have open communication. I11 added a comment about how they distributed or "pushed knowledge" through BIM champions (I11 00:12:11);
- Training – to help with "lack of clarity – inform people by having a training" (F18) (I3 00:30:15).

From interviews, it emerged that face-to-face communication and being in the same location is very important. The physical connection and everyday interaction are beneficial for BIM team development and working between several locations causes issues. BIM management participants pointed out how BIM practice is not a 'silo way of working' and how people need to talk and collaborate. This is further explained in factors F5 and collaborative team factor F25.

Simple language and a customised strategy

Other recommendations from the interviews are that the language needs to be concise and easy to understand. There should be no ambiguity in documents. Communication also needs to be customised for the client and everyone else within the team and organisation. When talked about EIRs, I7 said "I have got an 80-page document here and really all I need is four pages… so that I can focus on what is really important" (00:54:30).

The summary of all enablers is presented in Figure 6.8.

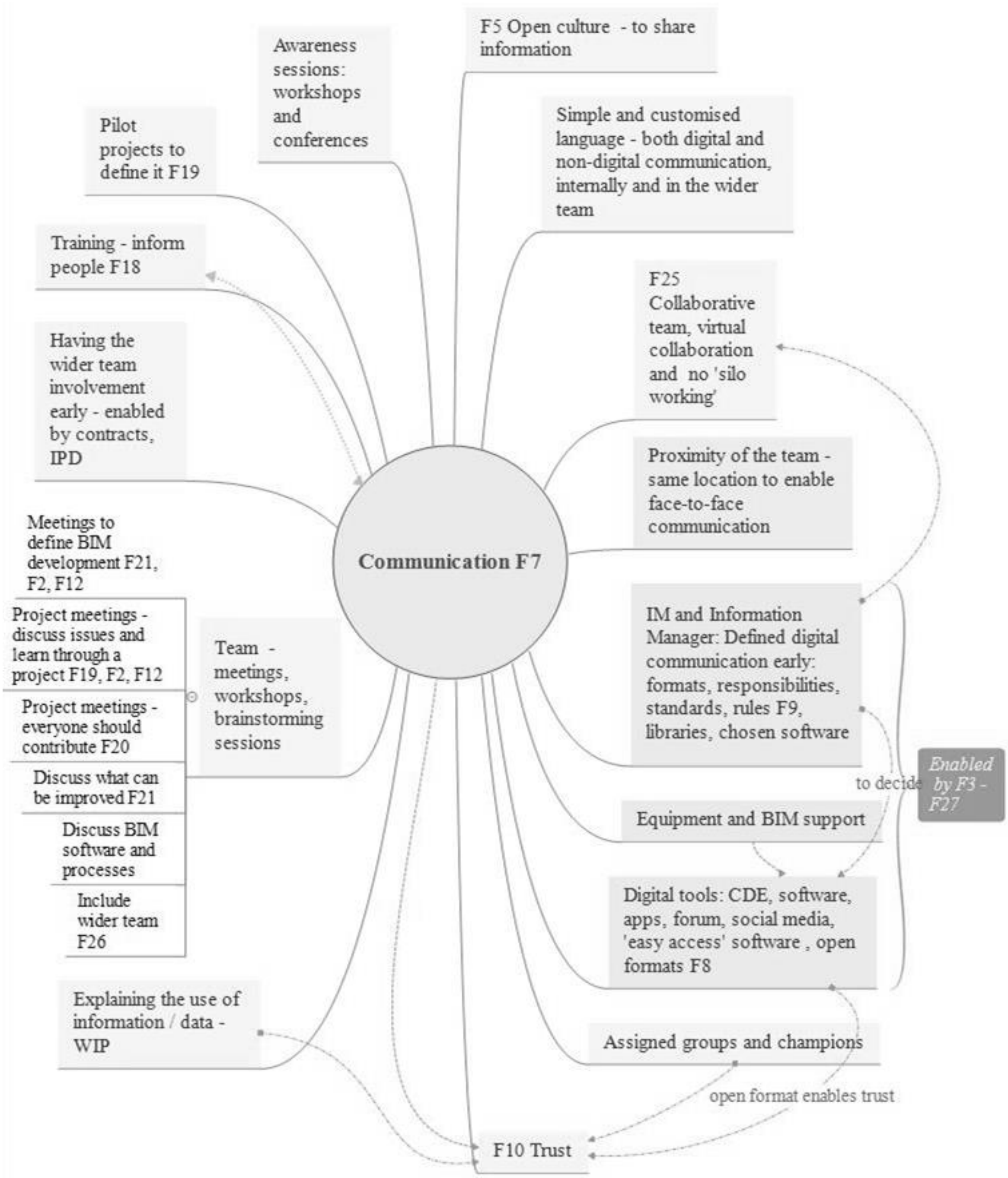

Figure 6.8 Enablers of communication F7 - exchange of communication

6.9 Factor 8 – Enabling the access to information

Table 6.9 shows the presence of this factor. It was perceived as very important in interviews. This factor incorporates sub-categories: access to knowledge, access to project information and access to information from external parties. ‘Access to knowledge’, mostly discussed by BIM management participants, is about having the support from other team members, access to guidelines and other learning material for everyone in the team. This sub-factor is further discussed in factor F27. Many F8 codes are also coded within F7; therefore, this factor is incorporated under F7 in Table 6.29.

Table 6.9 Presence of F8

	F8	F1	F2	F3	F4	F5	F6	F7	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	13	5	4	5	2	4	0	10	7	1	2	3	3	1	6	0	4	0	3	2	0
I2	6	0	1	1	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	1
I3	4	0	0	0	0	0	1	2	1	0	0	0	0	1	1	0	0	1	0	0	0
I4	8	1	0	0	1	1	0	7	5	0	0	0	0	0	0	0	1	0	0	0	0
I5	9	1	0	4	0	1	0	4	1	0	0	0	0	0	0	0	0	0	1	0	0
I6	6	0	2	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	2
I7	8	0	1	1	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0
I8	6	0	2	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
I9	16	0	0	5	0	1	0	13	2	0	0	0	0	0	0	0	0	1	2	0	1
I10	8	4	2	6	0	6	0	4	1	0	0	2	1	0	1	0	1	2	1	0	0
I11	8	0	0	2	0	0	0	4	0	1	0	0	0	0	0	0	0	2	0	0	1
I12	12	1	0	1	0	0	0	7	2	0	0	0	0	1	0	0	1	1	1	0	1
I13	7	2	1	2	0	0	0	2	1	0	0	0	0	0	0	0	0	1	3	0	0
I14	3	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
I15	4	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	1	0	0	2
I16	10	1	0	3	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
I17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
I18	5	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0
I19	5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
F8	139	15	13	31	3	16	1	80	36	2	2	5	4	3	8	0	8	10	11	3	9

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support and structure, F4 - Clarity about the change process, F5 - Ensuring open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information, exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

F8 is important because it allows more people to get involved. Therefore, more people will be able to provide their inputs (F2, F12). Participants also said that access to information is one of the biggest challenges for BIM projects and F8 needs to be enabled. Some examples include contractors that struggle to get information from designers and design teams that struggle to get all the needed information to populate the model. As a result, participants mentioned that the process is time-consuming. Participants also recognised other challenges:

- The complexity of language and acronyms, which makes knowledge about BIM less accessible;
- Providing access to information for the project team is difficult due to lack of clarity about requirements and needs (F1);
- Obtaining the information from specialised contractors, while obtaining the information for common products is less challenging.

Mechanisms

It was recommended for the communication strategy to be set early to enable the access to needed information. Other recommendations are to:

- Cover different levels in an organisation;
- Employ face-to-face to digital, individual to mass communication.
- Explain to people where to find the information – points of contacts, found as essential.

A summary of mechanisms and further information is presented in Table 6.10.

Table 6.10 Mechanisms to enable F8 'access to information', incorporated within the factor F7 (Table 6.29)

Phase	*Mechanism*	*Rationale or how*
Early phase	*Define communication strategy*	To address communication challenges, including access to information, establish communication strategy in terms of: frequency, tools, methods, the language that all parties can understand and define communication methods with end-users (I1 01:26:33).
	Early involvement of parties	Engage other parties early to make sure that the right information is delivered (I7 00:04:40).
	Increase awareness about the BIM strategy: requirements and steps	• Not only managers but the entire team needs to know what is expected from BIM and methods of achieving it (I12 00:24:37); • Set rules and responsibilities so that everyone understands the process and their role (I1 00:47:13, I1 01:19:48); • Develop requirements early and as a team, to manage expectations (I1 00:19:39).
	Defining the client's access	Define the methods of access for the client (I1 00:19:39).
	Networking opportunities	Attend networking events whilst creating the strategy – found beneficial for all management levels (I10 01:20:39).
	Define templates and libraries	• To reduce time people spend looking for information (I5 00:03:09); • Libraries for access to data and standardisation of the data (I9 00:32:41) (I19 00:54:18); • Selecting manufacturers' components – put agreements/orders early in place to get more accurate models (I19 00:54:18).
	Model management- rules and standards	• Establish rules early to avoid interoperability problems (I13 00:22:02); • Think about the future use of the model - e.g. availability of hyperlinks (I16 00:05:55); • Enable other disciplines to use the model information later (I18 00:42:38) (I4 00:19:11).
During the project	*Use 'easy to access' software and provide 'more access to the team'*	• Enable those who are not technically proficient to view the model – e.g. browser access (I4 00:33:30); • The model needs to be easily accessible for the whole team (I5 00:29:21, I12 00:17:09, I18 00:20:06, I19 00:28:25); • More people should be able to have access to the software. This was recognised for construction organisation (I15 00:14:33) • Access should be given to everyone – participants do recognise the challenge of not having enough licences (I16 00:47:44); • Access on-site to be established through portable devices (I19 00:14:22, I3 00:17:25); • When selecting software, consider interoperability within the wider project team (I9 01:06:00).
	CDE	• Enable access to project information in one place (CDE); so that if there are errors they can be tracked (suggested by many); • Ensure that information is structured so that it can be easily found (I7 00:05:39, I11 00:22:15); • A weekly update of information to ensure up-to-date information (I8 00:28:51, I2 00:13:37); • Ensure controlled access (I9 00:30:58, I14 00:06:10) – more discussion in F9.
	Open standards	• Ease the exchange of information and people are more receptive to them now (I6 00:25:09, I1 00:38:41, I11 00:45:28); • Think about the future use of model – e.g. will hyperlink be available in future? (I16 00:05:55);
	Open meetings	Enable accessing the right information, solving problems (I6 00:48:21).
	More meetings	Some participants suggest more, while some that it is not a necessity to have more meetings.
	Web conferencing	Access the model through web conferencing (I14 00:21:36), also saves time and travel costs.
	Accessible management	Steering groups, project managers, BIM managers should be available for face-to-face discussions and for solving issues – further in F3 and F27. Should provide information about technical capabilities and development (I10 00:15:30, I11 00:12:35).
	Pilot projects – F19	Practice the data exchange and the process of exports and imports (I1 00:38:41, I9 00:16:05).
	Mass communication through portals, forums	Respond to questions and provide the advice for more people remotely, for example, an open forum (I11 00:15:30, I1 00:27:11).
	Awareness about the process	Ensure that the team knows what has been delivered so far with BIM (I15 00:10:52).

6.10 Factor 9 – Ensuring the reliability of the information

Participants recognised this factor as highly relevant for BIM team development and recognised the importance of establishing it early. It relates to other factors - F7, F8 and F3 (Table 6.11). According to the data, ensuring the reliability of the information, or establishing formal routes in communication, is essential to validate day-to-day activities within the team, to use "check-approve process" and share the accurate information (I7 00:07:56).

Table 6.11 Presence of F9

	F9	F1	F2	F3	F4	F5	F6	F7	F8	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	18	4	4	5	0	5	0	10	7	1	2	3	3	0	1	0	2	0	0	0	0
I2	6	0	0	0	0	0	0	5	3	0	0	1	0	0	0	0	0	0	0	0	0
I3	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
I4	11	1	1	0	1	2	0	8	5	1	0	0	0	0	1	0	2	0	0	0	1
I5	10	1	0	2	0	0	0	4	1	0	0	0	0	0	0	0	0	0	1	0	0
I6	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	12	0	1	2	0	0	0	6	5	1	0	0	0	0	0	0	0	0	0	0	0
I8	5	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	1	0	0
I9	7	0	0	3	0	1	1	4	2	0	0	0	0	0	0	0	0	0	1	0	0
I10	3	1	1	1	0	0	0	2	1	0	0	0	0	0	0	0	1	0	0	0	0
I11	4	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
I12	3	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
I13	3	1	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
I14	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
I15	13	1	0	0	0	0	0	8	0	3	0	0	0	0	0	0	0	0	0	0	0
I16	12	1	0	3	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0
I17	7	1	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	9	0	0	1	0	0	0	1	5	0	0	0	0	0	0	0	0	1	1	0	0
I19	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F9	134	11	7	23	1	8	1	67	36	7	2	4	4	0	2	0	5	1	4	0	1

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Participants explained that F9 is important, because resolving the incorrect model information is a lengthy process. I4 added that model information needs to have the right quality, structure and classification system to be useful for the whole team. However, BIM management participants recognised that there is a resistance to adopt the data management requirements, because the modelling process is different to the old design practice and the change could take additional time.

The data shows that F9 does not help motivation, resistance to change or willingness to learn (Figure 6.9), but it is critical for achieving BIM competency. Figure 6.9 also shows enablers for this factor and how it can impact team development.

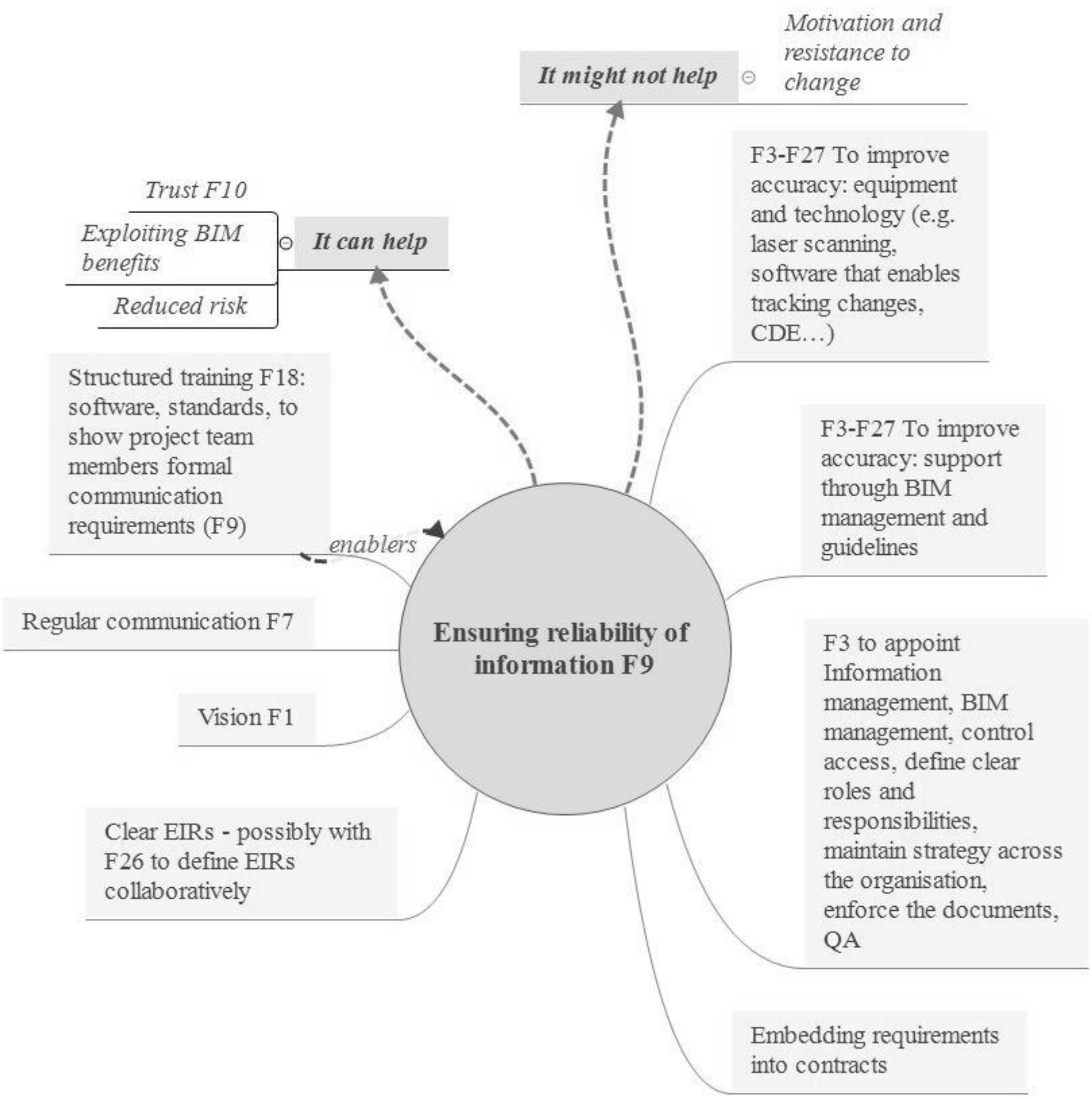

Figure 6.9 Enablers and consequences of F9

To enable this factor, participants suggested the following:

- Apply the industry standards (such as BIM standards, ISO quality management standards), define BIM execution plan and other relevant documents, organise CDE to ensure the storage and control of information. Support this by Information Management (IM) and design management roles. Decide the required level of data;
- Appoint an IM to be responsible (F3). Participants said that IM is ‘a data guardian’, someone who is responsible to regularly check the quality and the integrity of data, fill any gaps and prompt users. However, the responsibility for the data input needs to be within all roles.
- Provide the management support (F3) – enforce the use of document ‘set up’;
- Establish a system to track changes;
- Establish task team management with clear roles and responsibilities. Ensure that workset setup is correct and that right people have access to right parts of the building model (I9). Isolate disciplines to prevent changes across the disciplines;
- Ensure the reliability of information produced with manuals and guidelines (F27);
- Establish a verification process when deciding about the software – validate benefits and look for issues, check for the software upgrades and versions (and check their impact);
- Have regular project review meetings and exchange of information within the team (F7);
- Establish EIRs **-** this can be achieved by defining EIRs as a team, which improves the clarity of EIRS, reduce risks and increase confidence (additional comments below).
- Define contracts and tendering processes. Work with the legal team to ensure that essential things are embedded into contracts with suppliers and to make sure documents do not conflict with each other.
- Create ‘BIM strategy group’ across locations – to ensure consistency and meet standards.
- Provide structured training (F18):
    - Structured training about specific software tools, rather than the only F24;
    - Structured training to achieve compliance with standards – to follow procedures for model validation and sharing;
    - Structured training to explain processes, roles and responsibilities.
- Distribute the vision to the whole team (F1), so they understand the impact of their actions.
- Establish Quality Management (QA): system and processes, staff competence, training, automated checking, review meetings and risk management.
- Other suggestions are validation points, KPIs, schedule of delivery, laser scanning.

Additional comments that emerged from the interviews

F9 is mostly controlled by those responsible for IM and BIM management. However, everyone in the team needs to comply with standards, contribute review meetings et cetera. With customised or non-standard design, there might be more issues with responsibilities, and it needs to be established early who controls the data.

Interviewees mentioned that the process of sign-off by the client sometimes slows the IM process. Another challenge in the AEC industry is the ambiguity of EIRs requirements, which impacts F9. Participants suggested that design and construction teams should help the client develop requirements – showing that F26 enables F9. This is aligned to the concept of team integration and it will be discussed within the factor F26.

6.11 Factor 10 – The culture of trust, respect, understanding each other's role and a safe environment to try new tools

This factor explores the right culture for BIM team development. The concepts of trust and respect are discussed separately. Other recommendations include understanding each other's role and creating a safe environment to try new tools. These are discussed within the section on mechanisms. Table 6.12 shows the presence of F10. Figure 6.10 summarises the benefits presented in this section and previous factors (F5, F12, F7 and F9).

Table 6.12 Presence of F10

	F10	F1	F2	F3	F4	F5	F6	F7	F8	F9	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	12	0	1	4	0	5	1	2	1	1	2	0	1	1	3	0	1	0	0	0	1
I2	3	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	1	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	1
I4	6	0	1	2	0	4	0	2	0	1	0	0	0	0	4	0	0	1	0	0	2
I5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	5	1	0	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1
I7	6	0	0	0	0	0	3	2	0	1	0	0	0	0	3	0	0	0	0	0	0
I8	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	3	0	0	3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
I11	8	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
I12	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	3	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0
I16	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	4	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
F10	63	3	2	11	0	15	4	21	2	7	2	2	3	1	11	0	1	1	0	0	5

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

Trust

Mutual trust within the team is essential to achieve BIM development, the majority explained. It was previously mentioned that trust helps with F5 culture of openness, F12 collaborative decision making, F7 information share and F9 reliability. Managing trust also helps to manage the resistance to BIM change. Participants confirmed that there is a lack of trust that needs to be addressed and built-up on all levels – project teams, internal organisational teams and between different organisations. Inside some organisations, there is also a lack of trust in the company's commitment to adopt BIM, which needs to be addressed.

Respect

Interviewees recommended that showing respect to team members is important to address resistance and reduce the fear of change. According to participants, it is important to show to team members (less experienced with BIM) that they have knowledge, experience and value to bring. There should be mutual respect within the project team and appreciation for each other's roles. Establishing mutual respect within the wider team helps to create a common language, enabling people to understand more clearly the benefits and processes (F7, F1).

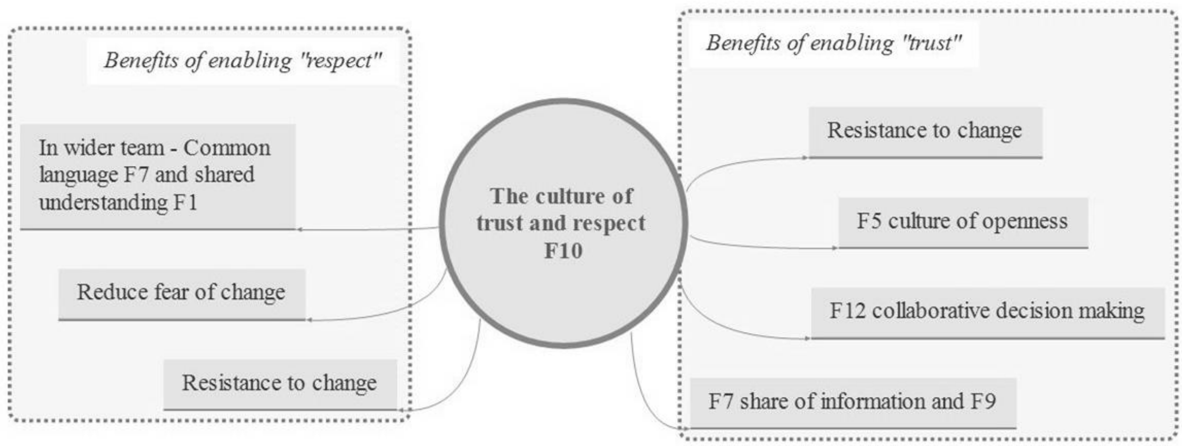

Figure 6.10 Benefits of F10

Mechanisms within the wider project team

Participants recommended collaborative procurement routes to reduce the risk of legal disputes, which enables trust and long-term collaboration in teams and other benefits in Figure 6.11. This is important for the AEC teams as currently:

> *It is difficult to bring people together to discuss errors and at the same time to try to reassure them, that this is not the basis for a legal dispute or a claim* (I4 00:20:34).

Other solutions recommended were isolating disciplines within the model to prevent changes (F9) and clarifying the use of work-in-progress information (F7).

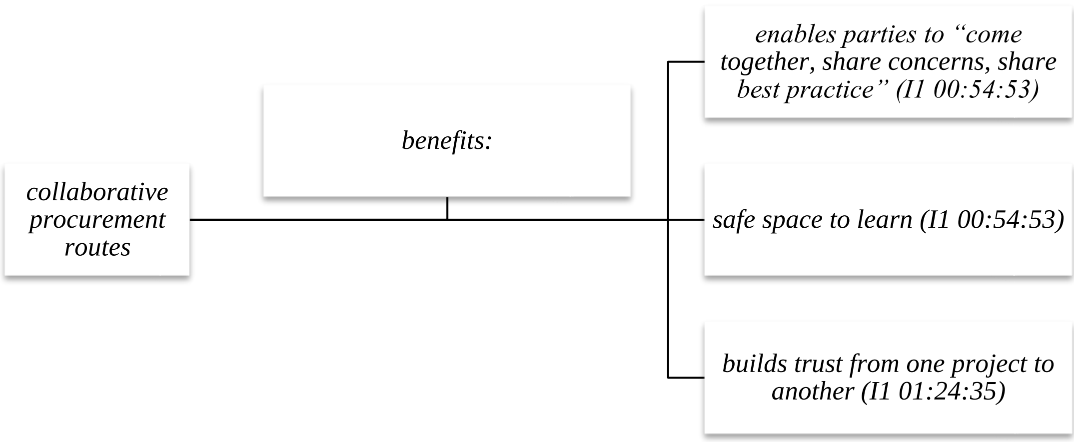

Figure 6.11 Framework procurement to enable trust in BIM teams

To build trust, participants I11 and I1 recommended to have a 'shared learning experience' as a project team – share knowledge about BIM practice and tools within the wider team (F24, F26) (I11, I1). For example, to have:

> *Competitions or learning kick-off of some kind, then you can get to the point where you feel more comfortable working with the rest of the project team* (I1 01:23:20) (F24, F19).

In terms of trust and suppliers, I11 noticed that a potential for a long-term collaboration pushed manufacturers to produce BIM families, improve the quality of models and to be more willing to share design. Other recommendations about the trust and information exchange externally were to use NDA, read-only files and IFC format.

Mechanisms within the project team

Interviewees explained the need for a ‘no-blame culture’ to enable learning and liberate people to raise issues on time (F5). There needs to be an opportunity for people to learn, to develop, to build trust (F3) gradually. It was mentioned that all members need to be valued and people should appreciate each other's views. This can be enabled by knowing about other disciplines and roles.

Interviewees recommended showing examples and case studies to help the team trust the new practice and reduce resistance. Clear and concise communication (F7) and reliable information (F9) also help with reassuring people. Disciplines are working at different speeds and some are only involved later in the project process, which causes a lack of trust. To help the trust participants recommend engaging all roles early and allowing them to contribute (F1, F2, F12, F26). Sharing ‘what did not work’, lessons learnt (F21), is another enabler because:

> *Most people identify with their failures than with successes* (I6 01:18:05).

Trust within the team is also enabled by seeing the commitment and strong leadership from the management (F3). Previously, in other factors, it was also explained that F4 and F5 are enablers of trust, while F12 is an enabler of respect. A summary of enablers discussed in this and previous sections is in Figure 6.12.

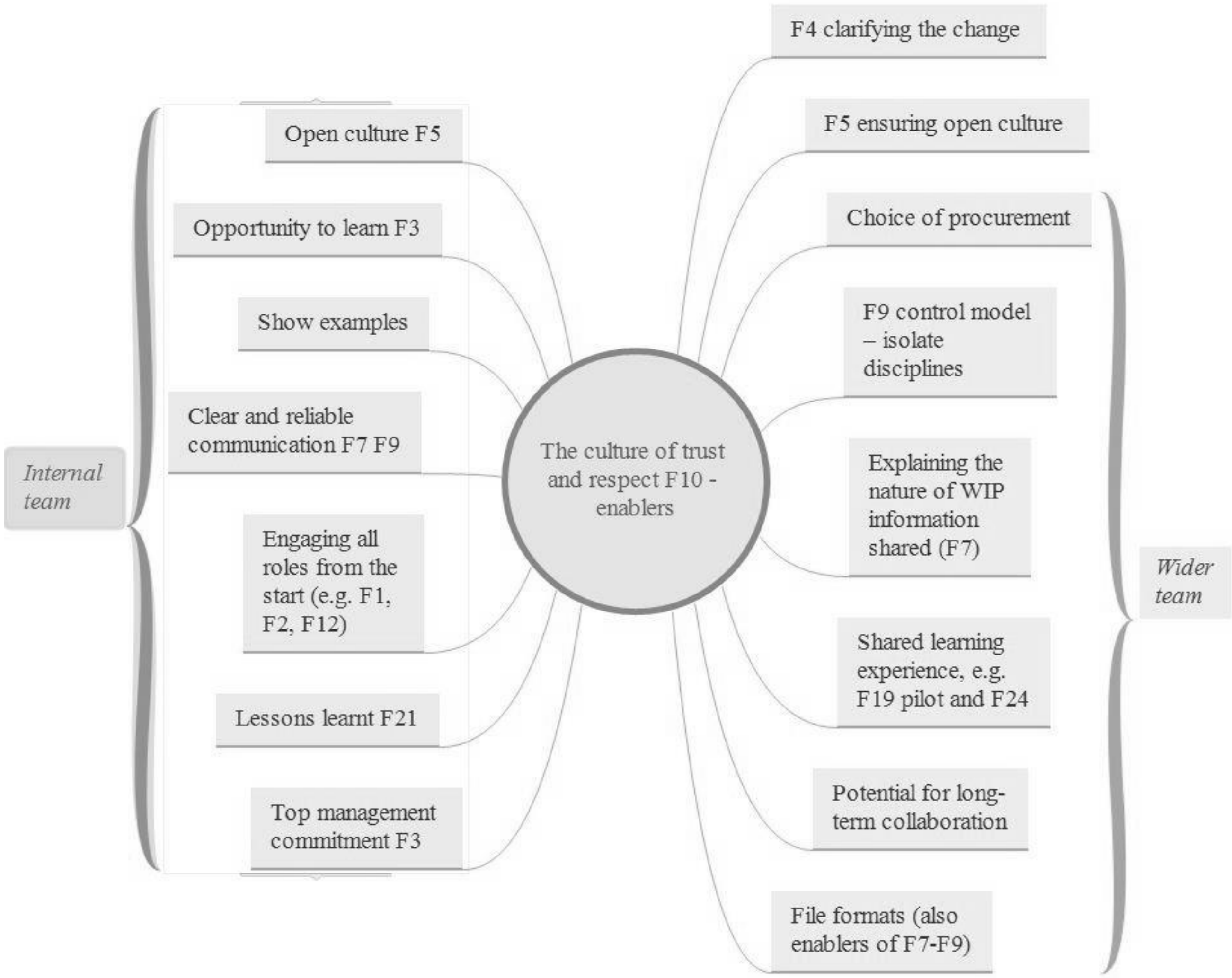

Figure 6.12 Enablers of trust and respect F10

6.12 Factor 11 – Team building – later incorporated within other factors F25 and F26

Table 6.13 does not show many references to F11. Participants who recognised F11 as important were I1, I9 and I17 and a summary is presented in Figure 6.13. These recommendations can stand under new factors F25 and F26, that are more comprehensive (Table 6.29).

Table 6.13 Presence of F11

	F11	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F25	F26
I1	9	2	2	2	0	6	0	4	2	2	2	2	2	0	2	0	0	1	3	0	1	1	3
I2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
I10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	1	0	1	1	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F11	11	2	3	3	0	6	2	4	2	2	2	2	3	0	2	0	0	1	3	0	1	2	4

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F25 - Collaborative team, F26 - Integrated team

Interviewees recommend team building as they recommend procurement strategies that enable long-term collaboration. This was explained in F10. They recognised that a constant change of collaborators and working with different parties on different projects can cause challenges for both construction professions and projects.

In relation to F11 enablers, a few ideas emerged. I1 talked about a wider project team and suggested having a 'shared experience' initiatives, relevant to the project. That could be a shared creation of EIRs, having shared learning sessions, organising pilot projects or competitions. I1 explained that the purpose is to bring people together, help team dynamic, enhance the culture of collaboration and learn about BIM practice. Other ways to support the team building in the wider project team mentioned earlier is the right procurement route, to reduce the fear of legal risks.

I10 discussed the organisational level and did not openly mention 'team-building' as such, however, I10 talked about the creation of BIM working groups. These groups were used to establish BIM strategy, distribute BIM vision and provide the support. I17 talked about an internal project team level. He suggested having key disciplines on the project and ensuring that roles need to provide support to each other.

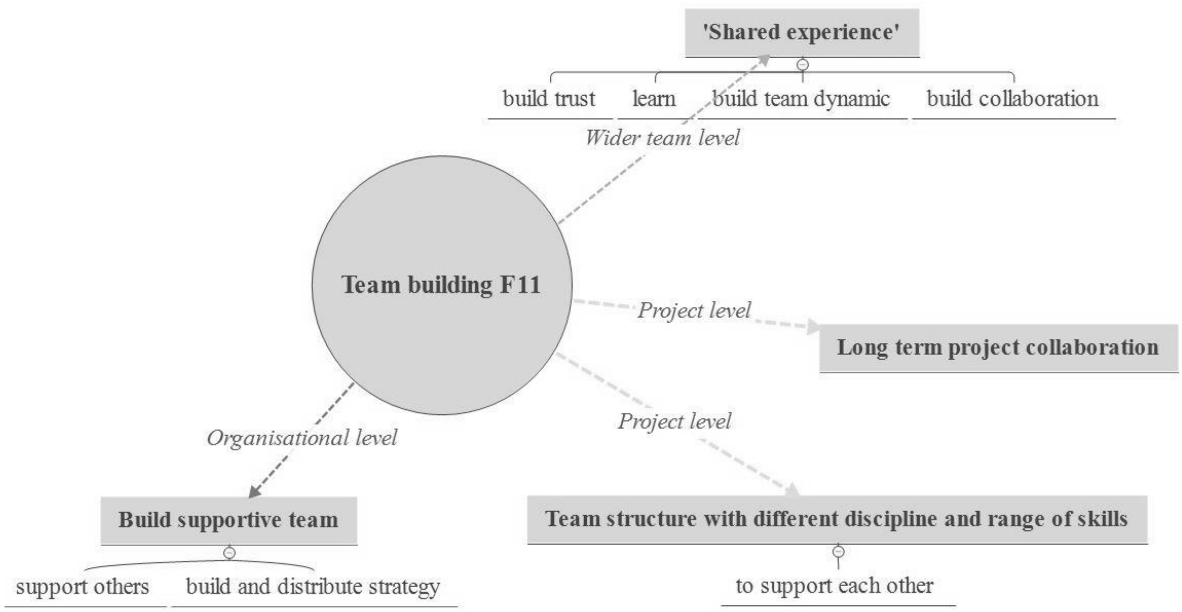

Figure 6.13 References to F11 – incorporated within other factors

6.13 Factor 3 – Establishing top-support and structure

Table 6.14 shows that F3 was one of the most coded factors. Participants explained that to deliver BIM projects, organisations need to grow capabilities, alternatively partner with other parties or pay external parties to deliver BIM aspect of the project. To achieve any of these, there must be management support. Participants added that only the management can define one overarching and sustainable strategy that can efficiently manage resources and benefit the organisation (F1).

Interviewees said that without the management support, BIM adoption is challenging, slow and only some members of the team can benefit. Those trying to implement the change without F3 also mentioned a lack of clarity in the team about the process. Interviewees explained that F3 is essential to clarify what needs to be delivered - explain processes and provide templates and tools. F3 is also enablers of other factors such as education F18 and F19, communication F7, F8, F9 and vision distribution F1.

Table 6.14 Presence of F3

	F3	F1	F2	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	31	10	11	2	13	1	6	5	5	4	2	9	8	1	7	0	5	1	1	0	0
I2	6	1	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
I3	12	3	0	2	1	0	4	0	0	0	0	0	0	2	1	0	1	5	2	0	0
I4	15	3	2	0	1	0	1	0	0	2	0	2	0	0	2	0	0	2	0	0	2
I5	29	3	1	2	3	0	2	4	2	0	0	1	0	0	1	0	0	3	4	0	0
I6	6	2	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0
I7	10	3	1	0	1	0	3	1	2	0	0	0	0	0	0	0	0	1	0	1	1
I8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	3	0
I9	12	0	0	0	0	0	3	5	3	0	0	0	0	0	0	0	0	5	4	0	1
I10	32	9	7	1	8	0	11	6	1	3	0	5	5	0	0	2	4	9	1	2	1
I11	14	5	3	0	0	0	3	2	1	0	0	3	0	0	0	0	1	5	0	1	1
I12	30	5	0	1	4	1	2	1	0	1	0	0	0	1	2	1	3	4	0	1	0
I13	13	2	1	0	3	0	2	2	0	0	0	1	1	1	2	0	0	2	5	0	1
I14	8	2	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	3
I15	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	15	6	0	0	0	0	1	3	3	0	0	1	0	0	0	0	0	2	0	0	0
I17	25	3	3	0	0	1	3	0	3	0	1	0	1	0	0	0	0	9	4	1	0
I18	18	5	0	0	0	0	2	0	1	0	0	1	0	0	0	0	3	1	4	1	3
I19	17	1	2	0	0	0	4	1	1	0	0	0	0	0	0	0	1	1	1	3	1
F3	302	64	32	8	36	3	52	31	23	11	3	24	15	5	18	3	18	51	29	13	14

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

The findings also show that F3:

- Controls the processes,
- Motivates people to learn,
- Enables time to learn and change,
- Enables an open and friendly environment,
- Integrates the team early,
- Provides finance and resources,
- Shows organisational commitment – by providing support and investing time and resources to reach the BIM vision; they added that this reduces the resistance.

Figure 6.14 summarises these findings.

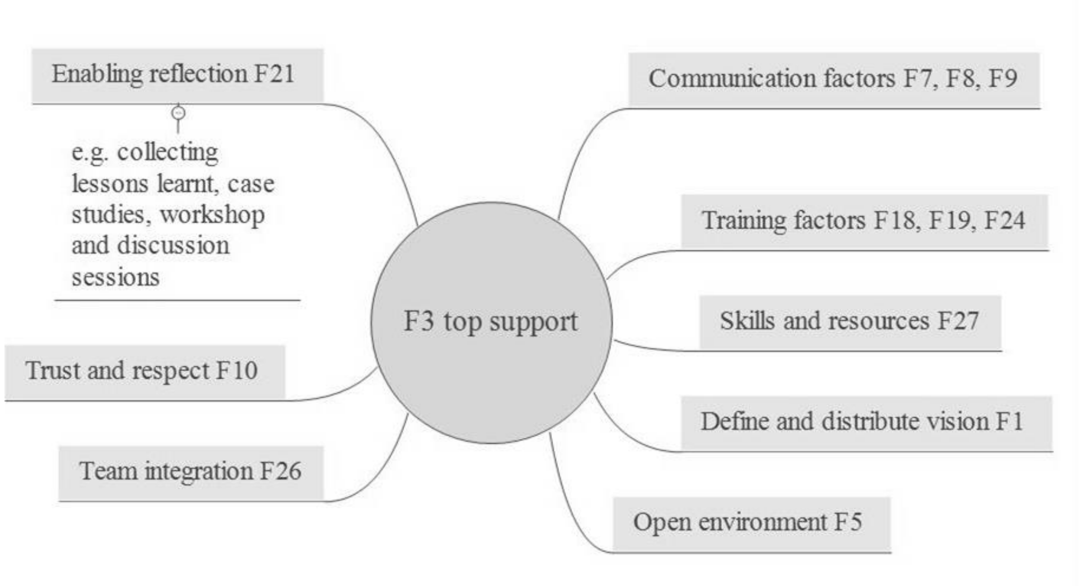

Figure 6.14 Summary of factors that were impacted by top-support F3

Recommendations from the interviews

Across interviews recommendations are similar. Some suggestions covered the project level, while others organisational level. Because principles overlap, they are discussed together.

Establishing standard methods of procedures and control

Several participants explained the importance to establish project procedures in accordance with BIM standards and quality management procedures, within both internal and wider teams. They recommended controlling the process: measuring outcomes and processes through KPIs and other measures. This was discussed in F7 and F9. Interviewees explained that F3 has a role in enforcing this. For example, to establish the data control, it is necessary to provide BIM management, which can only be provided top-down.

Showing commitment by allowing time and providing support

Participants recommended providing enough time and opportunities for people to learn new software and processes. Many participants mentioned pilot projects and learning-by-doing schemes (F19). Other suggestions were: e-learning, guides, an online library with case studies, accreditation schemes, social media or forum support, reliable learning material and training courses. In interview examples, during the learning phase, teams were also given additional management support, someone they could go to and ask for help. It was found that this helps with confidence and fear of change.

Establishing BIM mandate

Interviewees suggested for organisations to incorporate BIM mandate and provide active management and technical support. To implement BIM, interviewees formed BIM groups and engaged HR, IT, legal and other teams (F2). Participants also recommended incorporating new BIM responsibilities into existing roles to enforce BIM mandate. They explained that these initiatives pushed and motivated the team (F20, F15).

Providing the equipment

It was recommended that management needs to provide resources – time, finances and equipment (F27). Interviewees explained that it was challenging to provide the equipment and IT capabilities and this needed to be enabled top-down. It was also recommended for the management to enable access to models and equipment - make resources accessible when people need to apply skills and during the training phase (F8, F18, F19).

Managing motivation

Interviewees explained that other ways to address resistance are financial initiatives, pay rise, cash incentives, rewards, but also by providing a supportive, enjoyable working environment and culture to make people feel comfortable in the team and to motivate them to put an effort. Enabling the culture of trust and respect through the right leadership also helps to create an enjoyable working environment and builds motivation, as discussed in F10. They explained that the culture is mostly set by how projects are set and how clear roles and responsibilities are.

Providing BIM management support

Participants suggested having a BIM manager and coordinator within the team to ensure the reliability of the information and use of the same language throughout the project (F7-F9). BIM management also helps to distribute the vision (F1), as they operate as a link between the organisational and project level. Participants also recommended that all management professionals need to have some knowledge about BIM processes to support the change.

Requirements internally and externally

The management needs to establish requirements. Participants explained that during BIM projects, the lack of clarity about the requirements is one of the main challenges. A common mistake was to provide training without clearly explaining the requirements and deliverables to the whole team. The leading and BIM management need to ensure that requirements are also achieved within the external team, ensure that people in the supply chain have the right competencies and ensure that they are following the requirements.

Interviewees explained that clients also need to provide support. The data shows that clients have a role in:

- Team integration and collaboration in the wider team (F26);
- Providing well-defined requirements (F1);
- Supporting the team by enabling enough time;

Active involvement of the client and timely approval of the design and construction process, also contribute to information sharing process (F7).

6.14 Factor 27 – Providing skills and resources, an extension to factor F3

F27 emerged from the data. The coding started in the first interviews and it was mentioned by all interviewees – Table 6.15. It was decided that this new factor will supplement F3, because 'ensuring skills and resources' is mostly enabled by the management (in Table 6.29). F27 covers the following sub-topics, where some overlap with F3 (Table 6.16, Table 6.15):

- Choice of software to be easy and useful;
- BIM management team and support (discussed in F3);
- Equipment (discussed in F3);
- Establishing minimum knowledge within the team;
- Guidelines and help (discussed in F3);
- People with the initiative (discussed in F19, F15);
- Soft skills (discussed in F5, F10, F25);
- Team set-up;
- Enabling time (discussed in F3).

Underlined points are not discussed within other factors and they are discussed below.

Table 6.15 Presence of F27

	F27	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
I1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I2	4	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
I3	8	0	0	4	0	1	1	1	1	0	0	0	0	0	2	3	0	0	5	0	0	0
I4	16	2	1	1	0	2	0	4	1	1	1	0	0	0	0	0	0	0	2	0	0	1
I5	10	1	0	6	0	1	0	0	1	0	0	0	0	0	0	0	0	0	3	2	0	0
I6	11	3	0	2	0	1	0	5	2	3	0	0	0	1	0	0	0	0	3	0	0	0
I7	5	1	0	3	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
I8	20	0	0	7	0	0	1	2	1	3	0	0	0	0	3	2	0	0	1	5	1	1
I9	14	0	0	8	0	0	0	2	3	3	0	0	0	0	1	0	0	0	4	2	0	1
I10	24	7	5	19	1	5	0	5	6	1	0	0	4	5	1	0	2	3	8	1	0	0
I11	13	2	0	7	0	0	0	4	4	1	0	0	0	0	0	0	0	0	5	0	0	2
I12	16	0	0	6	0	0	0	2	5	0	0	0	0	0	0	0	1	3	1	0	1	1
I13	8	0	1	5	0	2	0	2	1	0	0	0	1	0	1	2	0	0	1	4	0	0
I14	8	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	6	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	2	0	0
I16	5	1	0	4	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	27	5	2	12	0	0	1	1	1	4	0	1	3	1	0	0	0	1	12	3	0	0
I18	7	1	0	5	0	0	0	1	1	2	0	0	0	0	0	0	0	2	2	4	1	2
I19	14	3	2	7	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0
F27	216	28	11	96	1	13	10	33	31	20	4	1	8	7	8	8	3	10	49	24	3	8

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F27 - Supporting skills and resources

Table 6.16 F27 and its sub-codes

	F27	*Software - easy, useful	*BIM management - support	*Equipment	*Establish minimum knowledge	*Guide-lines and help	*People with initiative	*Soft skills
I1	0	0	0	0	0	0	0	0
I2	4	0	0	1	0	0	0	1
I3	8	0	0	1	1	0	0	0
I4	16	2	4	0	1	0	0	4
I5	10	0	3	1	0	0	0	0
I6	11	3	3	2	1	0	0	0
I7	5	0	0	1	1	0	0	0
I8	20	1	7	0	5	0	2	0
I9	14	1	4	4	1	7	0	0
I10	24	1	3	6	2	1	0	0
I11	13	1	4	0	4	5	0	0
I12	16	5	1	4	1	0	0	0
I13	8	0	0	0	1	0	1	1
I14	8	0	0	0	5	0	0	0
I15	6	1	0	2	2	0	3	0
I16	5	0	0	3	1	0	0	0
I17	27	0	4	11	8	2	0	0
I18	7	1	4	0	0	2	0	0
I19	14	1	7	2	5	0	0	0
F27	216	17	44	38	39	17	6	6

Description: F27 - Supporting skills and resources, * are F27 sub-codes

Choice of software

This point emerged from the interviews, being referenced 17 times. Participants explained that working with a slow, complex software solution, without a straightforward access, was challenging their team. Management participants explained that instead of using the model they would find information traditional way as it was less frustrating and:

> *It is easier to do it the old way* (I13 00:27:22)

BIM professionals mostly suggested an integration of new and existing practice to make it simple and easy for people to accept (F17).

Minimum knowledge within the team

Participants recognised the necessity to establish a minimum knowledge about BIM for all members of the internal and wider team. It was recognised in 39 references, in 15 interviews. To enable it they suggested:

- Developing greater understanding within the team, by explaining the purpose of the BIM model and the BIM Level 2 processes (F1, F4);
- Providing ‘viewing’ tools to give more access to BIM (F8);
- Providing the internet connection on-site to access models (F7);
- Providing basic training (F18).

These incentives are mostly established top-down.

Team set-up

The management should enable the right team set-up for the process of BIM adoption. There are 17 references to this from 8 sources. As already discussed in F6, participants explained that the team structure is very important. The management needs to identify and bring key skills and supporting skills. This was achieved by creating skill matrices, assigning the BIM competency to each role and having mentors within the team (also discussed in F3 and F6).

6.15 Factor 14 - Adaptability of the team

F14 was moderately mentioned during the interviews and its codes overlap with F19, F15, F18, F6 and F3 (Table 6.17). F14 investigations show the importance of having an adaptable team and mechanisms to enable that for BIM team development. The data provides insights into some of the key aspects of BIM change, however, most of the points discussed are also coded within other factors; and in Table 6.29 it is merged with factor F6 due to their similarities.

Table 6.17 Presence of F14

	F14	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F15	F16	F17	F18	F19	F20	F21	F24	F25	F26
I1	6	0	1	1	0	1	3	0	1	0	1	0	0	1	2	0	1	0	1	0	0	0	0	0
I2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3	1	0
I3	5	0	0	2	0	0	1	0	1	0	0	0	0	0	1	0	0	2	3	0	0	3	0	0
I4	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
I5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
I8	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0
I9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
I10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
I11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
I12	2	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	2	0	0
I13	4	0	0	1	0	0	0	1	0	0	0	0	0	0	4	0	0	1	4	0	0	1	1	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F14	36	2	1	5	0	2	6	2	3	0	1	0	0	1	9	2	2	7	14	0	0	14	2	0

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F24 - Shared learning, F25 - Collaborative team, F26 - Integrated team

Interview findings are:

- A flexible team with shared responsibilities (F13) is recommended, particularly if there is a lack of needed skills or members are absent. However, interviewees explained that a dual role, such as BIM and another, can be excessive for the person, particularly if the management support is lacking.
- It was found that F19 and F24 help the team adapt more than structured learning F18:

  > *I learned more in office when I played with the model myself and my colleagues helped me obviously* (I2 00:20:37).

  Many other participants mentioned how their self-initiative to learn and shared learning in the team helped the process of adaptation to a new BIM software and practice.
- BIM management participants agreed that principles about BIM technology need to be taught, rather than only specific software, to make people adaptable to other software solutions.
- Participants recommended teams to accept that tools are changing. They explained that tools are constantly updating and in accordance with that, strategies need to be continuously updated. This will also be incorporated within F15.
- Having people with an initiative to learn on their own can enable adaptability when tools change, while having people in the team who do not want to change and adapt causes problems for the whole team. This should be incorporated within the factor F3 – F27 team set-up.
- Another interview recommendation was that adaptability starts once people learn about some of the concepts or some software tools, which can be enabled by training F18 or F19 or F24.

6.16 Factor 15 – Flexibility 2 – openness to new ideas

This factor was moderately mentioned in the interviews. It was recognised in 11 out of 19 interviews by different participants. Summary diagram of enablers and benefits is below in Figure 6.15. The presence is recorded in Table 6.18.

It was found that it is vital to have people in the team who are open to new ways of working. As mentioned in F14, some participants noticed that tools are constantly changing, therefore having a team who is open to learn and open to new ideas can only be helpful in that process. Individuals within the team should become "open-minded" and "make an effort" about the new practice once they are shown benefits (I12 00:35:25). Being open to new ideas and new tools can help to have more effective communication (F7), it can help the development of strategy as a team (F2, F12), enable the experiential learning (F19) and bottom-up implementation.

Mechanisms

In regard to making the team member more open to new ideas (F15), it was discussed:

- Top-management (F3) "could give people a boost" and managers should "stick to" implementing a new policy (I5 00:23:59, I8 00:35:20). This was also explained in F3;
- It was previously mentioned in F3 how BIM mandate could push people towards the change. People might assume that someone else in the team has responsibilities over BIM tasks, which causes issues. Therefore, BIM mandate and responsibilities should be clearly assigned across the team (similar to pressure in F20);
- Another issue is complex software and language – which makes people less open to BIM processes. Therefore, the choice of software is important, as explained in F3-F27;
- Top-management should get the feedback and input from team members to create an environment where the team is open to new ideas (F21, F2, F12, F3); It was also mentioned in F12 that involving people helps to get their buy-in.
- To create ideas, there could be an 'innovation team' in the company (F3);
- F15 is encouraged by shared learning incentives that can be outside their internal team (F24);
- F15 can be enhanced by providing time and space to learn, e.g. attend a workshop (F3);
- Another critical enabler is 'recognising benefits' and informing the team about the change. It was also mentioned in F4 that other than benefits, informing people about the change in general and challenges is motivating (F4).

Table 6.18 Presence of F15 - all primary factors

	F15	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F16	F17	F18	F19	F20	F21
I1	14	6	7	7	3	8	1	6	6	1	3	2	5	4	2	0	4	1	3	1	1
I2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	5	0	0	1	0	3	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1
I4	5	0	1	2	0	3	0	1	0	1	4	0	1	0	0	0	0	1	0	0	2
I5	5	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
I6	2	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	5	1	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0
I8	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
I9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	1	0	1	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	1	0	0
I11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
I12	5	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
I13	6	1	0	2	0	2	1	2	0	0	0	0	0	1	4	0	0	1	4	0	1
I14	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F15	52	11	9	18	3	17	6	14	8	2	11	2	7	6	9	0	4	4	8	2	5

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, * I14 and I15 have non-direct references

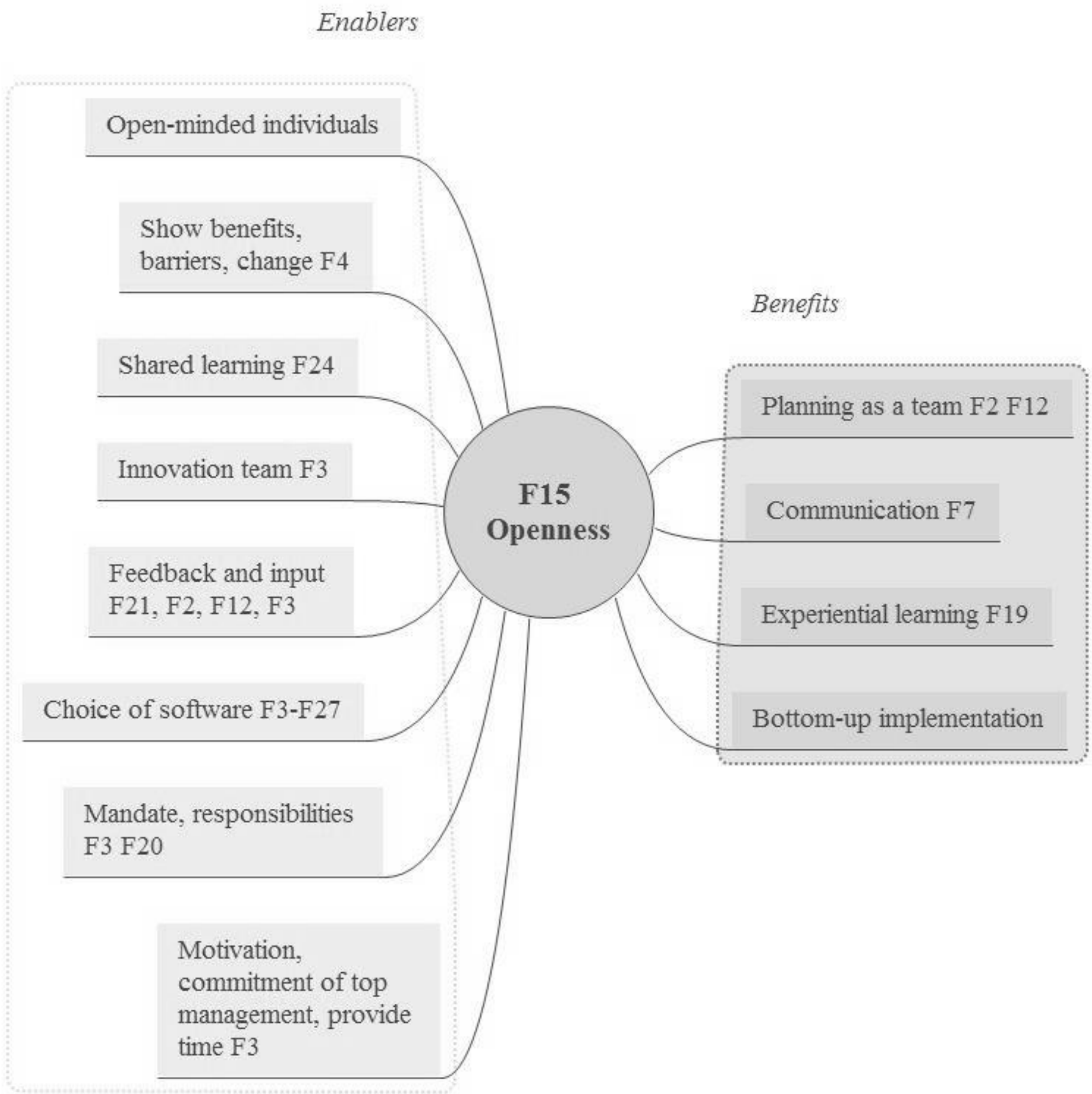

Figure 6.15 Enablers and benefits of F15

6.17 Factor 16 – Flexibility 3 - flexible team, without a fixed structure

This factor will be excluded, as there is not enough evidence to show how it would benefit BIM adoption (Table 6.19**)**. There were only two positive references to this factor by one BIM manager and one senior manager **-** I10 and I12. On the other hand, there were a few contra arguments to show why this factor might be contra-productive in the process of change, arguments by BIM managers **-** I4, I8 and I10.

Table 6.19 Presence of F16

	F16	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F17	F18	F19	F20	F21	F16*
I1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	2	2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
I5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
I9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	2	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0
I13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F16	6	3	1	3	1	0	1	1	0	0	0	0	0	0	2	0	1	0	0	1	0	4

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F16* - opposite or against the factor in a way

External resources

Participants, I10 and I12, described that expanding the team when needed, F16, is potentially useful for BIM team development as there is a need to employ additional resources into the team in the early learning, adoption phase. They agreed that companies should employ new people to support BIM processes. This principle is similar to factor F3 and F27 – on providing additional resources (Table 6.19). However, these participants also agreed that the organisational BIM strategy needs to be developed to rely less on the external resource, due to cost limitations, and this weakens the evidence for F16.

Temporary engagement

Another concept in relation to F16 is to have a flexible team, where people would join the team whenever their involvement is needed. Participants explained that this concept is not beneficial for BIM team development because those 'additional' members might not be able to comprehend the full depth of the project, or the project vision (F1).

One BIM management interviewee described a team where a member had a dual role, one was 'traditional', engineering role and the second was the BIM management role. The interviewee did not find this practice to be effective. He explained that this limits the ability of employee to dedicate enough time to BIM, particularly if the process of BIM team development is not fully supported by the management (F3).

6.18 Factor 17 - BIM implementation to support good existing practice

Most participants, 17 of 19, recognised that new BIM practice should be implemented to support the existing practice within the company. However, not many recognised F17 as a very important factor to BIM team development (Table 6.20). There were also several arguments against.

The first discussion in interviews was about whether the BIM practice should be brought-in as radically new for the company or supportive to the established practice. Findings are that it depends on the team and the organisation. For example, I6 suggested that it is better for the change to be disruptive, because it creates an opportunity for a positive change for some companies, such as consultants and software companies. However, for construction companies, he mentioned that it would need to be supportive due to lack of skills in the AEC industry.

Table 6.20 Presence of F17

	F17	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F18	F19	F20	F21	F17*
I1	18	5	3	5	5	3	1	5	4	2	1	0	2	1	1	4	0	0	0	1	0	0
I2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	8	1	1	0	0	0	0	2	1	2	0	0	1	1	0	0	0	0	0	0	1	1
I5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
I7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
I10	8	1	1	4	0	1	0	3	1	1	0	0	0	0	0	0	0	1	0	0	1	0
I11	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
I12	6	1	0	3	0	0	0	3	1	0	0	0	0	0	1	0	1	0	1	1	0	0
I13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
I16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0
I19	4	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
F17	69	8	6	18	6	4	1	13	8	5	1	0	3	2	2	4	1	3	5	4	5	7

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F17* - opposite or against the factor in a way

Interviewees explained that a supportive integration (F17) of new BIM technology helps with the resistance to change and openness to new ideas (F15) - it can make BIM seem helpful and relevant for the team. Participants also explained that it is more comfortable when a new practice is merged into the existing workflows and policies, such as sustainability or H&S policies that are already well-established and important for teams (Figure 6.16 below). People are also more receptive to change when they think that they are gradually progressing as the team progresses and when they think that the process of change is done “with them” rather than “to them” (I1 01:19:48) (F15). There were also other benefits of having a supportive BIM adoption and they are presented in Figure 6.16. From this evidence, it can be concluded that most rationale behind F17 is to enhance motivation and create an openness to BIM change (F15). It can also be concluded that F17 enables F15.

In addition to the previous evidence, one interviewee also recommend that new BIM practice should be supportive because it is already similar to ways of working in many AEC organisations. Therefore, there is no need to have a ‘radical’ change. He only added that change would need to incorporate some differences in communication strategy, exchange of information, contract documents and rules – which are factors F7, F8, F9, F3 and F27.

Disruptive

There were a few references in interviews to a different perspective, that the change should be disruptive. I4, I6, I7 provided arguments to implement a radical change and I9 and I14 said that the change should only be disruptive. I9 explained that this is an opportunity for the industry to “throw away all bad practice and introduce a good practice” (I9 00:55:04). However, he also added that making the change very radical can “scare people away” and cause a “fear of change” (I9 00:56:35).

disruptive

- Opportunity to achieve greater efficiency and better practice;
- Because it can be easier to start the project with new rules than to correct mistakes later (F9);
- It should be disruptive when existing practices are outdated and innefective.

supportive / non-disruptive

- Slower process is easier for people to understand;
- Resources, cost, infrastructure;
- To support existing, well-established systems - for example support existing communication (F7);
- Less resistance to change and fear of change (F15);
- Allows to gradually modell the information - in BIM projects;
- Because BIM on it's own is not a priorty for clients;
- Helps with lack of commitment;
- Helps with communication (F7).

Figure 6.16 Reasons for supportive and disruptive BIM change – interview findings

Mechanisms

Recommendations in interviews are that F17 can be achieved (Figure 6.17):

- By showing that there are benefits to existing practice;
- By having training that demonstrates that BIM change supports the existing team roles;
- By providing a supportive network, for example, a 'BIM group', to support teams (F3-F27);
- Through pilot projects – such as sections of a project that can become a pilot. Interviewees explained that this helps to understand how BIM practice can help the team and how to practically achieve it (F19). Similarly, smaller jobs allow companies to "push the boundaries" and explore a new practice (I19 00:43:44) (F19);
- By supporting the existing and established communication systems within the wider team (F7), however with new rules to manage the process (F9); also by using the language that other parties in the wider team can easily understand (F7-F8);
- By integrating new BIM tools to enhance the existing communication (F7);
- By integrating new BIM tools to establish better visualisation or to help other existing problems which will make BIM more relevant to the team (F15);
- By choosing tools that can support the existing practice and tools that people prefer to use (F15).

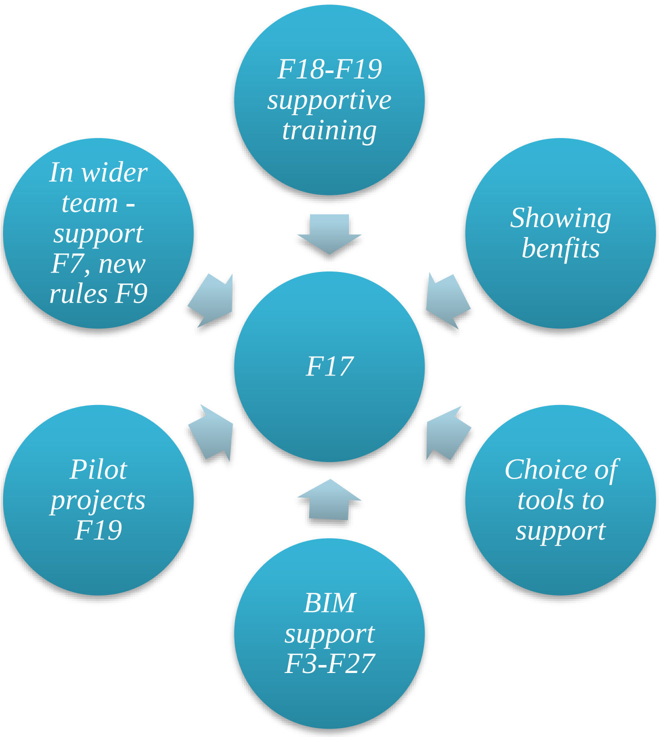

Figure 6.17 Summary of enablers of F17

6.19 Factor 18 – Structured, organised training

Providing an organised training is a critical component to BIM team development and this was recommended by many participants (I3, I4, I7, I9, I10, I11, I17). For example, I17 and I18 said that the training aspect and the acquirement of knowledge are some of the main aspects of BIM change and often a cause of resistance (I18 00:06:02). Another rationale behind F18 is that to show BIM competence, the UK AEC organisations need to demonstrate BIM training hours to stay competitive in tenders (I10 00:33:33).

Table 6.21 Presence of F18

	F18	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F19	F20	F21	F18*
I1	3	0	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0
I2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
I3	11	2	0	5	1	0	0	6	1	0	0	0	0	0	2	0	0	0	1	0	0	0
I4	5	2	1	2	0	0	0	2	0	0	1	0	0	0	0	1	0	0	1	0	2	0
I5	10	2	0	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
I6	8	2	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0
I7	5	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0
I8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I9	10	0	0	5	0	0	0	1	1	0	0	0	0	0	1	0	0	0	4	0	1	1
I10	10	3	3	9	0	1	0	0	2	0	0	0	2	3	1	0	0	1	1	0	0	0
I11	11	2	0	5	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0
I12	8	1	0	4	0	0	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0
I13	4	0	0	2	0	1	0	1	1	0	0	0	0	0	1	1	0	0	2	0	0	0
I14	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	10	0	1	0	0	2	0	1	1	0	0	0	0	0	0	0	0	1	2	0	2	0
I16	3	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	22	4	0	9	0	0	1	1	1	0	0	0	0	0	0	0	0	0	4	0	0	0
I18	9	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0
I19	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F18	136	21	5	51	3	7	2	16	10	1	1	1	2	3	7	4	0	3	28	0	6	1

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F18* - opposite or against F18 in a way

According to participants, structured training is also beneficial for the AEC teams to:

- Demonstrate different ways of using BIM tools,
- Demonstrate how to use tools, in early phase of adoption,
- Demonstrate the application of standards,
- Show that it is not difficult to use the software,
- Show benefits,
- Motivate and engage in the process of BIM change.

According to participants, the training can also help to change perceptions about the new digital way of working and the value of the data.

Participants recognised that in comparison with the experiential learning (F19), the knowledge transfer is quicker and more reliable, because with the experiential learning people might not recognise their errors and might use an unreliable source of information. Management interviewees explained that in their organisations, not everyone is able to learn on their own and that it would be great if there were more training opportunities. They said that organised training can help with the 'lack of clarity' about the project deliverables. Participants also added that F18 can help team collaboration (F25) when training sessions are "shared learning experiences" (I1 01:10:57) and help the commitment towards the BIM change.

Mechanisms

The factor F3 has an important role in managing F18. Interviewees explained that the management support (F3) is mostly required to push the team, facilitate training and make decisions about the type of training that needs to be provided. Organising training also depends on the budget and time that the management can provide. A few participants recognised that the management should make the training compulsory, while others would just appreciate more training opportunities. As a result of the interview data, it can be concluded that participants agreed that there should be some organised training available for the team in combination with other approaches – F19 and F24, as explained below.

Participants recommended that for the internal team, the training should:

- Enable awareness about Level 2 – or BIM level that the project needs to deliver;
- Help everyone in the organisation to have some knowledge about BIM;
- Include sessions on: software tools, standards, use of CDE, communication strategy, exchange of BIM models and the data exchange;
- Explain the type and level of information that needs to be incorporated into the model;
- Explain how to access and interrogate the model.

BIM management professionals recommended engaging the wider team in the learning process. They suggested training initiatives to engage and help the wider team with BIM, not just their internal teams. They explained that they helped clients raise awareness about the BIM project processes and helped them write the project requirements.

To enable training, ‘allowing time’ is a critical idea that emerged from the interview data, as touched upon in Section 6.14 (F3-F27). Management professionals explained that a common practice of having a single, short session is not sufficient to assimilate information. Therefore, interviewees suggest enabling a “dedicated period”, such as a few weeks or a “whole day” (I1). Introducing the training early was also recognised in interviews as essential due to time constraints during project periods.

Interviewees also recommend customising training for the team. They suggest combining different methods of teaching, such as face-to-face with online training, to suit the team. Participants explained that it is vital to:

- Establish what skills are already present in the team and identify skills to be developed; although this step is challenging;
- Organise training in smaller sessions, to respond to specific requirements and needs;
- Involve a mix of stakeholders, such as senior management, learning and development functions, HR and IT roles, when defining the training strategy;
- Obtain the commitment and support from the client, although this is challenging;
- Demonstrate how a specific software can address particular needs and roles in the team.

One of the key findings was that participants agreed that structured learning sessions should be combined with other types of training, such as shared learning and experiential learning (F24, F19). Further findings showed that participants recommended sessions with the “interactive use of software” over standard “presentation” style (e.g. I17 00:33:05) and:

> *Workshop environment is a lot more valuable* (I7 00:28:55, similar I17 00:32:24).

Interviewees explained that workshops encourage question asking, open dialogue and immediate responses. For example, I16 preferred face-to-face workshops more than e-modules because of the opportunity to get feedback and ask questions. Furthermore, participants recommended combining learning styles to address different learning preferences.

Findings emphasise that the training strategy needs to consider how to motivate the team to learn. Participants suggested a positive culture in the company (F5), incentives, a shared team vision (F1) and showing benefits about the BIM practice and specific software. There were other suggestions about:

- Collecting feedback about the training sessions (F21):

  Otherwise, you are just throwing people in a room and you do not know if they have learned anything or if they enjoyed it. I do not know if that counts as much, but if you enjoy it, you take it in and you remember more, which would help (I11 00:18:14).

- Providing additional support, such as guidelines, templates, someone in the team to help, equipment, to help with the lack of clarity and lack of experience (F3). Some people prefer to learn "in their own time, at their own speed", therefore providing guidelines where they can find information is more efficient than having an organised training where people might "feel embarrassed" if they do not understand (I9 00:10:11).
- Having an open culture (F5) in the team, being honest about what can be achieved and what are the challenges (F4).
- The training should be organised so that it can be applied on time during the project, not too late and not too early. Participants recognised that it is challenging to coordinate the training and project tasks, however it is important to do this. BIM managers said that when people cannot use the skills they have just learnt they become frustrated, "you get a resistance to change and a lack of commitment" (I17 01:01:36).

A summary of all mechanisms is presented below in Figure 6.19, while relation to other factors in Figure 6.18.

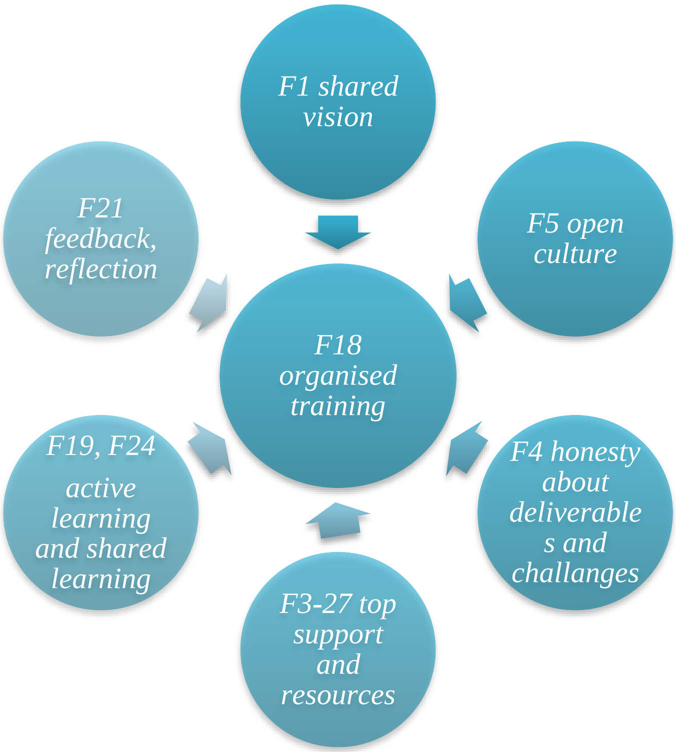

Figure 6.18 Other factors as enablers of F18

Who?

- ***Internal team*** *- minimum awareness level* ***for all members*** *(I9, I11, I13, I15, I19);*
- ***Key members first,*** *then other members of the team, through F24 (I2, I3, I17);*
- ***Wider team*** *- help them also to learn (I3, I5, I11);*
- ***Client*** *- help the client to understand (I3, I1).*

What?

- ***Training about software tools*** *(e.g. I2, I3, I15, I17);*
- ***Training about standards*** *(I3);*
- ***Training about the data sharing*** *(I3, I6);*
- ***Awareness about BIM*** *levels (I5, I10) and minimum knowledge for all team members (I9, I11, I13, I15).*

How?

- ***Allow and dedicte time****: few sessions, few weeks or any other dedicated time (I4, I3, I5, I11, I17), coordinate with project tasks, so that the knowldege can be applied shortly after (I9, I10) and so that the knowledge is established prior tasks (I11);*
- ***Customise for the team*** *(I4, I3, I5, I1, I12, I15, I17, I18, I19). Idenftifying training needs (I7, I6, I9, I10, I12, I19). Collect the feedback about the training sessions (I11) (F21);*
- *Organise* ***flexible*** *ways of learning (I1, I5);*
- *Combine* ***multiple approaches*** *to learning - F18, F19, F24 (I2, I3, I4, I5, I6, I7, I17, I18) and different learning styles (I5, I7, I11)*
- *Provide* ***additional support*** *- guidelines, templates, online library, as explained in F3-27 (I5), face-to-face support as F3-27 (I11, I18);*
- *Create* ***culture of openess F5, F4*** *- honesty about challanges and reqirements (I5)*
- ***Motivate*** *through incentives (I5), through a common vision F1 (I6) and by showing benefits (I12, I15, I18).*
- *Implement* ***the suitable style****: workshops rather than presentations. Provide an opportunity to get and provide feedback (F21) and ask questions (I5, I7, I15, I16, I17).*

Figure 6.19 Summary of mechanisms to achieve F18

6.20 Factor 19 – Experiential learning

The majority of participants recognised that experiential learning is highly valuable for the process of BIM change and highly effective for learning acquisition. There were 13 out of 19 participants who made several specific references to this (Table 6.22). In interviews, it was also recognised as ‘trial-and-error learning’ and ‘learning by doing’. It was coded in connection to other factors, mostly F18, F3, F24, F14, F7 and F8, with a few references ‘against’ (F19*) (Table 6.22).

Table 6.22 Presence of F19

	F19	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F20	F21	F24	F19*
I1	13	2	2	1	0	2	0	3	3	0	0	3	1	2	1	3	0	0	1	2	0	3	0
I2	5	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0
I3	5	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0
I4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
I5	10	1	0	4	0	1	0	0	1	1	0	0	0	0	0	0	0	0	4	0	0	0	0
I6	8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0
I7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	1	1
I8	5	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2	0	3	1
I9	9	0	0	4	0	0	0	1	2	1	0	0	0	0	1	0	0	0	4	0	0	3	0
I10	4	0	1	1	0	0	0	2	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0
I11	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	3	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	1	0	0	2	0
I13	13	0	2	5	0	0	0	1	3	0	0	0	1	0	4	4	0	0	2	0	0	1	0
I14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I15	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0
I16	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	6	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0
I18	7	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	3	3	0	3	2	0
I19	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
F19	113	4	5	29	0	4	0	9	11	4	0	3	3	2	14	8	0	5	28	4	4	19	4

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F24 – Shared learning, F19* - opposite or against F19 in a way

According to the majority, the actual learning acquisition happens during real projects, which is one of the key arguments for F19. Secondly, participants provided a rationale on why external, structured training courses (F18) are not suitable for their AEC teams. For example:

> *I do not think you can sit people in a room for three days and teach them everything they need to know about Revit, BIM, et cetera* (I8 00:22:00).

Interviewees suggested that for F18 to be efficient, for people to be able to ask questions during training sessions, people need to try the software. Thirdly, a few participants, such as I5, I9 and I10, went further and made a connection between F19 and learning as an organisation about BIM. For them, the entire process of defining the BIM implementation strategy and change was a trial-and-error learning process for the whole organisation.

Participants agreed that experiential learning was mostly achieved through:

- Pilot projects – real projects or projects in a simulated environment;
- Workshops – discussions;
- Learning directly on projects.

A Pilot projects

Participants suggested that experiential learning can be achieved by having sessions where team members participate in “something project-related together” such as part of the project, design competitions, a small, personal project or a simulated, “fake project” (I1 00:19:39, similar in interviews I6, I8, I9, I11, I16, I18, I19). In examples BIM consultants provided, the accent was on having a shared, team experience and kick-off initiatives for a project team that brought the team together. Those examples of pilot projects contributed learning and also team collaboration, team building, within the team internally (F25, F11); or when organised with the wider team, pilot projects helped the team integration (F26). Participants said that such initiatives help to create a better team culture (F5); however, this needs to be enabled by the procurement strategy.

Participants also explained that:

- Through a learning exercise on pilot projects, people can visualise the benefits of new practice for their teams specifically. This helps team members change their perceptions;
- Through experiential learning on pilot projects, they can understand how to organise BIM processes for future projects;
- When pilot projects are personally related to learners, they will also feel more motivated;
- Through pilot projects they practised: exchanging the data, communication in the team (F7, F8), use of different software, arranging roles and responsibilities, implementing 4D and 5D dimensions;
- Pilot projects helped them to understand how to add value to the project and how to make the project more efficient.

Interviewees recognised that a pilot can be a real project, or it can be organised in a simulated environment. Interviewees explained that it can be a small-sized real project or a part of it, which reduces risks and enables training of the staff. Within a simulated environment, the project is organised in a safe manner where:

> *People can figure out ways of working, how they will interact with each other, how will the technologies operate as well* (I1 00:22:16).

Participants said that in terms of financial aspects and health and safety, this method is also safer than practising on live projects. However, they explained that limitations are that a simulated project needs support from the management, additional funding, additional time and sometimes attendance outside the office premises.

B Workshops and discussions

Other mechanisms to achieve experiential learning are workshops and discussions, mentioned by five participants. A difference between workshops within F18 and workshops within F19, is that F19 workshops are within the company, solely on project-specific tasks. Unlike experiential training, both F18 and F19 workshops are always 'guided' by a team member.

One of the BIM management consultants explained how on one of the larger projects they involved a wider team in creating EIRs together and they were learning as a team. He explained that this was a 'shared learning experience' for a team and it also enhanced the collaboration (F24, F25). The participant was asked how similar this idea was to 'facilitated discussions' (F21) and the participant confirmed that the concept is similar and explained that those discussions are in essence about defining needs, capabilities and opportunities. Therefore, F21 is one of the enablers of F19 (Figure 6.21).

In examples given by other interviewees, the specialised training was organised in the form of workshops. In those workshops, a few participants had a chance to experiment and work on the project-related tasks. Interviewees mentioned that this initiative was combined with shared learning (F24), where a few members were helping the rest of the team. All participants described this experience as positive and helpful for BIM team development.

C Real project

Learning on real projects was the most discussed method in interviews. Many explained that learning on a live project enabled their teams to learn. I2 explained that a structured, external training was useful to achieve an initial understanding, however, he found that 'learning by doing' was more beneficial in terms of overall team development and to acquire a discipline-specific knowledge.

Many other participants also discussed the advantages of learning on real projects. Participants explained that in comparison with presentation-style training, the knowledge acquired through experience on real projects lasts longer and it gives people more confidence. Participants said that in comparison with pilot projects, the 'nature of the task' makes the live projects more suitable learning environments for BIM team development. I8 explained:

> *I think the software we use is a bit too in-depth for them to just, sort of play around with and pick up. You need to be doing something; you need to have a task, something obvious, something tangible and that is why I think the live project approach does actually work* (I8 00:26:30).

It was found that eight participants, who came from different disciplines, learnt on real projects. Interviewees described this learning as "experimenting", "learning on their own", "practice on daily tasks" and "hit and miss" (I3 00:14:23, I13 00:06:29).

To enable learning on live projects, interviewees recommended the following:

- The management needs to support the process (F3) (Figure 6.21);
- The management should encourage people to use the software.
- The management should allow reasonable cost and time to integrate the learning process into the daily tasks, as mentioned in F3-F27.
- The learning 'allowance' needs to be incorporated within the project programme to allow enough time to learn. However, it would be difficult to enable this on projects with a higher urgency, which explains why participants who were in the process of learning on the project with shorter deadlines and pressure found the process challenging and found more resistance to change within their teams (as found also in the case study).

Seven participants agreed that having more experienced staff physically present within the team and available is highly beneficial for BIM team development (F3-F27). Having one-to-one support to enable experiential learning was also found to be the most efficient technique in terms of BIM knowledge development (F24):

> *If you are doing it to a group, people just sort of lose interest. Whereas if you have got them one-to-one, you could engage with them and actually, get them physically doing stuff on a live project. It did take a lot of time, but I found it to be the most effective way because I would only have to do it on one project with each guy who was learning* (I8 00:22:00).

One of the participants added that when the team is larger, to achieve one-to-one support, a shared learning system (F24) can help, where colleagues are encouraged to help one another and learn as a team. This is discussed further within F24.

Interviewees mentioned that there should also be someone in the team to control the process (F3-27, F9) and the process needs to be regularly checked and modified to fit the team's needs (F3-27). Interviewees explained that this is particularly important because learning on the real project carries the most risk in terms of errors (Table 6.23). Interviewees also discussed an idea of incorporating additional resources, for example, online platforms to support experiential learning (F3-27). All these levels of support are explained within the F3-27 and F9 as a 'BIM management support'.

According to these findings, a summary of those methods and a comparison of methods in terms of risk, cost, time and knowledge acquisition is presented below in Table 6.23. This table can help organisations and managers decide a method to suit their goals.

Table 6.23 Comparison between methods - a decision-making tool table

	Risk	Cost	Time	Knowledge acquisition
Pilot	No/less risk	Costly	Requires additional time. Can be part of the live project practice.	Medium
Real project	High risk	No additional cost. Costly if there are errors	Additional time needs to be allocated within standard project practice. Easier to implement in the design stage.	Highest, Learning “at our own pace”
Workshops and discussions – part of real projects	No risk	Lower cost. There is a cost if additional parties are employed to help	Additional sessions within or out of the existing practice.	Low
Structured training	No risk	Costly	Additional sessions within or out of the existing practice.	Low

Interview findings regarding the comparison between experiential learning with structured learning

Different participants agreed that the main issue with the trial-and-error learning are potential mistakes (Table 6.23). They explained that this can be particularly challenging on larger projects “because buildings are big projects and they cost a lot of money, and once you make a mistake that is big, the end result will be quite big. That is the risk.” (I6 00:35:40). However, participants explained that this can be enabled by the right procurement strategy and the client’s support.

Interviewees explained that another issue with F19 is the lack of time. Learning on real projects allowed interviewees and their teams to learn at their own pace. However, the majority agreed that this took more time overall (Table 6.23).

However, interviewees explained that there are many reasons why F19 is valuable. Different participants recognised that trial projects provide opportunities to learn and to understand what works. To reiterate, a few participants said that ‘learning by doing’ is “inevitable” to acquire learning (I6 00:31:40, similar I9, I13). Many also explained that knowledge acquisition is greater than during the organised training (F18). One of the participants explained this by saying:

> *It is not until you have to actually do it, sort of ‘concentrate’ if you like* (I9 00:30:28).

This evidence shows why F19 is essential for BIM team development, despite its limitations.

Many different participants suggested combining F18 and F19. Some suggested to begin with a general introduction, such as a presentation or basic external training, followed-by experiential learning. They mentioned that the structured, external training and presentations, in this case, have a more informative and clarifying role than a training role, as real learning occurs in the later stage through experience and by having customised training sessions. As explained in F18, F19 needs to support F18; what is learnt should be practised on real projects (Figure 6.20). Interviewees explained that not everyone has the "intuition" to learn on their own with little or no support (I13 00:07:45), which is a further rationale for F19 to be integrated with F18. Following Figures 6.20 and 6.21 summarise the conclusions from this section.

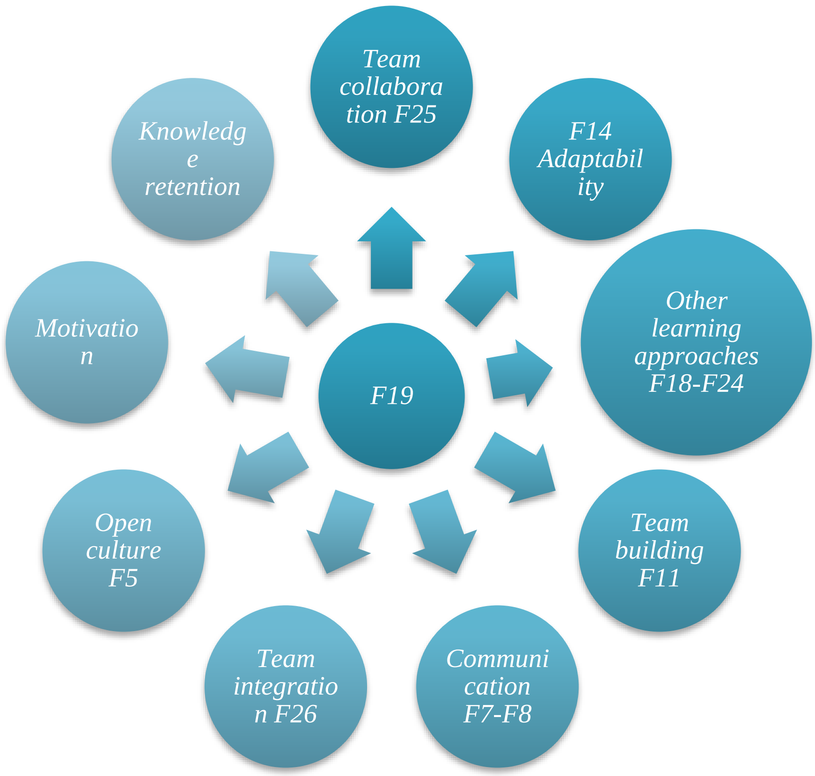

Figure 6.20 F19 can positively influence

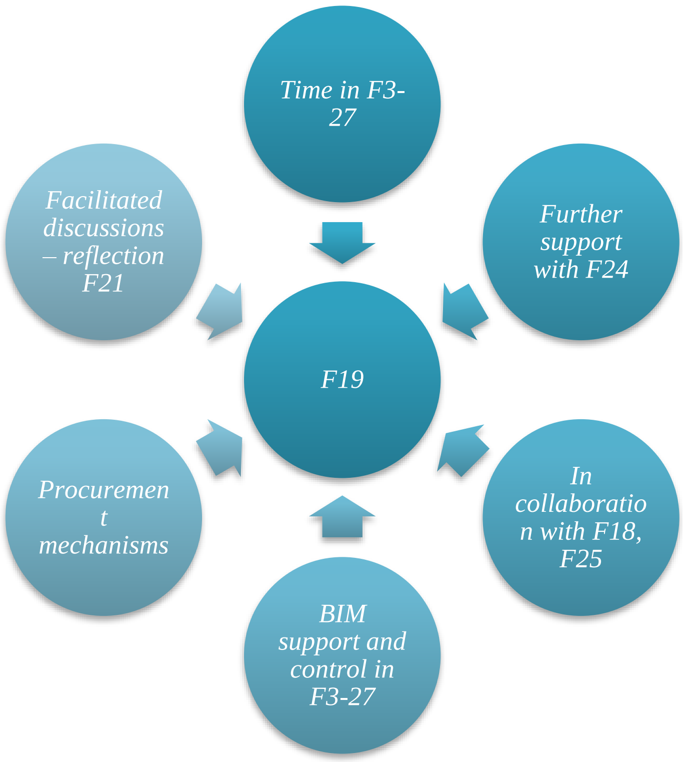

Figure 6.21 Enablers of F19 experiential learning

6.21 Factor 20 – Creative pressure

This factor was not mentioned and coded as many times as other factors (Table 6.24). It was coded in 13 out of 19 interviews, but with a lower number of codes. There are 42 codes, while for example, F5 'Ensuring an open culture' has 105. Its principles were found to be important, but they were similar to other factors, particularly F3. Table 6.24 below also shows a potential relation with F1, F3, F7, F17 and F19.

Table 6.24 Presence of F20

	F20	F20*	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F21
I1	5	0	2	1	0	1	0	0	2	2	0	0	0	0	1	0	1	0	1	0	2	0
I2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
I7	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	13	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0
I9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I10	4	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I11	4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
I13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	3	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
I19	4	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F20	42	1	6	1	13	1	1	0	6	3	0	0	0	0	1	0	2	1	4	0	4	1

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F20* - opposite code

The main purpose of F20 is to motivate people to accept the change and provide a healthy pressure which will make the team engage with BIM adoption. A few principles coded within F20 were already discussed within F3 as 'BIM mandate'. This was mostly about having BIM mandate within the organisation, incorporating BIM roles within the existing roles, to ensure commitment and motivate, all discussed within F3.

The first level of ‘pressure’ interviewees recognised is the Government mandate. Interviewees explained that this impacts organisations as a whole, impacts teams internally and motivates people within the team, as they acknowledge that adopting BIM “widens the net of the projects” they can do and enables companies to be leaders in the industry (I8 00:10:43, similar I4, I10). Strategic BIM management professionals also suggested a ‘carrot and stick’ approach, to help with the lack of commitment, to stop people from avoiding issues and avoiding responsibilities. To use it as a form of encouragement, interviewees suggested educating people about the mandate, showing that BIM is useful**,** that it will not “go away” and explaining “why” (I8 00:47:01, similar I18, I1). Interviewees said that it needs to be explained that they need to adopt it as a team, to help reduce the resistance and enhance motivation.

Mechanisms - deadlines and education

As previously mentioned in F1 and F18 (Sections 6.1 and 6.19), participants recommended educating and informing the entire team about the mandate, through leadership, training and project team vision. Participants also suggested to introduce deadlines as a project pressure to enable learning:

> *I8: If you get someone work to a deadline, they will learn a lot quicker…If you say, “I need you to do this and you have a month to do it”, after that nothing happens… Whereas if you say, “We have got two weeks to do this, then the director is going to come down and will want to know why” you will find that the people learn a lot quicker.*
>
> *Interviewer: So, the pressure is useful?*
>
> *I8: Yes. It focuses the mind a bit* (I8 00:26:14).

In F19 in Section 6.20, it was mentioned that a similar pressure helps learning to be more effective on real projects. One strategic BIM manager made a comment which explained why this type of pressure is suitable when implementing and learning BIM type of software, the software is:

> *A bit too in-depth for them to just sort of play around with and pick up. You need to be doing something, you need to have a task, something obvious, something tangible* (I8 00:26:30).

This highlights the impact of pressure and how learning can be achieved with the help of live projects and targets.

Other mechanisms

Participants explained that a disruptive change can be beneficial to the team to enhance creativity and innovation. This was discussed in Section 6.18. However, participants explained that the ability to do that depends on the member of the team and type of the projects they are working on (I6 01:06:30).

Participants explained that one of the main ‘pressure’ mechanisms was BIM certification process. According to I11, this helped their construction and design team to achieve BIM capabilities. He said that deadlines drove the team to achieve the competencies and that the initiative was:

> *A good kick, to get everyone into a good working state* (I11 00:11:21).

Another F20 initiative found in interviews was related to F7 communication factor. There was a suggestion that people need to be pushed to exchange the information during meetings actively and for that, a senior manager mentioned an initiative where each party would need to bring three topics to the meeting. This was already highlighted in F7 and F5.

Challenges and summary

With regards to challenges, I17 explained that a ‘pressure’ cannot benefit without the supportive structure and infrastructure, as per F3-F27 (Section 6.13-6.14). Participants further mentioned that a ‘pressure’ or a ‘mandate’ also needs to incorporate clarifications on why the team is adopting BIM – F1 (Section 6.1). Participants added that if management fails to explain benefits, the mandate would not be successful. The data findings about explaining the benefits are also part of factors F1, F15 and F17.

Overall, to achieve F20 interviewees suggest:

- Leaders should explain the mandate to people and ensure that requirements are part of their roles, as highlighted within F3 and F13 (Sections 6.13 and 6.4);
- Educating people about the mandate through F1 and F18,
- Establishing deadlines to define mandate requirements;
- Having to learn through real or pilot projects with clear targets (F19).

The final summary of enablers and explanation of how this factor helps is presented in diagrams below in Figure 6.22 and Figure 6.23.

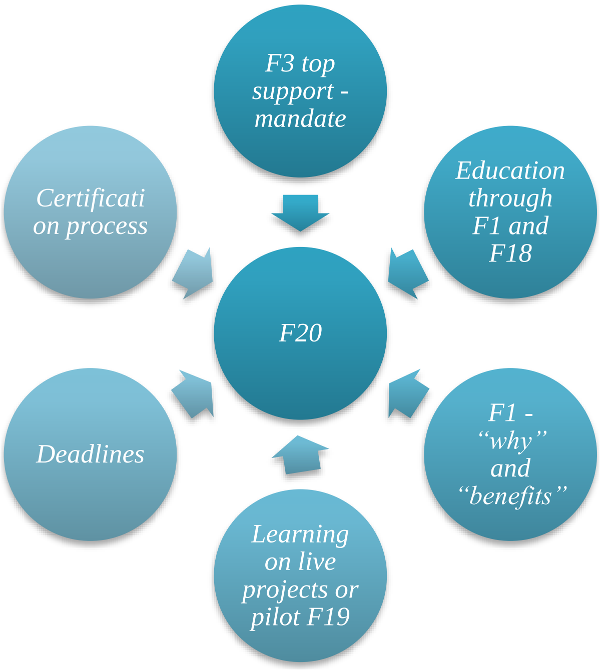

Figure 6.22. Enablers of F20

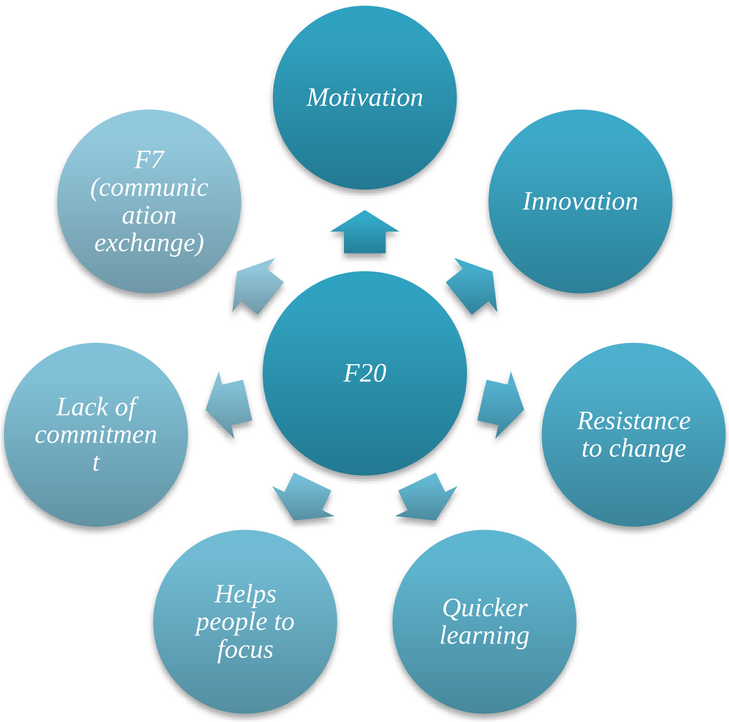

Figure 6.23. F20 helps with following

6.22 Factor 21 – Opportunity for reflection

The concept behind F21 is in providing a space and time where a team could meet to discuss how to achieve BIM team development and reflect on the existing BIM practice. Table 6.25 shows the presence of F21. Factors F2 ‘planning as a team’, F3 ‘top-support’, F5 ‘open culture’ and F7 ‘communication, information exchange’, were often mentioned together with F21 (Table 6.25).

Table 6.25 Presence of F21

	F21	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
I1	6	0	0	0	0	1	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0
I2	2	0	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
I3	2	0	0	0	0	2	0	2	0	0	1	0	0	1	0	1	0	0	0	0	0
I4	5	2	3	2	0	1	0	2	0	1	2	0	1	1	0	2	0	1	2	0	0
I5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	4	0	2	0	0	1	0	3	2	0	1	0	0	0	0	0	0	0	0	0	0
I7	8	1	2	1	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
I8	2	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
I9	7	0	0	1	0	1	0	3	1	0	0	0	1	1	0	0	0	0	1	0	0
I10	7	0	2	1	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	0	0
I11	4	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	0	0
I12	6	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
I13	3	3	0	1	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
I14	4	1	1	3	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
I15	5	0	0	0	0	5	0	5	2	0	0	0	0	0	0	0	0	0	2	1	0
I16	5	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	7	0	6	0	0	6	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
I18	9	0	0	3	0	3	0	4	0	0	0	0	0	0	0	0	0	3	0	3	1
I19	5	1	1	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0
F21	94	11	20	14	1	26	0	46	9	1	5	1	5	4	0	6	0	5	6	4	1

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection

In the analysis so far, F21 was found to be an enabler:

- In F5 as ‘discussions/ lessons learnt/ workshops’;
- In F7 as ‘departmental meetings every two months to suggest what can be improved which will enable people to share opinions, provide feedback and discuss lessons learnt’;
- In F10 as ‘sharing ‘what did not work’ and ‘lessons learnt’;
- In F15 as ‘top management should get the feedback and input’;
- In F19 as ‘discussions would be in essence about defining needs, capabilities and possibilities’, and as ‘facilitated discussions’.

These findings confirm the importance of this factor. Although commonly mentioned as an enabler or a mechanism, this factor can stand on its own to emphasise the importance of reflective practice. One of the participants, BIM manager, who discussed this the most, explained that gathering the team, discussing what needs to be achieved, what are the solutions, discussing the progress and discussing the processes and practice, not just the software outputs, are all part of good management practice. Other interviewees added that reflecting on performance, discussing, sharing, being open and honest about practice helps to motivate people. Interviewees explained that reflecting on how a new practice helped the team, helps to appreciate the change, the time and the effort the team put in:

> *If it had not been for BIM, the first time we would have found these problems would be when we are putting it out there* (I12 00:09:00).

Interviewees explained that reflecting and lessons learnt also help to standardise and systematise the knowledge and transfer the knowledge from one project to another (Figure 6.24). F21 can also be an effective tool for training (F18) and social learning (F24), interviewees explained.

Participants explained that as such discussions involve more people than usual, F21 helps to find more effective solutions to problems. This was emphasised within F2, F12 and F1, where it was suggested to have greater involvement of team members, for example, during the decision-making process (F12). On the other hand, participants discussed the number of people to be involved, with the majority suggesting engaging key or relevant parties only and some suggesting organising thematic meetings for specific disciplines rather than everyone. In contrast, others explained that it would be helpful to bring everyone around the table after the project to discuss what worked and what did not work.

Figure 6.24 F21 can help with following factors and aspects of BIM change

Mechanisms

Main ideas about achieving F21 were presented below in Figure 6.25. Many participants suggested the idea of having early discussions, brainstorming sessions, to decide how to achieve the project requirements and what rules and procedures to follow. I10 and I19 suggested workshops for key members to discuss “How should we do it? How should we exploit it? How are we actually going to deliver it and who needs to be involved?” (I10 00:51:30, similar in I19). I19 suggested that everyone in the team can help to develop the vision (F1) by exchanging views, expectations and solutions:

> *At the start the projects, the whole team should get together and have a bit of brainstorming session and make sure that the model does everything it needs to* (I19 00:42:25).

This was already mentioned in F1-F2, where it was explained that such initiative helps to manage expectations, therefore also helps motivation.

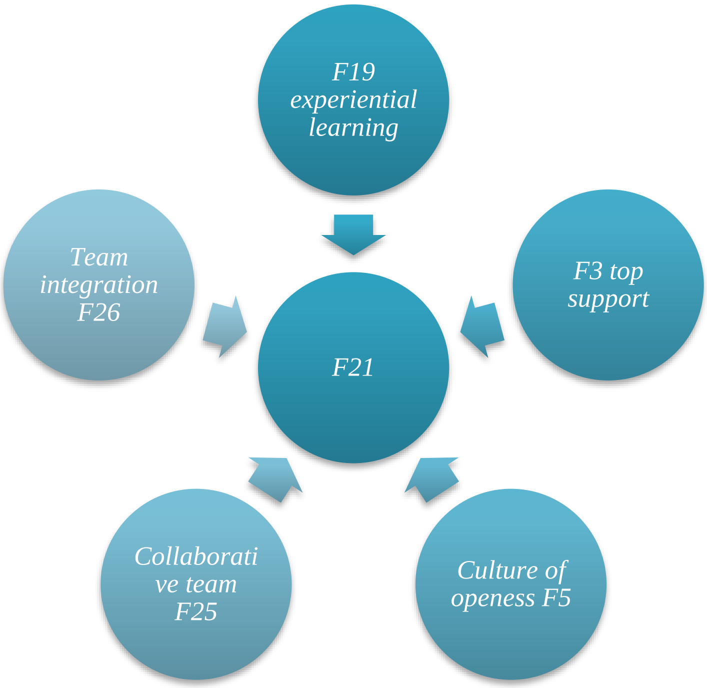

Figure 6.25 Enablers of F21

On a project team and organisational team level, most participants found it beneficial to meet and discuss:

- Concerns and challenges;
- To ask questions;
- To provide feedback to management;
- Gather ideas;
- Show and discuss the progress and check what needs to be achieved;
- To see "how can we add more value?" through new BIM practice (I18 00:11:09, F19);
- To suggest what can be improved;
- To see what is happening with a BIM strategy;
- To see "what is good and bad about BIM" (I17 00:41:54);
- To reflect on the project as a team (F24).

Enhanced communication within the internal and wider team

The implementation of BIM practice enhanced weekly meetings and discussions about processes, project and models, as explained by one of the engineers and BIM pioneers (I4). A few also suggested brainstorming ideas with the wider team, as an enhancer of communication (F7). Participants explained that currently there is not enough information exchange with external parties (F7, F26), as per the case study findings. Therefore, senior management participants suggested greater team integration, more openness and more discussions about the progress with the wider team (F26). One of the BIM consultants and strategic managers suggested sharing good practice and challenges with a wider team; while other BIM management professionals recommended similar forms of opportunities for reflection (F21), such as workshops and training sessions, with the wider organisational team.

Lessons learned

Participants emphasised the value of understanding mistakes, learning from them and discussing what worked after the project completion, many suggesting 'lessons learned' meetings. For example, I16 said that it would be good to have an overview of the processes and get the feedback. I12 and I19 suggested that it would be useful to discuss potential improvements for future practice. 'Lessons learnt' were also recognised as valuable to gather the knowledge to help future projects by two other BIM management professionals. This was also said to be helpful to support the culture of openness (F5) and trust (F10) and help with the clarity (F1, F4).

Open meetings and facilitated discussions

When asked about the idea of 'open meetings', many interviewees agreed that the idea is useful. For example, I4 explained about open meetings:

> *That is all part of the learning environment. It is essential to BIM. So, everyone's input is valuable... Any ideas are perfectly valid* (I4 00:42:26).

Interviewees mostly confirmed that having open meetings to brainstorm what has been achieved and what can be improved is a useful practice. For example, one of the BIM managers added that such meetings could create a working experience for people "more fun" (I6 00:49:24). It was agreed that brainstorming can help the process of BIM adoption, because people will have a more interesting experience.

In terms of challenges, interviewees stated:

- It might be difficult to organise such meetings in later stages of the project, as one senior manager found;
- Having open meetings could be challenging because people have different understandings, different issues and it would be better to have more focused meetings - with certain disciplines, therefore, they might not be open to everyone;
- There needs to be a collaborative structure to support that practice (F25) and a culture of openness (F5), as BIM team development managers explained.

In accordance with Objective 3, this study tests how useful participants perceive the idea of having 'facilitated discussions' as a mechanism to enable BIM team development. These discussions would be a mechanism to achieve F21. The practice of 'facilitated discussions' was recommended explicitly in interviews I9, I4 and I10, to establish requirements and enhance skills in internal and the wider team.

It was mentioned that facilitated discussions can address the challenge of having unfocused sessions, typical for open meetings, by ensuring that:

> *People that do go are actually involved in the BIM process and know what they are trying to achieve* (I16 00:38:57).

Facilitated discussions, unlike open meeting, have a facilitator who controls the conversation and makes sure that there are relevant key parties.

Limitations for the use of F21

Interviews explained that sometimes it is better to have a simple conversation individually, face-to-face because people have more confidence to share what they think this way, rather than to raise their hands. Another issue mentioned is not having an open culture in the AEC teams, which is needed for F21 to work. Further, some mentioned that there is no need to have a meeting "to raise suggestion" (I17 00:42:43); instead, it is enough to simply talk to people daily, especially if they are physically in the same location and the team is not large. Alternatively, they could have a dedicated, casual time to socialise and exchange the information, other senior manager suggested.

Participants also recognised time and resource limitations with F21. Some mentioned that due to time constraints, there were no 'lessons learnt' and they only had discussions or brainstorming meetings early on the project (F3). Participants suggested that it is vital to have key people to attend the meetings and some suggested a need to have pressure from the management for people to contribute:

> *You would have to schedule a call, Skype, whatever, video conferencing facility, have key stakeholders there but make them bring information to the meeting* (I18 00:22:53).

Furthermore, to organise learning sessions where people would also have the opportunity to brainstorm ideas, there is a need to have a top-support (F3, Figure 6.25), BIM consultants explained.

Summary

Interviewees confirmed that the idea of having workshops is useful, to provide a platform for people to ask questions, provide suggestions or comment, not only listen. It was agreed that having workshops enables brainstorming ideas as a team and helps knowledge management within the project, organisation or even a wider team. The majority of interviewees are open to the idea of having open meetings; however, not everyone supports the idea of having the meetings fully open for everyone within the team. Most participants supported having brainstorming sessions within the internal team and a few also recommended including external parties.

According to participants, there is an issue of not transferring the knowledge from one project to another and not understanding the implications of design and construction decisions. Interviewees explained that knowledge transfer is challenging for new practice or technology such as BIM. Using the information gathered, F21 can address the knowledge transfer with initiatives such as 'lessons learned' or discussions about what was planned, expected and what was achieved. This will be discussed in Section 7.4.2.

6.23 Factor 24 - Shared experience and shared learning

As explained in Chapter 4, Framework Analysis allows for themes to also emerge from the data and as a result, new factors F24, F25 and F26 are discussed in this and following sections. F24 emerged from the first interview; therefore, all interviews were checked for F24 codes. The presence of F24 and its relations to other factors are presented below in Table 6.26. It is mostly related to F19, F18, F3 and F7. There are some relations with F14 and F8 and less with other factors.

In the analysis so far, F24 has been mentioned as:

- As an enabler of F14 ‘Adaptability of the team’: ‘F24, with F19, helped teams to adapt, and more than structured learning F18 to achieve adaptability’;
- Useful to combine with F18 (Figure 6.18);
- Useful to combine with F19 (Figure 6.21).

Table 6.26 Presence of F24

	F24	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F25	F26
I1	6	1	1	2	0	2	0	2	1	0	2	3	1	0	0	2	0	0	1	3	1	0	2	4
I2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	2	0	0	1	0
I3	2	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	4	0	0	0	0
I4	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
I5	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0
I6	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0
I7	3	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	1	0	0	0	0
I8	6	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	3	1	0	0	0
I9	5	0	0	3	0	0	0	0	2	0	0	0	0	0	1	0	0	0	2	3	0	1	0	0
I10	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
I11	9	1	0	3	0	0	0	2	3	0	0	0	0	0	0	0	0	0	3	0	0	2	0	7
I12	8	2	0	1	1	1	0	4	3	0	0	0	0	0	2	0	0	1	0	2	0	2	0	0
I13	3	0	1	1	0	1	0	2	0	0	0	0	1	0	1	1	0	0	1	1	0	0	2	0
I14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I15	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
I18	6	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	1	1	2	0	2	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F24	62	6	3	17	1	6	0	14	10	1	2	3	2	0	14	4	0	2	16	27	2	8	5	11

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F24 - Shared learning, F25 – Collaborative team, F26 – Integrated team.

Participants explained that shared learning is important as:

- It is a recommended way of learning BIM practice;
- It brings the team together, therefore helps collaboration (F25);
- Enhances trust within the wider team (F10);
- It is cost and time effective;
- Having someone within the team increases confidence;
- Peer support provides control.

It was mentioned that 'team learning experience' can also be a platform for the team to achieve other factors such as planning as a team (I6 00:15:57, F2). The same participant said that their team went through a learning process "of identifying how are we going to do" the process of BIM adoption (I6 00:15:57). A similar suggestion was made by another BIM manager, I1.

The data shows that F24 could also help the culture of trust, respect, understanding each other's role (F10). One of the participants explained how important it is for disciplines to have knowledge about other roles. He explained that social learning (F24) can help F10 because during shared learning practice and collaborative practice, people exchange information about their needs in relation to BIM team development:

> *The technicians need to know what the engineers are talking about and the engineers need to know the limitations of the software and also need to know what is needed for BIM as well…* (I8 00:41:34).

In examples, interviewees provided the practice of shared learning was also a collaborative experience to support BIM adoption. Many participants also explained that true learning happened when they were learning on their own with someone on the team. This was part of the previous factors F19, F8 'access to information' and F3-27 'top-support'.

Mechanisms

Interviewees recognised that a shared learning experience can be achieved through short-term or long-term initiatives. Long-term initiatives can be enabled by partnering agreements, where parties collaborate on several projects. Participants said that an integrated team provides a platform for continuous learning, where lessons learned are shared from one project to another (F26). Another participant explained how they were willing to share the knowledge and educate parties they worked with on a project:

> *Because there is no point having one person or one company in a project that does not know what they are doing* (I11 00:06:35).

Participants explained that the challenge in the AEC industry is that people are afraid to share information and knowledge because of issues such as "legal sides of liability and insurance" (I11 00:07:05). However, it was said that this could be addressed by contract mechanisms or previously mentioned partnering agreements.

Interviewees recommended to achieve learning by having one-to-one support in teams and to have people learn from each other and as a team. In examples interviewees provided, learning was achieved on live or pilot projects, as suggested in F19. I8 explained:

> *If you are doing it to a group, people just sort of lose interest. Whereas if you have got them one-to-one, you could engage with them and get them physically doing stuff on a live project. It did take a lot of time, but I found it to be the most effective way because I would only have to do it on one project with each guy who was learning* (I8 00:22:00).

Interviewees recommended that learning can also be achieved by sending a few members to attend a training (F18), who would then introduce the knowledge to other people within the team (F24). Another way of continuous, shared learning is within the wider organisation. I6 and I7 said that their team was learning from different offices across the world and within their organisations (F26 and F25).

Mechanisms - Short-term suggestions

In terms of short-term suggestions, interviewees suggested “kick-off meetings” early in the project (I1 00:23:13) (F7). This can be achieved through workshops or pilot projects, which was explained within F18 and F19. Interviewees mentioned that workshops are used for awareness and also to discuss and share knowledge about specific topics. I6 provided an example of short-term, social learning, involving developing new BIM models for existing buildings as an exercise or a pilot. The participant said that it was a “team learning exercise” – together they identified a plan for implementing BIM (F2), tried different processes to find, check and input the information, then add the final FM data (I6 00:15:57). This is also an example of F19 ‘pilot project’ with F24.

Participants explained that regarding larger teams, some initiatives such as pilot projects, intra- and inter-organisational knowledge exchange, need to be enabled by the management (F3). However, I2 and I3 mentioned that there were examples of shared learning initiatives that required less top-support. In these examples, interviewees learned as a team, without relying on the organisation.

Interviewees explained that ‘willingness to share information’ and an ‘open culture’ (F5) and opportunities for reflection and discussion (F21) can be a tool to transfer knowledge in line with F24. Interviewees explained that ‘lessons learnt’ provide a casual discussion opportunity, a time where people can discuss and transfer the knowledge – aligned to F24.

The summary of enablers is presented below in Figure 6.27.

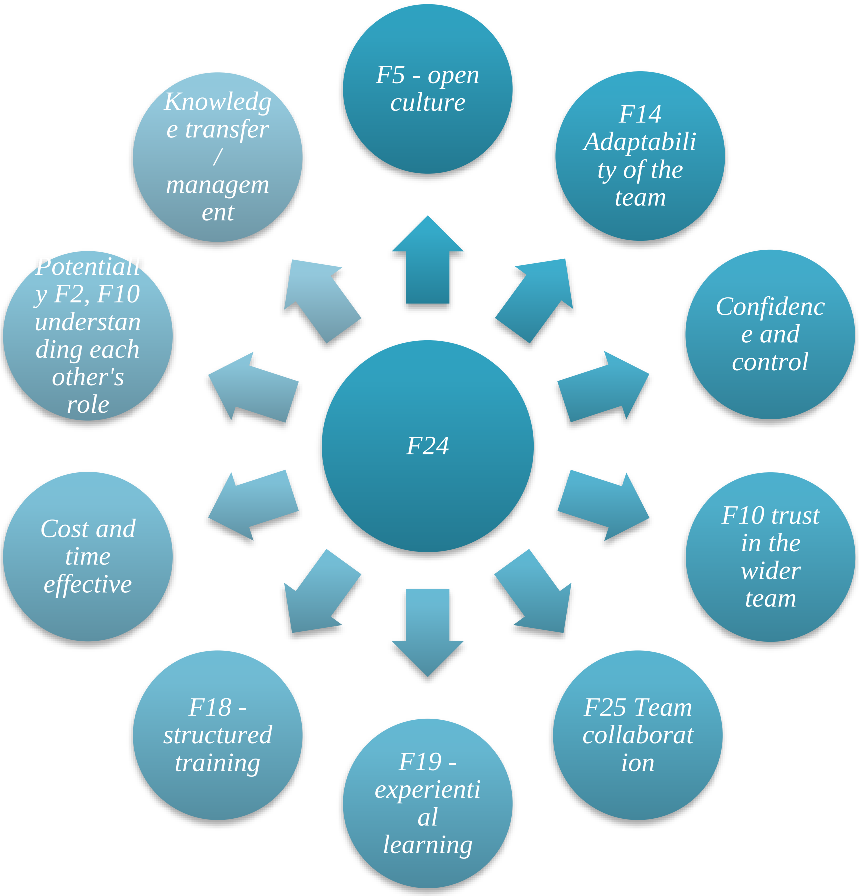

Figure 6.26. F24 can help with following

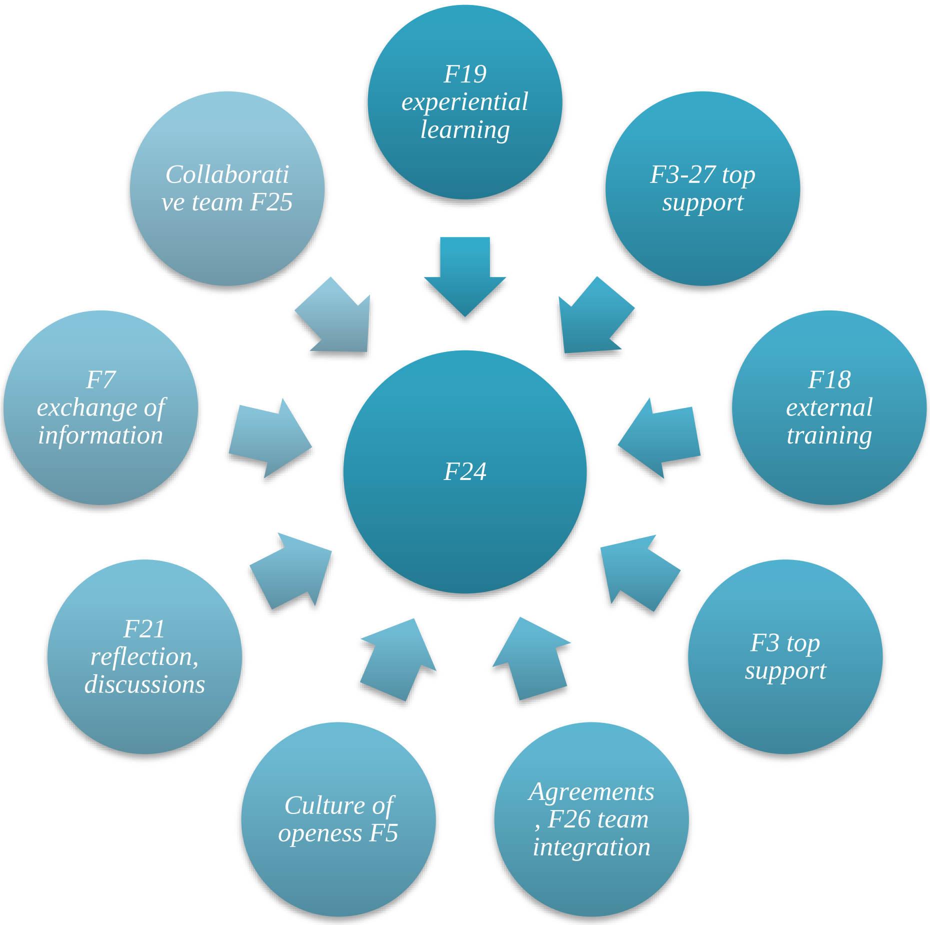

Figure 6.27. Factors to enable F24

6.24 Factor 25 – Collaborative team

This is a new, emerging factor, coded from the first interview. Table 6.27 below shows the presence and relation to other factors. There was a similar theoretical factor F11 on team building, whose aspects will be incorporated within this factor in Section 6.26.

Table 6.27 shows that there is a potential connection with *F7 'Communication digital and non-digital information', F26 'Integrated team', F1 'Aligning vision', F5 'Ensuring open culture', F2 'Planning future actions as a team', F3 'Establishing top-support and structure'*, and to a less extent with other factors. In the analysis so far, it was discussed that F25 could help:

- Factor F21 - I18 and I4 explained that there needs to be a collaborative structure to support the practice of open meetings (F21) and
- Factor F24 – different participants said that collaboration helps to share the knowledge within the organisation.

Table 6.27 Presence of F25

	F25	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F24	F25 *	F26
I1	3	1	1	0	0	0	0	2	2	0	1	1	0	1	0	1	0	0	0	2	2	0	2	0	2
I2	7	0	1	0	0	2	0	4	2	1	2	0	0	0	1	0	0	0	0	1	0	1	1	0	2
I3	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
I4	6	2	0	0	1	2	1	3	1	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	1
I5	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	6	5	1	0	0	1	0	4	0	0	0	0	1	0	0	1	0	1	2	0	1	0	0	0	3
I7	5	3	2	3	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
I8	9	3	2	0	0	1	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
I9	7	0	0	0	0	3	0	5	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6
I10	5	1	2	4	0	1	0	2	0	0	2	0	2	1	0	0	0	0	1	0	0	1	0	1	1
I11	4	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
I12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I13	5	2	1	2	0	3	1	3	0	0	0	0	1	1	1	3	0	0	1	1	0	3	2	0	0
I14	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
I15	3	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	1	0	0	0
I16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I18	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
I19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F5	69	19	12	10	1	16	3	41	8	4	6	2	6	5	2	7	0	2	7	5	3	9	5	1	25

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F24 - Shared learning, F25 – Collaborative team, F26 – Integrated team, F25* - opposite in a way

Having a supportive team and a collaborative culture was mentioned by the majority of participants as one of the key factors to BIM team development and adoption. Participants agreed that they are bringing their team with all disciplines together to achieve BIM implementation, for example, to learn together, to define requirements and strategy, to exchange information, to make sure that they deliver models not only for their own disciplines, but for the entire team. One of the participants said that they are working towards bringing together engineers, software technicians and BIM management, they were integrating the team more than it was previously before BIM practice. Others, I13 and I2, even mentioned how collaboration within their team was one of the keys to shared learning and BIM adoption (F24).

Bringing the team together also helps:

- To create effective communication (F7);
- To incorporate different perspectives and needs;
- To define BIM strategy and requirements (F1, F2 and F12);
- To track changes, to adopt changes promptly and deliver the design as a team.

A summary is presented in the diagram Figure 6.28 below.

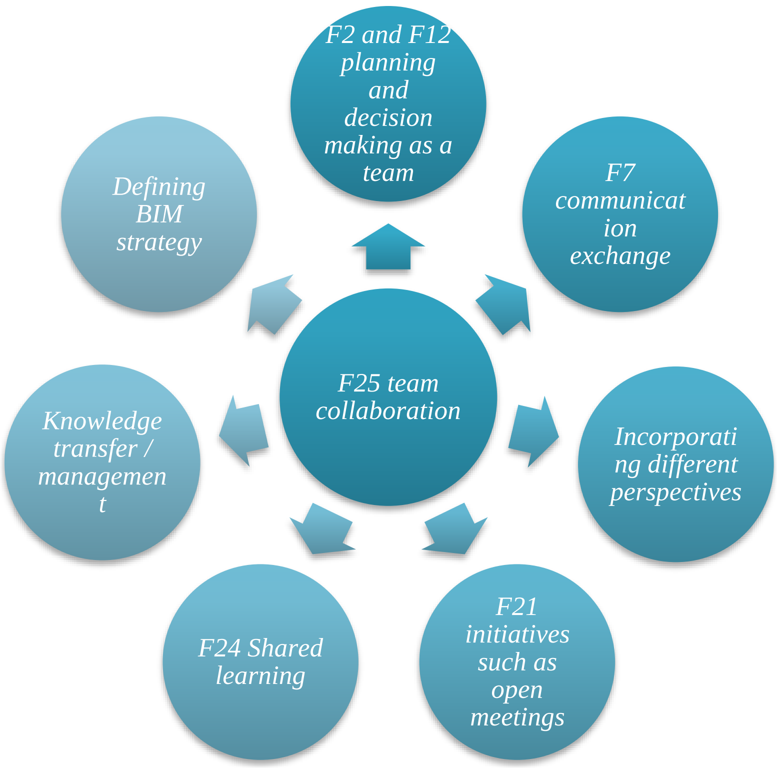

Figure 6.28 F25 can help following

Mechanisms

Many interviewees recommended that one of the ways to achieve F25 is to make sure that disciplines share their models and WIP information from the early stage and that they do not work in silo environments (F7). Similarly, there was a suggestion in interviews that the data should flow from one stage of the project to another, to create a "more connected business" (F7). Interviewees emphasise that management needs to make sure that there is an exchange of information throughout the project to enable a connected, collaborative team (F3, F7).

Participants overall recognise the value of having the project team in the same location. That way, people can "talk with each other over a coffee" (I9 00:35:58). I17 explained that team proximity helped collaboration more than the virtual data sharing, digital tools and meetings. Similarly, I2 explained that it was important to work as a team from the same office. I9 also suggested that it is the most beneficial to have a team together, within the same location, who works on one project.

Participant I6 pointed out the role of a 'shared vision' and 'sense of togetherness' within the project team. He explained that vision helps the team members to understand:

> *Why they are so important to the team, to feel motivated, to feel like a co-part of the team* (I6 01:04:58).

Therefore, having a vision encourages building a team culture (F25). Similarly, I4 suggested educating the team about the vision, explaining to them that BIM is about collaboration, trust and exchanging of the data (F1, potentially F18, F25), all of which can be achieved through top-management support (F3) (Figure 6.29).

Interviewees recommended other mechanisms:

- Knowing about each other's role helps with the shared understanding and this further helps F25. This was discussed within F6 and F10. Within F6, I4 explained that the more people know about each other's disciplines, the more skills they have, they will be more sympathetic and collaborative;
- Participants explained that BIM adoption can be achieved through collaborative experiences - brainstorming sessions (F21, F7);
- The management needs to support a no-blame culture, increase communication and trust (F5, F7 and F10);
- Enhancing factors in relation to learning; F18 can help F25 when training sessions are collaborative team experiences, F19 can help F25 in pilot project examples and F24 as it creates a shared-learning experience.

There were challenges to collaboration mentioned in interviews such as: conflicting views, financial interests and lack of interest about BIM. According to I10 one of the ways to tackle those challenges is the right procurement route that enables collaboration. Participants explained that this not only impacts collaboration in the wider team (F26) but also affect the internal team collaboration. This factor is closely related to factor F26 and this factor is explored in more detail in Section 6.24. Both factors represent the enhancement of team integration and collaboration, just on different levels.

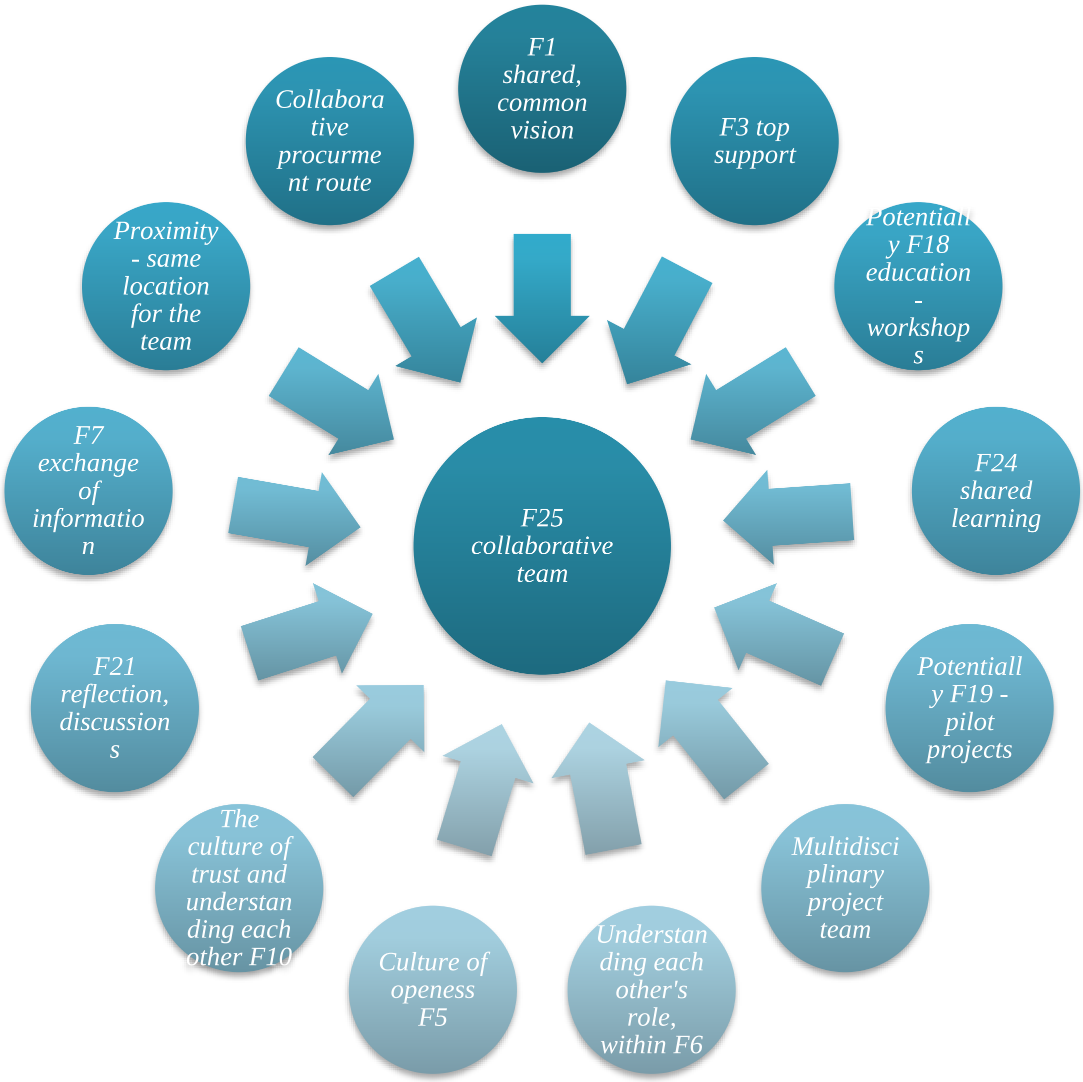

Figure 6.29 Enablers of F25

6.25 Factor 26 – Integrated team – within the organisation and the wider project team

Having an integrated team means greater collaboration within the external project team, including clients, subcontractors, suppliers and other parties that are involved in the project. This is also a new emerging factor, as highlighted from the first interview. Table 6.28 shows its presence.

Table 6.28 Presence of F26

	F26	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F24	F25
I1	18	10	10	11	1	14	0	8	5	5	4	3	8	7	0	6	0	1	1	4	2	0	4	2
I2	3	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
I3	5	2	0	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
I4	7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I5	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I6	6	3	1	0	0	1	0	4	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	3
I7	9	4	3	3	0	0	0	4	2	2	0	0	0	0	0	0	0	0	0	0	0	2	0	3
I8	7	2	2	0	0	1	0	2	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2
I9	15	1	0	1	0	4	0	8	3	1	0	1	0	0	0	0	0	0	0	0	0	1	0	6
I10	5	0	0	3	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
I11	25	4	0	2	0	0	0	6	3	2	5	0	0	0	0	0	0	0	1	0	1	0	7	2
I12	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0
I13	2	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I14	4	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
I15	3	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
I16	6	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I17	15	1	0	2	0	1	0	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
I18	5	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
I19	8	2	1	3	0	0	0	4	1	0	0	0	1	0	0	0	0	0	1	0	0	3	0	0
F26	149	34	19	31	1	25	2	58	18	11	14	4	10	7	0	7	1	2	5	4	4	12	11	25

Description: F1 - Aligning vision, F2 - Planning future actions as a team, F3 - Establishing top-support, F4 - Clarity about the change process, F5 - Ensuring an open culture, F6 - Diversity in the team, F7 - Communication digital and non-digital information exchange, F8 - Enabling access to information, F9 - Ensuring reliability of information, F10 - The culture of trust and respect, F11 - Team building, F12 - Shared decision making, F13 - Shared leadership, F14 - Flexibility 1 – Adaptability of the team, F15 - Flexibility 2 – Openness to new ideas, F16 - Flexibility 3 - Flexible team, F17 - BIM implementation to support good existing practice, F18 - Structured organised training, F19 - Experiential learning, F20 - Creative pressure, F21 - Opportunity for reflection, F24 - Shared learning, F25 – Collaborative team, F26 – Integrated team

According to Table 6.28, there is a possible connection with factors: F7, F1, F3, F5, F25 and to a less extent with F2, F8 and other factors. In the analysis so far:

- It was mentioned in F12 that a long-term collaboration helps with the shared decision-making (F12). According to I10, a collaborative procurement route is an enabler of a consensus within the project team.
- It was mentioned that long-term collaboration and integrated team on multiple projects enable learning. Within F24, it was discussed that F26 provides a platform for continuous learning from one organisation to another or from one project to another.
- Within F9 there was a conclusion about the joint creation of EIRs, which will be further discussed within this factor too, where it was said that F26 enables F9.
- It was mentioned in F11 that some of its ideas will be integrated within F25 and F26. It was found that integrating the team though procurement and right contact mechanisms enables a collaborative culture. It was also found that having a shared team experiences, such as the creation of EIRs or learning sessions, help better team dynamic and culture both internally and in the wider team (F25). It was found that long-term collaboration and collaborative culture have a positive impact on both projects and individuals.

Participants agreed that a rationale for having an integrated wider project team is that all parties need to be included in the BIM processes. Participants explained that when some parties are not included in the process "things break down" (I9 01:14:53, similar I19):

> *There is no point of having one person or one company who does not know what they are doing… if there is one person who is not (included), it is going to be confusing* (I11 00:06:35).

One BIM manager said that the only way to make BIM useful is to have everyone working together. However, that can be difficult due to "conflicting views and everybody's financial interests" (I8 00:17:16).

Participants mentioned that it would be better for the whole project team if construction and design teams were collaborating early on, to spot challenges early and produce a better design. Participants pointed out that if the design team is formed of few other teams, organisations, it needs to be fully integrated to avoid duplication of the work, mistakes, gaps in the work and information being lost (F7, F8). For example, participants I6 and I7 explained that a project where an architectural team was working independently caused challenges in the data exchange later (F7). Therefore, the entire project team needs to be brought together from the start, to learn from each other and address all project needs.

Interviewees agreed that to define the BIM strategy, it is helpful to involve all parties, including clients, contractors, design, FM teams, key suppliers and hear opinions early in the project (F12, F2). As an example of collaboration with clients, participants mentioned how they helped clients, educated them or helped them word the EIRs. They explained that wording the EIRs as a team helped to avoid misunderstanding, improved the clarity about the requirements, managed expectations and helped to define vision and objectives for the BIM model. Participant I11 also mentioned how they educated clients about benefits to make them more interested and involved in the process. In interviews, it was also found that the client should be part of the team rather than an external party and that design and construction parties were often helping clients with BIM adoption.

Interviewees also recommended integration within the organisation. Collaboration between offices can enable the team to share and access the information, save work and time by using, for example, the same components and libraries (F7, F8). Participants also recommended organising BIM steering groups to include all disciplines. They suggested involving different functions across the organisation (similar in F12), giving the voice to people across the organisation and making a greater connection between disciplines.

Mechanisms

The interview data and the previous analysis shows that F26 could be achieved with the help of:

- F19 – pilot projects can help team collaboration; interviewees suggest including a wider team for 'pilot project' exercise;
- F3 – the management support is required to allow the involvement of all parties, including subcontractors and suppliers;
- Regular communication and exchange of information;
- Digital integration of the wider team and enhanced sharing of the information, previously discussed in F7-F9;
- Discussing the exchange of information with external parties (F8, F12). Investigate the interoperability of tools to make sure that they can exchange the data throughout the supply chain (F8);
- Employing the right contract mechanisms that support BIM adoption, to obtain the information from suppliers and parties on time.

There were many comments in interviews about partnering and enabling the team integration contractually. Interviewees explained that this helps to grow capabilities, reduces conflicts, access the right information and enhances trust. Interviewees said that in the AEC industry, people are afraid to share the knowledge and information "because of legal sides of liability, insurance aspects as well" (I11 00:07:05) and there are also "conflicting views and everybody's financial interests" to consider (I8 00:17:16). On the other hand, interviewees recognised that it is necessary to share the information for the industry to grow, to make people do BIM and to initiate the culture of mutual help. This is the point where interviewees explained that long-term collaboration and partnering can help. For example, I1 mentioned that having framework agreements with other organisations enabled their team to develop EIRs jointly and enabled to get questions quickly asked and answered, which means it tackled the fear and helped to align views and financial interests.

Regarding suppliers and subcontractors, two management interviewees recognised that they were willing to share their models, families, equipment information, more than before, which helped BIM team development. However, the other two management participants said that obtaining the model information was still challenging. In terms of solutions for the supply chain management, participants suggested helping other parties with BIM implementation, upskilling the supply chain, as it benefits the project ultimately. One of the interviewees provided an example of a client and contractor team that is "spending money genuinely to upskill their supply chain, for their mutual benefits" (I4 01:44:30). Similarly, other participants suggested explaining the supply chain how to use BIM standards and raising awareness.

Another finding, also highlighted within F25, was about being in the same physical location. Having face-to-face communication and integrated team meetings are other ways to enable F26, recognised by many participants. In terms of meetings and communication, participants also mentioned brainstorming, kick-off sessions early with the wider project team to establish how to achieve BIM deliverables and brainstorm the progress (F21). Such integration also enables F12 and F1. Figures 6.30 and 6.31 present a summary of these findings.

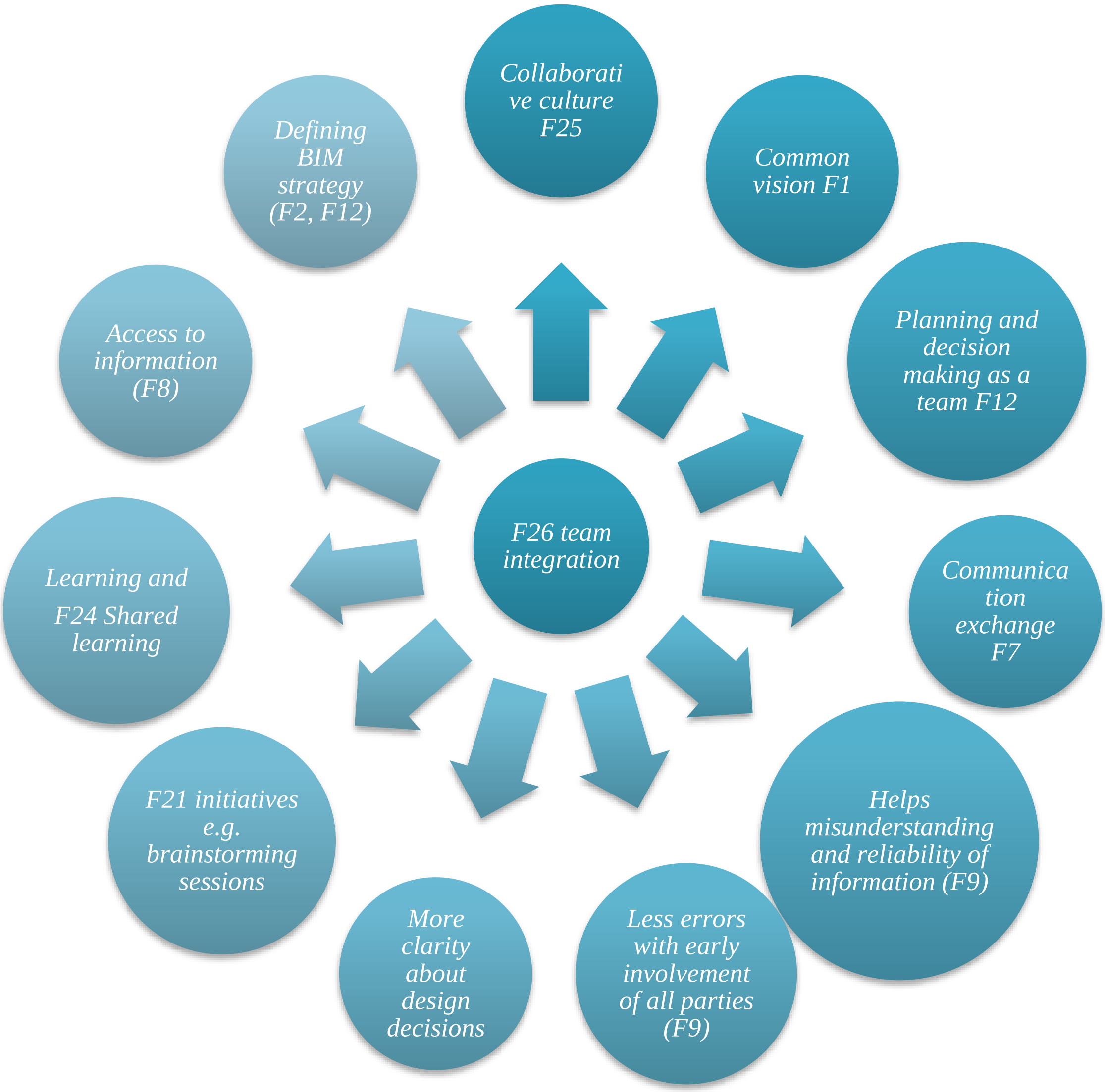

Figure 6.30 Benefits of F26

Figure 6.31 Enablers of F26

6.26 The final list of factors

6.26.1 Connectivity of factors

The results show how factors are connected. This is presented below in Figure 6.32 and Figure 6.33. These figures are established based on all previous diagrams and findings written in Chapter 6. Figure 6.32 maps how factors were enablers of other factors, where the maximum number is 23. Following Figure 6.33 summarises these numbers and shows how important certain factors are, being enablers of others. As a result, primary factors: F1, F3, F5, F7, F12, F12, F19, F21 and F26 are found the most enabling. In particular, F3 top-support, F19 experiential learning and F21 brainstorming opportunities were found to be key in enabling many other factors.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F24	F25	F26
F1				1	1				1	1				1	1			1		1			1	
F2	1						1			1					1									
F3	1				1		1	1	1	1		1			1		1	1	1	1	1	1	1	1
F4			1		1					1		1	1		1			1						
F5		1					1			1		1						1	1		1	1	1	
F6		1										1	1	1	1								1	
F7	1				1			1	1	1					1		1					1	1	1
F8	1				1		1																	1
F9							1			1							1							
F10	1				1		1		1			1											1	
F11							1																	
F12	1				1		1			1				1	1						1	1		1
F13												1												
F14																								
F15		1					1										1							
F16																								
F17			1				1								1									
F18	1						1		1								1		1	1		1	1	
F19					1		1	1	1		1			1			1	1		1	1	1	1	1
F20							1								1			1	1			1		
F21	1				1		1			1		1			1			1	1			1	1	1
F24		1			1					1				1				1	1				1	
F25	1	1					1					1							1		1	1		
F26	1	1					1	1	1			1									1	1	1	

Figure 6.32 Diagram of enabling factors – matrix connection between factors

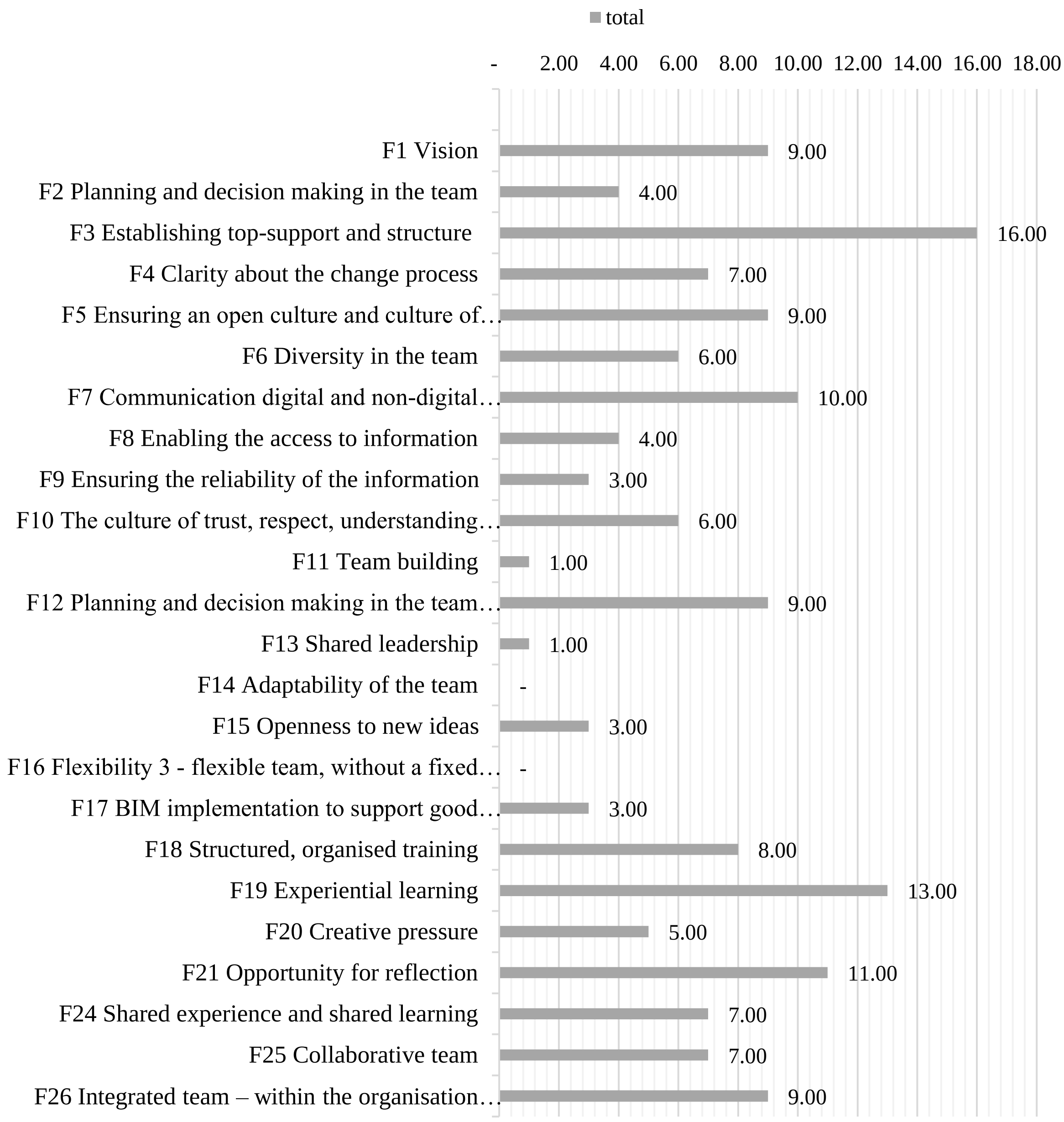

Figure 6.33 Diagram of enabling factors, a summary of previous matrix factor

6.26.2 Summary – final list of factors

As a result of all expert elite interviews findings, Table 6.29 below presents the final list of factors. The case study findings and preliminary findings in Section 5.2.2 were taken into consideration for the development of this final list. Table 6.29 shows how the final list is developed, how factors are merged, modified, removed or renamed. It also shows which motivational aspects were confirmed in expert interviews. It further shows which factors can enable collaboration, which can further help BIM team development.

Table 6.29 Final list of factors

n	**Preliminary factor** Variable – Area of improvement	Motivation factors ✓ means confirmed by results	Collaboration factors ✓ means confirmed by results *No evidence means it was assumed but not confirmed*	*Names in the analysis process*	**Conclusions based on the interview data analysis** **A new name is in bold** *Italic are additional comments.*	
1	**Aligning vision** **(agreeing a common vision)**	c) Knowledge and skills (clarity) ✓ *From results* *a) Personal motivation*	✓	*Aligning vision* *Clear and Common Vision* *Vision and clarity of requirements*	✓	**Vision and clarity of requirements** *Principles of F4 "Clarity about the change process" integrated*
2	**Planning future actions as a team**	c) Knowledge and skills ✓ *From results* *a) Personal motivation*		*Planning future actions as a team*	✓	*Integrated into F12*
3	**Establishing top-support**	b) External m. ✓ *From results* *d)Acting opportunities*	*From results*	*Ensuring top-support*	✓	**Establishing top-support, structure and providing skills and resources**
New 27	**Extension to factor F3**	*From results* *c) Knowledge and skills* *a) Personal motivation* *d)Acting opportunities*		*Skills and resources*	✓	

4	**Clarity about the change process**	c) Knowledge and skills ✓ *From results a) Personal motivation d)Acting opportunities*		*Clarity about the change process*	✓	*Integrated into F1*
5	**Ensuring an open culture**	*From results a) Personal motivation*	✓	*Ensuring an open culture* *Ensuring an open culture and culture of collaboration*	✓	**Ensuring an open culture and culture of collaboration**
6	**Diversity in the team** **(e.g. skills, roles)**		✓	*Diversity in the team (skills, roles)* *Diversity in the team*	✓	*Diversity in the team and adaptability* *Merged with F14 into "Adaptability and diversity within the team"*
7	**Communication digital and non-digital information exchange** **(regular meetings, face-to-face meetings, discussions)**	c) Knowledge and skills ✓ *From results a) Personal motivation*	✓	*Communication flow 1 - Inf. Exchange* *Communication digital and non-digital information exchange*	✓	**Communication digital and non-digital information exchange** *F8 "Enabling access to information" integrated into it, Table 7.10.*
8	**Enabling access to information** **(interconnectivity of team members, ability to get information)**	c) Knowledge and skills ✓ *From results d)Acting opportunities*	*No evidence*	*Communication flow 2 - Inf. Access* *Enabling access to information*	✓	*Integrated into F7.*
9	**Ensuring reliability of information** **(a transparent flow of information, ensuring up-to-date information)**	*From results Goes pro and against a) Personal motivation*	*No evidence*	*Communication flow 3 - inf. Reliability* *Ensuring the reliability of the information*	✓	**Ensuring the reliability of the information**
10	**The culture of trust and respect**	a) Personal motivation ✓	✓	*Trust and respect*	✓	**The culture of trust, respect,**

						understanding each other's role and a safe environment to try new tools *It can be integrated into F5.*
11	**Team building**		✓	*Team building*	✓	*Some ideas incorporated within other factors F25 and F26.*
12	**Shared decision making** **(shared problem resolution process, everything understood by all members)**	c) Knowledge and skills ✓ *From results a) Personal motivation*	*No evidence*	*Decision making shared* *Planning and decision making in the team with contributions from all team members*	✓	**Planning and decision making in the team with contributions from all team members** *Principles of F2 "Planning future actions as a team" are integrated.* *Some principles of F13 "Shared leadership" are integrated.*
13	**Shared leadership**	*No evidence*	*No evidence*	*Shared leadership (shared roles and responsibilities)*	× ✓	*Some principles integrated within F12.*
14	**Flexibility 1 – Adaptability of the team** **(adaptable to equipment changes or changes within the team structure)**		*No evidence*	*Flexibility 1 - tool changes, a member is missing* *The adaptability of the team*	✓	**Adaptability and diversity within the team** *Merged with F6 and removed*
15	**Flexibility 2 - Openness to new ideas**		*No evidence*	*Flexibility 2 - open to new ideas*	✓	**Openness to new ideas**
16	**Flexibility 3 – Flexible team** **(the team is not a fixed structure, it should be modified when**		*No evidence*	*Flexibility 3 - the team is not a fixed structure* *Flexible team, without a fixed*	×	*Due to lack of evidence excluded.*

	there is a need for it)			*structure*		
17	**BIM implementation to support good existing practice**	d)Acting opportunities ✓ *From results* *c) Knowledge and skills* *a) Personal motivation*		*BIM Implementation to support good existing practice*	✓	**BIM implementation to support good existing practice** *See comments in F17.*
18	**Structured organised training (Training as an assignment)**	b) External motivation ✓ *From results:* *c) Knowledge and skills* *d)Acting opportunities* *a) Personal motivation*	*From results, when training is a 'shared experience'*	*Training as an assignment*	✓	**Structured organised training**
19	**Experiential learning** **(learning through active participation or learning by doing)**	a) Personal motivation ✓ c) Knowledge and skills ✓	✓ *In pilot projects*	*Active participation - learning by doing*	✓	**Experiential learning**
20	**Creative pressure** **(competitions, time limitations, mandate)**	b) External motivation ✓ d)Acting opportunities ✓		*Adding creative pressure*	✓	**Creative pressure** *Alternatively, it can be merged with F3.*
21	**Opportunity for reflection** **(confusion, brainstorming, positive deviance, deep reflection)**	a) Personal motivation✓ d)Acting opportunities ✓ *From results:* *c) Knowledge and skills*	*From results*	*Opportunity for reflection (confusion, brainstorming, positive deviance, deep reflection)*	✓	**Opportunity for reflection**
New 24	**Shared learning**	*c) Knowledge and skills* *d)Acting opportunities*	*From results*	*Shared learning*	✓	**Shared experience and shared learning**
New 25	**Collaborative team**	*a) Personal motivation*	*From results*	*Collaborative team*	✓	**Collaborative team**
New 26	**Integrated team**	***d)Acting opportunities*** ***c) Knowledge and skills***	***From results***	***Integrated team***	✓	**Integrated team – within the organisation and the wider project team**

In addition, there were other, emerging, potential factors during coding; however, these are integrated within the existing factors:

- F22: Clear roles and responsibilities, incorporated into F13, F5, F7, F9 and F3.
- F23: Structure and control and measure, now incorporated into F3, F9.
- F28: Easy to use, now incorporated into F3-27.
- F29: Showing benefits, now it is incorporated as a mechanism to enable other, example F1, F18.

To summarise, the final list of factors is:

1) **Vision and clarity of requirements,** *Principles of F4 "Clarity about the change process" integrated;*
2) **Establishing top-support, structure and providing skills and resources;**
3) **Ensuring an open culture and culture of collaboration;**
4) **Communication digital and non-digital information exchange,** *F8 "Enabling access to information" integrated into it, Table 7.10.;*
5) **Ensuring the reliability of the information;**
6) **The culture of trust, respect, understanding each other's role and a safe environment to try new tools***;*
7) **Planning and decision making in the team with contributions from all team members,** *Principles of F2 "Planning future actions as a team" are integrated. Some principles of F13 "Shared leadership" are integrated;*
8) **Adaptability and diversity within the team;**
9) **Openness to new ideas;**
10) **BIM implementation to support good existing practice,** *See comments in the factor;*
11) **Structured organised training;**
12) **Experiential learning;**
13) **Creative pressure;**
14) **Opportunity for reflection;**
15) **Shared experience, shared learning;**
16) **Collaborative team;**
17) **Integrated team – within the organisation and the wider project team.**

These factors are discussed and compared with the literature in the following Chapter 7 – Discussion.

Chapter 7. Discussion

7.1 Introduction

This chapter discusses the key primary data findings in the context of the main literature findings, by establishing similarities, differences and interpretations of new findings. In the current industry, based on the primary data and the available literature, it can be observed that there is pluralism in terms of BIM practice and ways of achieving it. While there is greater awareness in the literature about the benefits of BIM, there is less clarity on mechanisms for people management to achieve those benefits. Some recent studies, such as Son et al. (2015) and Lee et al. (2015), mention specific factors that impact BIM adoption, but there is little discussion in those studies and practical means of achieving these factors and their interconnectivities. To provide a solution for this problem, this study applies key existing literature of KM, IM and CM. As a result, this study initially established a conceptual list of factors that can contribute to BIM team development in the AEC organisations as they emerged from existing theories. These topics were compared to the exploratory case study and qualitative inquiry – expert interview findings. This allowed for a creation of the final list of critical factors for BIM team development, through a comparison between theoretical recommendations, critical findings and consensus in the data. The final list contains seventeen factors that have been grouped into nine themes, as presented in Table 7.1.

The results regarding the critical factors are thoroughly discussed throughout Chapter 6. Chapter 6, as a contribution also shows interconnections and mechanisms for accomplishing these factors to achieve BIM team development. Chapter 7 further continues to discuss these critical factors and conclusions of this study by showing connections to existing theories and showing contributions to existing theories and research. This way the study achieves its aim, which was to "to establish the critical factors for successful BIM implementation and team development processes for the AEC organisations".

These are the central findings of this study and these are further discussed in Sections 7.3 – 7.6. Prior to these discussions, there is a need to briefly re-state and summarise key findings about "challenges and development strategies for BIM implementation in the AEC industry", which corresponds to the first objective, in Section 7.2. The second objective "To investigate principles of Innovation Management, Knowledge Management and Change Management that can help BIM team development, within the context of the AEC project teams." is achieved in Chapter 3. The third objective "To establish key enabling factors for strategic planning of BIM Change

Management process and team development. To critically evaluate the theoretical list of factors established." is achieved in Chapters 3 and 6 and this is summarised in Section 7.1.1 and Table 7.1. The last, fourth objective "To evaluate existing theories of CM, KM and IM and show how they benefit BIM team development processes." is achieved throughout this Chapter 7.

7.1.1 Key enabling factors for strategic planning of BIM Change Management process and team development

The table below summarises the key enabling factors for BIM team development, established in Section 6.26. This table also identifies themes behind groups of factors. To establish a connection with the previous chapter, this chapter also uses references F1-F26 when discussing factors.

Table 7.1 Summary - table of key themes and factors

In Ch. 7 discussed within	Theme	Final factors (see Section 6.26)	Initial factors (see Section 6.26)
7.6	**1 Vision**	1 Vision and clarity of requirements	*F1, F4*
7.3 **7.4** **7.5**	**2 Management support**	2 Establishing top-support, structure and providing skills and resources 13 Creative pressure	*F3, F27, F20*
7.6	**3 Culture - open, collaborative, trust, respect, safe**	3 Ensuring an open culture and culture of collaboration 6 The culture of trust, respect, understanding each other's role and a safe environment to try new tools.	*F5, F10*
7.6	**4 Communication and quality of information**	4 Communication digital and non-digital information exchange 5 Ensuring the reliability of the information	*F7, F8, F9*
7.3 **7.5**	**5 Planning and decision making in the team with contributions**	7 Planning and decision making in the team with contributions from all team members	*F2, F12, F13*
7.5	**6 An adaptable, open and diverse team**	8 Adaptability and diversity within the team 9 Openness to new ideas	*F6, F14, F15*
7.3 **7.4**	**7 Knowledge**	11 Structured organised training 12 Experiential learning 14 Opportunity for reflection 15 Shared experience, shared learning	*F18, F19, F21, F24,*
7.6	**8 Internal and external integration**	16 Collaborative team 17 Integrated team – within the organisation and the wider project team	*F11, F25, F26*
7.6	**9 Supportive approach**	10 BIM implementation to support good existing practice	*F17*

7.2 Summary of conclusions about challenges and BIM team development strategies

This section provides a summary of key conclusions from Chapter 2 and Chapter 5 regarding challenges and BIM team development strategies, which corresponds to the first objective. The conclusions from Chapter 5, case study, as per Table 5.2 and Table 5.3, are that the key challenges are communication challenges, lack of clarity, lack of commitment, resistance to change, lack of management support in the sense of late introduction of BIM management and requirements, lack of knowledge, lack of skills, lack of equipment and complexity of software tools to achieve the project tasks the team requires and lack of experience in the internal and wider teams. These findings align to results from Chapter 2, as per discussion in Section 5.1.7.2. and Table 5.4. The same Section 5.1.7.2 also discusses and compares the findings about BIM team development strategies and concludes that it is necessary to have both bottom-up and top-down involvement to achieve BIM team development. The conclusions and findings about development strategies are further incorporated into investigations on F17 'BIM implementation to support good existing practice' and the results are presented in Section 6.18, Section 5.1.7 and further in Section 7.6.5.

Section 5.1.7.2 shows the connection between the case study with other objectives and the rest of the study. Each dimension A – E discussed in the case study is a theme to address challenges and each of these themes corresponds to factors identified in Chapter 3 and IM, KM and CM theories, as explained in Section 5.1.3.

To conclude, from the mentioned list of challenges, it is found that motivation, commitment and resistance are essential topics to address and this is addressed by CM, but also by recommendations from IM and KM. Motivation is addressed by the majority of critical factors, as shown in Table 6.29 and discussed across multiple factors in Chapter 6. It is also discussed in Section 5.1.3.5 and in Sections 7.3-7.6. In particular, the resistance and motivation are addressed in Section 7.3.3, Section 7.5.1, Section 7.6.1 and Section 7.6.4. The communication challenges have been addressed with factors F7- F9. This has been discussed in Section 5.1.3.2 and to a greater depth in Chapter 6 – Sections 6.8, 6.9 and 6.10. As a result of these discussions it has been found that improving communication is one of the most relevant mechanisms for BIM team development as per Figure 6.33, and the final factor 4 has been concluded in Table 7.1. The lack of skills and experience is addressed by KM and directly by the factors F18, F19, F21, F24 – as presented in the final Table 7.1. Not only are these factors enablers of knowledge, but also they are enablers of motivation, openness and innovation. This finding is also one of the contributions of this study and this is discussed in Sections 7.3-7.6, in particular Section 7.4. The lack of vision, clarity and requirements have been briefly identified in studies highlighted by the systematic review, while this study discusses this in more depth in Section 5.1.3.3 and provides recommendations in Section 6.1 and Section 7.6.3. Finally, providing the right support and equipment is discussed firstly in Section 5.1.3.1, then in factors such as F3 and F27 in Sections 6.13 and 6.14, and concluded as the final factor 2 “establishing top-support, structure and providing skills and resources” and factor 13 “creative pressure” in Table 7.1.

7.3 Change Management (CM) application to BIM team development – comparison with critical factors and summary

All key points suggested by CM theoretical models are confirmed through the empirical data. However, there are some differences between the data and theories in the value of certain CM suggestions. Elite-expert interview results show that by adopting only one model of change, such as Kotter (2012), the practitioners might not consider all key points to BIM change and development. While CM theories, such as Kotter (2012) and Lewin (1951), provide structured guides on managing change, they are not exclusive lists for planning BIM team development. In the context of BIM change, there are other important aspects such as knowledge development and having a collaborative team externally to acquire more information, added as an emerging factor F26 ‘Integrated team’. The topic of ‘knowledge’ is not as apparent in CM models such as Kotter (2012), while the results of this study recognise four critical factors in relation to knowledge development – F18, F19, F21, F24. For these reasons, it is established, that the development strategy needs to employ principles of CM, IM and KM to achieve BIM team development. This is further discussed below in Section 7.3.4.

7.3.1 Engagement of people

The suggested level of engagement of all team members in CM, KM and IM theories is higher than the level interview participants suggest as practical and feasible. In particular, CM literature advises that active participation and involvement of team members is essential for the success of CM strategies (Levasseur 2001 and 2005, Lewin 1951, Kotter 2012, Hiatt 2006, Schein 2017, Henderson and Ruikar 2010). Still, views of the industry practitioners in elite-expert interviews demonstrate a somewhat different perspective. This conclusion derived from discussions on factors F2, F12, F13, F1 and F21, that recommend greater engagement of all team members during BIM team development. It is found that brainstorming ideas from the whole team, generously suggested in CM, is not always welcomed by managers, for example when the vision needs to be defined, when the team is choosing software or when there is a need to understand new standards and guidelines. The data from expert-elite interviews shows that due to time and cost limitations, it is recommended to ask only those who are knowledgeable. The second set of data, the case study, consistently show that inability to involve more people in discussions is due to time limitations and other pressures on the project. Expert interviewees suggest that the management needs an input, knowledge and feedback, but overall decision-making should come from the top of the organisation and the team, which is a different level of engagement in comparison to one proposed by initial factors and theories of IM, KM and in particular, CM models.

The majority of interviewees still recognise the value of enabling everyone in the team to make suggestions and express their needs. The interviewees recognise that this conveys many benefits such as adding new knowledge to the team, achieving a greater understanding in the team overall, a better understanding of needs, solving issues, help in defining the organisational strategy and capabilities, and help in motivating people. Therefore, greater engagement and consultations with the whole team can help BIM team development and should be encouraged.

7.3.2 Team building and collaboration

There was less emphasis on factor F11 'team-building' in practical recommendations from the interviewees. Instead, the interview conversations were more around the inter- and intra-organisational collaboration. For example, interviews recognised that a constant change of collaborators can cause challenges for both professionals and projects and they recommend procurement strategies that enable long-term inter-organisational collaboration. This is shown in Figure 6.33, Table 6.27 and Table 6.28 and further discussed in Section 7.6.2.

Kotter's CM model recommends creating a 'guiding coalition', a team who is going to guide a change (Kotter 2012: 53). However, this is only stated by a few interviewees (Figure 6.13). For example, a few expert interviews recommend management-enabled mechanisms such as having BIM working groups across the organisation to provide overall, greater management support. Other recommendations are to provide a 'shared development experience' for a team and a safe environment to learn as a team (Figure 6.13). The data still shows that the factor F11 is valuable, however other factors, such as integration of the team (F26), top-support (F3) and open culture (F5) have a much greater contribution in achieving BIM team development, as per Figure 6.33.

7.3.3 Establishing the urgency and enforcing the mandate

Establishing the urgency, which is the first step in CM theories, is confirmed in the results of this study. A top-management initiative, 'BIM mandate', and mandatory, organised training are mechanisms highly recommended by expert interviewees, as per discussions in F3 and F18 (Section 6.13 and Section 6.19). It is also suggested to integrate BIM responsibilities within the existing roles to support this mandate. The case study findings and discussions on challenges (Table 5.3) also show positive correlations between factors such as top-support F3, organised training F18 and creating pressure F20 with commitment and resistance to change. However, the case study data also shows that although the case study project team had a level of urgency, they had other issues such as the lack of clarity about vision and deliverables, lack of time, and these challenges potentially cancelled the 'urgency' and mandate for BIM. This shows that while the urgency is important to establish, it is also vital to apply all critical factors together to achieve benefits of a mandate.

Establishing the urgency or a mandate to adopt new technology is not a mechanism present in KM literature and is also not present in studies identified in the systematic review such as Son et al. (2015) and Lee et al. (2015). These studies advocate 'softer' measures and recommend enhancing the 'perceived ease of use' and 'perceived usefulness' instead. However, a common stance between these approaches and the results of this study is that people's perception needs to be changed and managed, to achieve BIM team development.

7.3.4 Mechanisms for learning – Lewin and Kotter CM models

Expert interviews and case study results agree that establishing mechanisms for learning is critical to BIM team development. Kotter's CM model does not emphasise the importance of this, however another CM model by Lewin, as discussed and developed further by Schein (2017), specifically suggests mechanisms to support learning such as trial-and-error learning, organised training and providing resources to learn. For these reasons, the Lewin/Schein model is more suitable for BIM team development because it emphasises the role of knowledge and learning. However, in comparison with KM, even though the Lewin/Schein model talks about the 'knowledge transfer', it neglects the 'knowledge creation' which is vital to create innovative organisations and for KM (Nonaka 2008, Lu and Sexton 2006). For these reasons, incorporating CM, IM and KM together leads to having a more comprehensive approach to team development, which is one of the findings and contributions of this study. While there are a few academic studies that briefly recognise how KM and education could help CM, such as Schein (2017) on

Lewin (1951), Henderson and Ruikar (2010), it is not a well-acknowledged matter and not often mentioned in studies and CM theories. The risk for the industry practitioners is that they could only apply key ideas from Kotter's CM model, without applying principles of IM and KM and that would not be sufficient to achieve BIM team development.

7.3.5 Role of reflection

One of the initial factors on reflection, F21, that later becomes a final factor 14, as per Table 7.1 is suggested in Lewin's model as a concept of 'lessons learnt'. There is little in other literature on CM and BIM team development, that shows the value of this practice or relations to resistance to change. However, the role of reflection, as discussed in Chapter 6, Section 6.22, is very important, being one of the most enabling factors (Figure 6.33). Some participants did not put emphasis on it as much as they did on aspects of top-support, communication and experiential learning. However, the final results presented in Figure 6.33 and Figure 6.24, further show that even experts in the industry are not fully aware that enabling reflecting activities is highly beneficial for their team for KM, motivation and overall for BIM team development. Therefore, showing the role of F21 and ways to achieve it is one of the contributions of this study.

7.4 Knowledge Management (KM) application to BIM team development – comparison with critical factors and summary

Implementation of many new products and technology in the construction industry failed due to lack of learning mechanisms (Maqsood et al. 2007, Gann 2001). This study confirms how KM can support both IM and CM and compliment them in the process of BIM adoption. This study contributes by providing an in-depth perspective on functional KM solutions in practice. In support of this, existing theories of KM and data highlight that the right approach is to combine an organised training and learning through practice (Nonaka 2008, Nonaka and von Krogh 2009, Leonard and Sensiper 1998) (see Figure 7.1). The data confirms this and adds into it by providing in-depth insights about proposed learning mechanisms in Sections 6.19, 6.20, 6.22, 6.23 and 5.1.3.4.

As explained in Section 6.20, many participants suggested combining F18 and F19, due to their benefits and limitations. Interviewees suggested starting with a general introduction, such as a presentation or a basic external training and following with experiential learning. Participants explained that the structured, external training, has a more informative and clarifying role than a training role and the real learning occurs in the later stage, through experience and by having customised training sessions. This was also confirmed in the case study findings, where experienced team members learnt through experiential learning while the structured learning was used to raise awareness. As explained in Section 6.19, F19 needs to support F18 - what is learnt should be practised on real projects. Finally, the main argument for combining F19 and F18 is that external help is needed because not everyone has the “intuition” to learn on their own with little or no support (I13 00:07:45).

Another key finding that emerged from the data is the emphasis on social learning, a new factor F24, discussed in Section 6.23. This factor was also recognised in the work of Nonaka (Table 3.2), however the factor itself was not highlighted in KM, CM and IM in comparison to other factors. The data also shows the importance of having the management support to provide the necessary infrastructure for KM (Sections 6.13 and 5.1.3.1). Further to that, the findings show that there needs to be an established minimum knowledge about BIM for all members of the team (Figure 6.19, Section 6.14).

7.4.1 SECI model, KM literature and social learning

The core idea of the SECI model and other KM models is to support interaction, which creates and transfers knowledge (Nonaka and von Krogh 2009, Leonard and Sensiper 1998, Davenport and Prusak 1998 and 2000). This idea was initially translated into factors on communication (F7-F9), open culture (F5), reflection opportunities (F21) and planning as a team (F1, F2, F12, F13) which were found to be highly beneficial for BIM team development (Figure 6.33). However, another idea of having ‘learning as a team’ emerged from the first interview, as an effective way of developing BIM team skills and practice. The new factor F24 called ‘social learning’, emphasises the idea of interactions and socialisations – “shared experiences in day-to-day social interaction” (Nonaka and Toyama 2003: 4), and it is in accordance with the knowledge creation theory (Table 3.2). The data shows that social learning improves the adaptability of the team more than organised, structured learning. This is important as the ability to adapt quickly is vital for BIM team development according to the evidence presented in IM (Section 3.2.1) and the study by Ahn et al. (2016). Social learning also builds collaboration, trust and is cost and time effective. These aspects are particularly important for BIM team development, as per interview and case study findings. The literature findings also confirm that building collaboration and trust is vital for BIM team development (Mahalingam et al. 2015, Won et al. 2013, Linderoth 2010, Babič et al. 2010, Hartmann et al. 2012, Sebastian 2010). This evidence demonstrates the role of 'social learning', factor F24 (new factor 15 in Table 7.1).

In relation to socialisation, the data shows that not all knowledge needs to be transferred to explicit, externalised or documented. The initial literature review of KM and KM in construction shows benefits of codification of knowledge to provide a better understanding and access to knowledge and access to the information within the team (Davenport and Prusak 1998, Leonard and Sensiper 1998, Frappaolo 2006, Robinson et al. 2005, Carrillo et al. 2013). Providing access to information, which was the initial conceptual factor F8, is confirmed by the results in this study. However, the data shows that less effort should be invested in that dimension. Both interview and case study results show that instead of mechanisms such as manuals and guidelines, the actual knowledge creation and transfer occurs through practice and socialisation within and outside the team. The findings agree with the perspective of Boisot (1998), Leonard and Sensiper (1998), Senaratne and Sexton (2009), Hansen et al. (1999), that the knowledge can be accessible without being coded. In fact, Boisot (1998) argues against coding the knowledge to avoid losing the competitive advantage. In addition to that, Hansen et al. (1999) explain that this approach, they called 'personalisation strategy', is more appropriate when dealing with innovation and instead, the KM strategy needs to be based on conversations and building networks. Therefore, for the purpose of developing BIM skills, it is more appropriate to emphasise the personalisation aspect of KM. This will enable the team to share knowledge, learn on their own, while the codification stays beneficial as a supportive practice. In terms of practical mechanisms to achieve this, suggestions are to have peer-to-peer learning, workshops, discussions, pilot projects, long-term collaborations of teams on multiple projects and other intra- and inter-organisational knowledge exchange initiatives.

7.4.2 The role of reflective practice

An idea to have 'reflection opportunities' or brainstorming sessions, also discussed in Section 7.3.5, was initially developed in this study as a factor F21. This factor was made as a response to KM advise to have enhanced dialogues and discussions in the team (Nonaka and Toyama 2003, Leonard and Sensiper 1998). This idea has not yet been discussed in the literature on BIM adoption, while a few studies on KM in construction discussed some of its principles. In particular, the concept of 'lessons learnt' and 'project reviews' was advised by studies - Senaratne and Sexton (2009), Carrillo et al. (2013), Carrillo (2005), Disterer (2002). During the interviews, when asked about the key activities to BIM development, only one participant recognised the idea in relation to this, specifically ‘having lessons learnt’ practice. However, through other questions, it was found that F21 is a highly useful tool and an enabler of other factors (Figure 6.33 and Figure 6.24). The data confirms that the lack of time and moving quickly from one project to another are often reasons for not having lessons learned on projects, as the literature also suggests (Senaratne and Sexton 2009, Carrillo 2005, Anbari et al. 2008, Disterer 2002). Both the literature and data findings show that the industry is not aware enough of benefits of reflective practice and a study like this can help management visualise benefits, provide guidelines and motivate managers to incorporate such practice. This study shows how reflective practice can significantly contribute to all other critical factors to BIM team development and all phases of development, such as planning, problem-solving, communicating vision, knowledge creation and transfer, building an open culture, communication and motivation (Figure 6.24).

7.4.3 Management support

Within the discussions on management support factors (initial F3 and F27, new final factor 2), it is established that management needs to provide the infrastructure for KM. Participants mentioned mechanisms such as BIM management, steering groups or working groups and BIM champions. A parallel can be drawn between those suggestions and previously discussed work of Davenport and Prusak (1998) who recommend having development teams and the creation of specialised knowledge networks. So far, the topic has not been explored in studies on BIM change, while there is some recent research on KM in the construction industry that demonstrates the role of knowledge networks (Robinson et al. 2005).

The data agrees with KM literature, such as Davenport and Prusak (1998), that there is a need to allow enough time and provide space for collaboration and interaction of team members. The data also confirms that there is a need to provide dedicated resources, as Robinson et al. (2005) suggest. These findings on providing the equipment and infrastructure for KM can be explained with the literature on IT adoption - ‘availability of technical means’ in the work of Adriaanse et al. (2010) or ‘facilitating conditions’ in UTAUT model by Venkatesh et al. (2003). As a contribution, this study presents various perspectives on needed infrastructure, that can help other practitioners to define their strategy. The main recommendations emerging from the data are to provide: easy-to-use software, effective software solutions, model-viewing tools to provide greater access to the model, better internet connection on-site to access models, an explanation for the team about the processes, an explanation about the purpose of BIM, provide templates, tools to use, standard methods of procedures, pilot projects to learn from, e-learning, basic training for all, specialised training courses and additional BIM management support during the learning phase.

Another finding is that the timing for providing the resources is essential. Particularly, it is vital to provide the equipment during the training or when the team needs to apply their knowledge. Other than to enable learning, it is found that KM infrastructure enables people to have more confidence and feel the commitment from the management which can reduce the resistance to change, one of the greatest challenges in practice (Table 2.2, Table 5.2). There are studies on KM in construction that mention how crucial it is to have the core infrastructure for all KM initiatives (Robinson et al. 2005). However, studies on BIM rarely go into details or present the specific mechanisms to address the resistance to change and specific mechanisms to achieve knowledge development.

As a result of this discussion, Figure 7.1 presents a proposed model that includes conclusions made in this study; and these data and findings were presented at InfraBIM conference in Finland in January 2019.

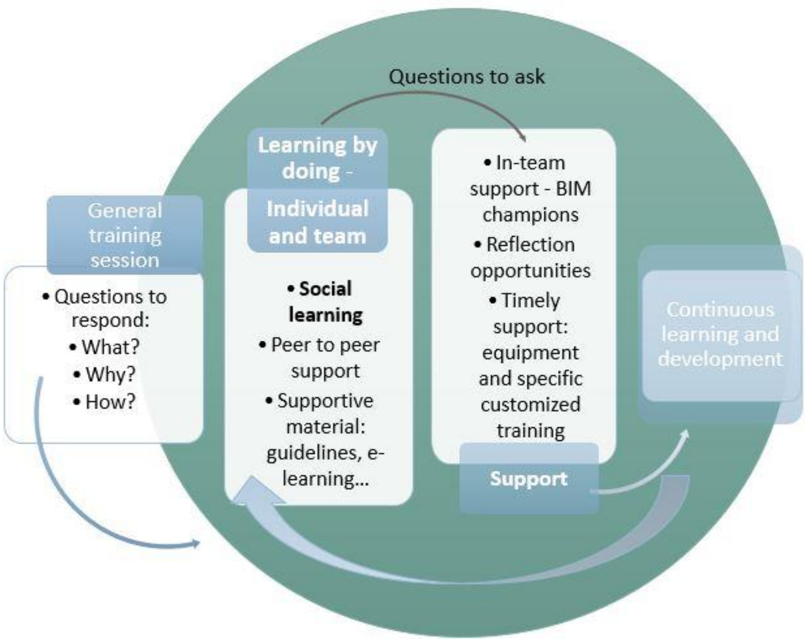

Figure 7.1 KM mechanisms for effective learning and BIM adoption

7.5 Innovation Management (IM) application to BIM team development – comparison with critical factors and summary

The literature review shows that there are a few studies that make a connection between IM and BIM, as per Section 1.1.1. Further to that, a novel finding of this study is in the implementation of IM principles found in the organisational management literature to address BIM team development issues in the AEC organisations. It is found that some of the key IM principles are beneficial for BIM team development of the AEC teams. As a result of the comparison between the data and IM literature, this study defines key factors that can help to manage the practical issues with adoption and development of collaborative technology in the AEC industry. The primary data in Chapter 6 also provides in-depth insights on how to achieve each of these critical factors in practice.

7.5.1 Establishing top-support and achieving the motivation

Results show that the factor on 'establishing top-support, structure and providing skills and resources' is the most important factor for BIM team development (Figure 6.33). This finding is also in accordance with the findings from the systematic review and IM, KM and CM theories, presented in Chapters 2 and 3. In terms of management support and motivation in the literature, both intrinsic and extrinsic rewards, are found beneficial to build the culture of innovation (Schneider, Brief and Guzzo 1996 in Ahmed 1999, Hartmann 2006), productivity (Locke et al. 1986), KM (Robinson et al. 2005, Hall et al. 2000) and to overcome the learning anxiety during CM (Schein 2017). However, the study results show that rewards are mentioned only once during expert interviews. That was an example of financial rewards for employees who make efforts towards BIM development. For these reasons, the study findings are aligned more with the perspective of Peansupap and Walker (2005) and their study on ICT adoption; a study that explains that rewards are not critical when adopting a new technology. Instead, the findings in Chapters 5 and 6 show that other aspects of top-support are more influential. For example, suggestions are that an enjoyable working environment should be established in the team, there is a need to provide resources, to provide and develop skills, to build the culture of respect and trust. This further confirms other critical factors, such as to have an open, collaborative culture, trust and respect in the team (final factor 3 and final factor 6 in Table 7.1). In addition to this, the idea of having a vision and understanding benefits is also one of the critical contributors to motivation according to the expert interview data (Figure 6.33) and this is discussed in Section 6.1. It can be concluded that the results are in line with McGregor's Theory Y perspective (Leavitt et al. 1989) when it comes to motivating people to accept the change and contribute towards BIM development processes within their teams.

The results of this study align with the statement of Hartmann (2006) that the ability to innovate depends on resources that can be allocated by a company. This is confirmed both in expert interviews and particularly in the case study where the lack of managerial commitment to invest in time and resources negatively influenced the adoption. Due to lack of resources, team members perceived BIM adoption as less important than their other daily project tasks. The case study results show that in organisations aiming to develop their BIM skills, the management needs to provide technical and human resources: better equipment, more licenses, strong leadership and knowledgeable people. Another important implication of the case study when it comes to top-management support is that it is crucial to set clear requirements and integrate the mandate early into the project.

7.5.2 Shared task ownership

Having distributed leadership and shared task ownership is another point suggested in IM literature to achieve creativity, better solutions to complex tasks and flexibility (Goodman and Dingli 2017, Moran 2015, Carson et al. 2007, Pearce and Sims 2000). However, the study results recognise this factor less important in comparison to others. A few expert interviewees elaborated that there is already enough shared ownership in BIM projects and generally in construction projects. A few participants explained that BIM responsibilities need to be shared among everyone, while some suggested that responsibilities should be constrained. Therefore, there is no consensus in the data around this recommendation. Instead, the study results in other recommendations that are recognised as more beneficial, such as to integrate BIM responsibilities into the existing roles, to establish clear roles and responsibilities, to duplicate the skills within the team, to understand each other's roles and responsibilities. These recommendations are integrated into factor F12– final factor 7 'planning and decision making in the team with contributions from all team members'.

As presented in Table 6.29, F13 was removed. According to participants, due to the AEC industry conditions, liability issues, it would be difficult to suggest that responsibilities should be shared more than how they already are and suggest this factor as a solution to BIM team development (Section 6.4). Having this factor enhanced in the AEC teams would also be more radical and would have a more significant impact than enhancing factor F12 'shared decision making'. This implies that although shared leadership is recognised as valuable in the process of change, the

BIM change might not be a change that has a power to transform the way the project teams are structured in the AEC industry and change present leadership styles. Instead, F12 is sufficient as it would deliver similar benefits and it is easier to apply.

7.5.3 Creating an adaptable, open and diverse team

As previously discussed, the AEC organisations need to learn how to adapt and continuously improve (Ahn et al. 2016, Robinson et al. 2005, Kamara et al. 2002, Abdirad and Pishdad-Bozorgi 2014, Wheatley 2007). On the other hand, as discussed in Section 3.3.3, current studies on BIM and ICT adoption have provided little information about improving the adaptability. The advice is mostly about improving capabilities and attracting the new knowledge capital - new people. Instead, this study demonstrates an idea to have a long-term, self-sustainable development by gradually building adaptability. For this, this study identifies conceptual factors - F14, F15, F16, as a result of investigations of IM literature (Schlegelmilch et al. 2003 in Hidalgo and Albors 2008, Moran 2015). In addition, as explained in research methods, this study also enables new concepts to emerge from the data, that have not been identified in the initial list of factors in Section 3.5.

The study also investigated the matter of team structure within the factor F16. The results show that between perspectives of Schlegelmilch et al. 2003 (in Hidalgo and Albors 2008) and Cole (2019), about dynamically changing the team structure to respond to project's needs, the results agree with Cole's perspective. The results confirm that the team structure should stay the same from the start until the end of the project. The data shows that this enables people to understand the project vision fully and to be more dedicated, focused on one main role and one project. As a result of these findings, F16 was removed from the final list of critical factors.

Regarding other factors on adaptability, the results confirm the suggestions on building the openness in the team, derived from Moran's recommendations (2015) on Agile IT management. This also shows that the literature on Agile and innovation can further contribute future studies about BIM team development or general technology adoption in the AEC industry. In addition, as a contribution, the study results provide a number of suggestions to achieve adaptability and responsiveness, such as:

- There should be a certain level of shared responsibilities in the team;
- Learning through practice should be encouraged;
- There should be social learning initiatives;

- Both management and team members should accept that software tools are changing;
- Teams need self-learners within their members.

Section 6.15 shows that self-learners improve adaptability, while those less open to change can cause problems for the whole team. This implies that hiring those who are adaptable, willing to change and learn, is the important point and should be incorporated into the recruitment strategy. A solution could be hiring people who are proven to take initiatives or who can independently learn. This is incorporated within the factor F3 – F27 team set-up.

The findings also confirm the perspective found in IM and KM literature about the connection between the diversity in terms of skills and adaptability (e.g. De Dreu and West 2001, Moran 2015, Nonaka and von Krogh 2009, Nonaka and Toyama 2003). As a result, these two factors are eventually integrated. This is presented in Table 6.29 Final list of factors.

Figure 6.15 shows that openness is very important as it improves planning, communication and learning, all vital aspects of BIM team development (Figure 6.33). Findings also show that there is a need for openness in the team for bottom-up initiatives to succeed. In terms of building the 'openness', suggestions that emerge from the study results are:

- There is a need to bring new policies;
- There is a need to establish BIM mandate and assign new responsibilities;
- There is a need to introduce new policies;
- There is a need to show benefits to all team members;
- There is a need to choose easier software tools and use simple language;
- There should be steering or innovation teams;
- The management needs to allow time, space resources and workshops.

While these suggestions are also discussed and recommended within other factors, by investigating the matter of 'openness' separately, this study was also able to identify how to build a team open to a new practice such as BIM. As a result, the recommendation about explaining benefits and informing people was one of the most often cited responses in interviews that can help the 'openness'.

7.6 Other key findings

There are a few critical factors that are related to all theories - IM, KM and CM, and for those reasons, some of them are discussed individually within this section.

7.6.1 Comparison with models of ICT adoption

The model of Adrianse et al. (2010) for ICT adoption in the AEC industry, is used in this study to show how certain factors help in achieving different motivational factors for ICT adoption (as per Section 0 and Table 3.2). Most critical factors are given the right category, which explains how they contribute to motivation. However, there are also other factors - F6, F11, F13, F14, F15, presented in Table 6.29, that are not easy to categorise into any of the motivational categories. These factors mostly emerge from the literature on IM. Upon the data analysis, some of these factors are confirmed to be vital for BIM team development. These are factors about improving diversity (F6), improving the adaptability of the team (F14) and improving the openness of team members (F15). In the model of Adrianse et al. (2010) the closest category for these factors, F6, F14 and F15, is 'Knowledge and Skills to Use ICT'. However, these factors can be better explained by other models such as the Technology Acceptance Model (TAM) created by Davis in 1989 and new models that emerged from the TAM model, identified in the systematic review – Chapter 2 (Section 2.3). These studies are Lee et al. (2015), Son et al. (2015) and Won et al. (2013), and they present models designed specifically for BIM adoption. In comparison with these models, the factors F14 'adaptability' and F15 'openness to new ideas' can enable the TAM categories 'perceived usefulness' and 'perceived ease of use' (Table 2.1). A comparison with TAM models also shows that TAM models can be useful to categorise factors or to obtain a greater understanding about BIM team adoption.

What is different to TAM models and studies is that this research study provides practical suggestions and in-depth insights on ways to achieve some of the points TAM studies recommend. This research study also acknowledges the role of F5, F6, F10, F14, F15, F19, F21, F24, and other factors not recognised by TAM models. This research study identifies new ideas that have not been mentioned in those studies. Upon the results, these ideas and new factors were confirmed and incorporated into the final list of critical factors presented in Table 7.1, final factors: 6 The culture of trust, respect, understanding each other's role and a safe environment to try new tools; 12 'Experiential learning', 14 'Opportunity for reflection'; 15 'Shared experience, shared learning' and 17 'Integrated team – within the organisation and the wider project team'.

In comparison with these studies, identified in Section 2.3, this study agrees that it is vital to impact people's perceptions. However, some differences exist in ways to address people's perceptions. For example, addressing the 'perceived usefulness' is found more important, than 'ease of use', according to results of this study; and this is slightly different to findings of Son et al. (2015). The other category 'compatibility to existing practice' is important and this is aligned to findings of Son et al. (2015) and Lee et al. (2015). In this research study this is recognised as an individual factor F10 'BIM implementation to support good existing practice'. While the studies by Son et al. (2015) and Lee et al. (2015) are more abstract, the study by Won et al. (2013) provides more specific suggestions, which are the closest to the findings of this study. However, by starting from broader theoretical evidence, of IM, KM and CM theories and by allowing for new findings to emerge from the qualitative data, this study identifies more mechanisms and factors that impact the acceptance of BIM technology. More work could be done to classify and measure this, but that would be out of the scope for this study.

Assigning different types of motivation from Adrianse's model for each factor was found very beneficial to reach a greater understanding of the factors (Table 6.29). Through that comparison, this study concludes that 'personal motivation' and 'knowledge and skills' aspects have the highest impact on motivation and adoption in the team, 'acting opportunities' factors have less impact, while 'external motivation' factors have the lowest impact. This again shows the value of Theory Y approach to managing people; it shows the importance to show how beneficial the new technology is, the importance to clarify the new practice, to engage everyone in the team, to integrate the mixture of knowledge mechanisms rather than to solely apply a pressure to adapt. As a contribution of this study, this finding can help management teams understand where to place the most efforts when creating a development strategy.

7.6.2 New factors on team integration

Being focused on self-efficiency and guides of KM, IM and CM, the initial list of conceptual factors in Table 3.2, does not include factors that make connections with the external environment, outside the project team. However, new, emerging recommendations on inter- and intra-organisational collaboration are found to be significant in contribution, as factors F25 and F26 show in Figure 6.33 and discuss in Sections 6.24 and 6.25. These factors on internal and external team integration – factors F25 and F26, are also aligned to the concept of BIM, as BIM on its own is based on collaboration (Cao et al. 2017, Liu et al. 2017). As a result, the list of factors was expanded with F25 and F26, which were later renumbered in the final list of factors – as final factors 16 and 17 (as per Table 7.1).

In this research study, the topic of team integration emerges from both, the case study and expert interview sets of data. The results in Chapters 5 and 6 show that bringing the team together internally and externally can help communication, knowledge sharing, help in defining vision, capabilities and planning processes. This is aligned to suggestions found in a case study, a conference paper presented by Lindblad and Vass (2015: 180) who recommend for BIM change to occur collectively and include networks of partners.

In comparison with a recent study by Liu et al. (2017), that qualitatively, inductively, investigates how BIM impacts collaboration, the key results about enabling the collaboration are aligned to this research study. However, this research study also finds a number of other factors, such as social learning (F24) and experiential learning (F19) and show how these also help collaboration. This study also finds that there is an impact of having a common vision (F1) on building a collaborative team and other aspects such as – having a team in the same location, collaborative procurement, understanding each other's role and reflection opportunities. This research study also makes a distinction between internal and external collaboration and shows how some factors are cause and some are effects of collaboration. This research study also finds that external team integration is beneficial to help other key factors, particularly:

- Defining strategy and planning,
- Learning,
- Clarity,
- Communication.

However, for the external collaboration to be realised, it needs to be enabled contractually to achieve an alignment of interests and trust.

The concept of enabling the collaboration at all levels, across the project team boundaries, to enable the knowledge sharing can be explained by KM literature. In KM, there is a concept of *ba* which tells how knowledge-creation is not enclosed by boundaries of one team, group or organisation, but belongs to a dynamic wider context (Nonaka et al. 2006, Nonaka and Toyama 2003). In line with this, this study shows that *ba* in the context of BIM team development includes clients, suppliers, subcontractors, steering/interest groups and the project team. The project team cannot be an isolated entity during the development processes.

7.6.3 Top-support, clients' support and vision on the project

As already discussed, having the top-support is one of the key recommendations based on all theories, the systematic review findings and the data (e.g. Mahalingam et al. 2015, Lewin 1951, Kotter 2012, Lines and Vardireddy 2017, Henderson and Ruikar 2010, Maqsood et al. 2007, Zakaria et al. 2013). While the data shows examples where a standalone team managed to develop their BIM skills separately, the data still confirms that for a wider adoption, there is a need for the management support. Providing support and investing time and resources to reach the BIM vision shows that management is committed, which reduces the resistance to change. Other benefits are: addressing the lack of clarity in the team, enabling education, communication and vision distribution, controlling the processes, enhancing the speed of change, motivating people, enabling time to learn, enabling open and friendly environment, integrating the team early and providing finance and resources. This study further contributes by providing in-depth suggestions on how to enable the right level of support and resources needed. These are discussed in Sections 6.13, 6.14 and 7.5.1.

Having the owner's support and the incentive is found vital in results and also in the systematic review studies, such as Mahalingam et al. (2015), Sackey et al. (2015) and Won et al. (2013). Through an analysis of initial factors F3 and F1, this study provides in-depth insights on what is expected from the client. Firstly, it is found that the client's role is the key as it enables other key factors: team integration, collaboration, providing clear requirements, providing enough time and support. According to one of the participants, there is a need for the active involvement of clients and their timely approvals to enable effective communication. Further to that, clear clients' requirements can enable the creation of vision (F1), which is also one of the key factors.

Having a vision is another key recommendation based on both IM and CM; and the data greatly supports this. Figure 6.33 shows that F1 is one of the most enabling factors. While vision is one of the key aspects of IM and CM, it is also one of the common challenges for the AEC industry (e.g. Goodman and Dingli 2017, Duggan 1999, Hidalgo and Albors 2008, Kotter 2012, Maqsood et al. 2007, Poirier et al. 2015c). While being recognised as a challenge in the literature, there are very few BIM management studies, such as the position paper by Miettinen and Paavola (2014), working paper by Kunz and Fischer (2012), a case study by Poirier et al. (2015c), that explain and explore the idea of 'vision' in the context of BIM implementation process.

This research study provides additional, practical guidelines on planning and communicating the vision. In this study, both expert interviews and case study elaborate on the concept of 'vision' and provide contextual, detailed examples in Section 5.1.3.3 and Section 6.1. The case study discussions in Section 5.1.4 also show that one of the key challenges to BIM team development is not having a clear vision, requirements, plan and deliverables. It is also found that the lack of vision has a negative impact on collaboration, expectations and motivation, among other aspects of BIM change. In addition to that, the data explains that the key is to define a clear and tangible vision early before the project starts and to distribute it to a wider team. This study reveals that planning of the vision should be achieved through brainstorming within a wider team and by involving different people who understand the entire process; while distribution should be delivered through face-to-face communication, BIM steering groups and champions. In comparison to the existing IM literature, results are similar to the perspective of Goodman and Dingli (2017), Christenson and Walker (2004) on how vision needs to be created as a team to incorporate different perspectives. This differs from the IM study in architectural companies by Lu and Sexton (2006) where it was created by the top-management, the CM literature by Schein (2017), Kotter and Dan Cohen (2002), the article by Kunz and Fischer (2012), the BIM adoption case study article by Poirier et al. (2015c) and the recent literature review study about BIM implementation by Liao and Teo (2018), who all advise ‘vision creation and distribution’ to be a task delivered by the senior management and guiding teams.

7.6.4 Open and collaborative culture and enhanced communication

Giving people a ‘voice’ is established as important in IM (De Dreu and West 2001), open culture in KM (Bhatt 2002), a safe, non-judgmental environment in CM (Lewin, Schein and Kotter models), while collaborative culture and shared values in studies on implementing BIM (Murphy 2014). These suggestions are confirmed by the vast majority of participants, who also said how these would benefit all projects in the AEC industry not only BIM projects. Results show that open culture impacts communication, enables people to share ideas, views, motivation, enables knowledge sharing and improves clarity within the team. It also emerged that it can be achieved by:

- Having open meeting and workshops in the team, reflection opportunities, including lessons learnt,
- Spending time in the same location,
- Having the leadership that is open to share and ask questions,
- Online portals to ask questions,
- Providing digital access by providing equipment, including internet access and licenses.

The case study results show, however, that this topic is challenging to observe, but the case study results still show that the lack of open culture in the team potentially inhibited knowledge sharing. The results of expert-interviews in the final results, in Figure 6.33, show how open and collaborative culture is within the most enabling factors (F5, F25, F26). In the same Figure 6.33, on a slightly lower level is the factor about the culture of trust and respect (F10), recommended by IM and KM. The data confirms that trust enables the knowledge sharing and data further shows that culture of trust and respect helps communication, openness and resistance to change, therefore, can contribute to CM. Both case study and interview findings also provide some additional practical advice on managing trust (Table 5.3 in the case study) and it is recommended to establish trust on all intra- and inter-organisational levels.

BIM is a technology that improves the project team communication (Miettinen and Paavola 2014, Morlhon et al. 2014), but also findings of this study show that mechanisms of enabling communication in the team are critical for the use of BIM technology (Figure 6.33). The principles of enabling communication emerge from IM, KM and CM. By merging results and theories of IM and KM, the results recommend not only to establish regular and face-to-face communication, but also to focus on the access to information. As a separate factor (F9), it is also confirmed that it is important to establish the reliability of the information that is shared. The results show that this reduces risks, help trust and improves the use of BIM. Current BIM literature largely focuses on ways to achieve this technical aspect, but to add into it, this study provides some practical advice recommended by the interviewees.

7.6.5 Supportive and incremental BIM team development

There is a consensus in findings that there is a need for an incremental and supportive BIM team development process. This idea initially emerged from KM and CM and it presents suggestions and solutions on how to improve the existing practice, particularly the idea of lessons learned (Leonard and Sensiper 1998, Frappaolo 2006, Carrillo et al. 2013, Lewin 1947 in Cameron and Green 2012, Kotter 2012). Further to this, the IM literature in construction explains how it would be challenging to have a radical change due to nature of the projects and the industry, although it would be beneficial to achieve a novel practice (Maqsood et al. 2007, Tidd 2001). The systematic review conclusions are in accordance with these recommendations, that BIM adoption strategy needs to include an understanding of the existing practice and mechanisms to improve it (Hartmann et al. 2012, Babič et al. 2010, Ahn et al. 2016, Arayici et al. 2011b, Dossick and Neff 2010, Son et al. 2015). A radical transformation would need a strong leadership and would require a change to be the most important for the team (Goodman and Dingli 2017), and this in practice is often not achievable. Within the primary data, there are a few opposite perspectives, how disruptive could be more beneficial. However, the majority recognises that due to the lack of skills in the industry, resources, resistance to BIM change and many other reasons (Figure 6.16), BIM adoption should be supportive. It is found that a 'supportive' approach would make people more open to new ideas, which is also one of the factors in BIM team development.

7.7 Summary

This chapter firstly presents the final list of factors in Table 7.1 which addresses the aim of the study "to establish the critical factors for successful BIM implementation and team development processes for the AEC organisations". This is one of the main contributions of this study. Secondly, as a further contribution, this chapter provides the key findings for each of the theories KM, IM and CM, compares them to the primary data results and shows which principles are the most valuable to achieve BIM team development. This achieves the last, fourth objective. As a result, in Section 7.2, this chapter also summarises the challenges that are identified in previous Chapters 2 and 5 and shows sections where these challenges are addressed by specific factors. The following Chapter 8 presents the main conclusions emerging from the study and Chapter 7.

Chapter 8. Conclusions

This chapter presents an overview of the study, including the problem, aim and research methods used in the study. It further presents the main findings and summarises some of the key contributions of the study. It shows the contributions in relations to findings and methodological contributions. It also presents recommendations for the future studies and limitations.

8.1 Research overview

Academic studies in the last few years have recognised many challenges that inhibit BIM adoption and BIM team development, with the strong emphasis on challenges concerning the lack of skilled professionals and practice, and inability of practice and people to adapt. These challenges are presented in Section 1.1 of this study. These challenges are further discussed in Chapters 2, 3 and 5. To help the AEC organisations become more adaptable and innovative, to help them adopt or develop their BIM practice this study established the aim to:

> *Establish the critical factors for successful BIM implementation and team development processes for the AEC organisations.*

This aim was established in Section 1.2. It is found that theories of IM, KM and CM can help to support and contribute to the current body of research by providing guidelines for BIM team development. It was established in Section 1.2 that:

> *By implementing principles identified within those factors, construction organisations will be able to achieve improvements in terms of their individual and team skills, particularly: development of BIM practice, motivation to use BIM technology and practice and knowledge about BIM technology and processes.*

To achieve that, the research applied the case study research method and qualitative survey – expert elite interviews with experienced BIM and managerial professionals from the AEC industry. The study applied Framework and Content Analysis (FA and CA). The protocols and methodology are discussed in Chapter 4.

8.2 Research outcomes

To achieve the aim, there were four research objectives. How objectives are achieved and how they lead to key contributions is presented in Chapter 1 in Table 1.1 and Chapter 5 in Figure 5.5. The summary of findings and contributions is presented below.

The first objective was to identify challenges and development strategies for BIM implementation in the AEC industry. This was discussed firstly in Section 1.1; then Chapter 2 presents challenges identified in the systematic review (Table 2.2). Chapter 5 also discussed challenges that emerged from the case study data and demonstrated how principles of IM, KM and CM could help. These principles are aligned to critical factors identified in Chapter 3. Following contributions emerged from this objective:

- A summary of the challenges emerging from the literature in Chapter 1 and Chapter 2;
- A summary of the challenges emerging from the longitudinal case study data in Chapter 5 and comparison to literature findings in Section 5.1.7;
- In-depth understanding about the real-life practice, achieved in Chapter 5;
- A summary of main approaches (guidelines) to BIM adoption, their benefits and challenges, achieved in Chapter 2 and 5 and discussed in Section 5.1.7 and Section 7.2;
- Further rationale for developing critical factors and for the application of IM, KM and CM theories in Chapter 3.

The second objective was to investigate principles of Innovation Management, Knowledge Management and Change Management that can help BIM team development, within the context of the AEC project teams. This objective was achieved in Sections 1.1.1-1.1.3 and more in-depth in Chapter 3. The contribution of Chapter 3 is in demonstrating how IM, KM and CM literature can benefit practitioners to achieve BIM team development. Interconnectivities between CM, IM and KM literature are also shown (Figure 3.5). The chapter concludes with the theoretical set of factors, in Section 3.5, which is the main contribution of this chapter. This is further evaluated in Chapters 5 and 6.

The third objective was to establish key enabling factors for strategic planning of BIM Change Management process and team development and to critically evaluate the theoretical list of factors established. This is achieved in Chapter 6. Chapter 5 provides additional evidence and shows the processes of preliminary analysis. The following discussion below explains this more in-depth.

The models of IM, KM and CM in this study are used as a lens to understand and interpret the primary data about BIM practice. While the systematic review, review of other studies on BIM management and case study results helped to establish preliminary ideas, particularly on existing practice and industry challenges; the key findings emerged from the universal principles of IM, KM and CM literature and the primary data coming from the expert-elite professionals with years of experience in the UK and other countries. This study enabled new ideas to emerge by focusing on people management issues and by investigating other relevant literature such as Technology Acceptance Models, principles of motivation and studies on ICT adoption that all provided rich and relevant insights.

The aim of the study “to establish critical factors that can positively contribute to BIM team development processes in the AEC organisations and guidelines for the industry practitioners”, resulted in a final list of critical factors for BIM team development. This is presented at the end of Chapter 6 in Section 6.26 and in Chapter 7 – Table 7.1 The study started with the set of 21 conceptual factors and modified, grouped and extended this into the set of 17 factors in Chapter 6. Each of the initial 21 factors and new emerging factors are discussed in Chapter 6. One initial factor is entirely removed and four new factors emerged from the data. As a result of these investigations, better understanding of each of these factors, understanding their impact and interrelations, some of the factors were merged or re-named. Finally, the results present 17 factors (Section 6.26 and Section 7.1, Table 7.1).

The Objective 3 resulted in the following results and contributions:

- Longitudinal single case study: analysis of the existing, large construction project team to map and understand challenges and understand the efficiency of measures in practice. These findings are presented in Chapter 5.
- Preliminary FA analysis of interviews is presented in Section 5.2.2.
- Chapter 6 presents the FA of expert - elite interviews. The primary data about each factor are discussed in-depth. Quantitative data are presented to support qualitative findings.
- Chapters 3 to 6 show a process of developing an analysis model. This model is one of the contributions of the study and can be applied in future studies.
- Chapter 6 discusses each critical factor in relation to BIM team development. Chapter 6 presents the impact of each factor, mechanisms and connection with other factors. This chapter also contains practical recommendations from experts in the industry that can benefit the industry practitioners.

The main contribution achieved as a result of study findings is a validated model of critical factors, presented in Section 6.26.

The last objective was to evaluate existing theories of CM, KM and IM and show how they benefit BIM team development processes. This reflection on IM, KM and CM theories and comparison between the primary data findings and the literature is achieved in Chapter 7. Results of this objective are:

- Key findings from Chapter 5 and Chapter 6 are compared to the existing literature in Chapter 7.
- Existing theories of IM, CM and KM are evaluated. It has been shown that to achieve BIM team development, the AEC teams shall apply these principles together. Some deficiencies of CM literature and other literature are also identified.
- Key recommendations and contributions of the study are also discussed throughout Chapter 7.

8.3 Theoretical and practical contributions of the study and recommendations

In comparison between the primary data, with the emphasis on the expert-elite interview data, and key principles of IM, KM and CM, this study has established the set of critical factors presented in Figure 6.33, Table 6.29 and Table 7.1. This is one of the main contributions of this study. This is achieved by discussing each factor – why is it important, how to implement it, how is it connected to other factors and discussing limitations or diverse opinions. The results highlight that the best results are achieved by providing the management support, improving communication, by having social learning, experiential learning, reflection opportunities, planning as a team, clear vision and collaborative team internally and externally. This set of factors can guide the practitioners. This set of critical factors also benefits by helping to manage people’s perceptions by showing how useful BIM tools are. These factors are also a tool or mechanisms that help practitioners adapt BIM technology to suit their team’s specific needs. These are further contributions from the results.

This study confirms the benefits of having a wider team engagement in the process of early planning and further BIM team development. This idea firstly emerged from the review of IM suggestions, then it was confirmed in CM suggestions. It was not evident in the existing theory how to achieve this practically and to what extent the engagement should ensue. To address that, this study presents practical solutions on how to engage the wider project team by implementing factors such as F21 on reflection or F19 on experiential learning. The right level of people engagement can be further explored in future studies, through case studies to demonstrate how this can be organised in practice.

The recommendations on learning and training are discussed in this study and presented to the public through conference papers and presentations. Some results were also incorporated into online BIM courses at Coventry University. The main recommendation is to combine different types of learning, with an emphasis on experiential learning and social learning. This conclusion emerged from the expert-elite interview data, which shows that the greatest knowledge acquisition occurs when people learn as a team and on real or pilot projects.

Currently, there are not many studies that go into details when they discuss issues such as motivation and knowledge in the AEC BIM teams. Many current studies solely mention issues such as the lack of skills, lack of knowledge or resistance to change, from other references (other BIM studies) or by discussing results from quantitative surveys or case studies, without investigating these challenges. This study, instead, starts with more global and comprehensive management theories that are rarely mentioned in current BIM studies. These theories (IM, KM and CM) helped to discuss these challenges in more depth and also to find solutions. In addition to that, some insights are also taken from the literature on ICT adoption and TAM models. This study also applies different methods, in-depth expert-elite interviews. As a result, this study shows how important it is to engage people and it explains engagement methods, methods of managing perceptions and also methods to achieve better knowledge sharing for BIM team development.

Another contribution of the study is in establishing sustainable mechanisms that are not resource consuming and expensive to implement. When it comes to top-support, CM suggests on-going support and investment over several years to embed the change into practice and management to be constantly with the team (Kotter 2012, Lines and Vardireddy 2017). However, according to other studies on BIM in the systematic review, the investment and cost issues are some of the most significant issues for BIM practice and generally for the construction industry. Therefore, it would be difficult to provide continuous support over several years. For this reason, this study provides alternative ways of creating innovation and knowledge within the team by maximising the resources the company already has and building the adaptability of the team.

This study firstly recommends the application of critical factors presented in Table 7.1. To achieve this, practitioners can read results in Chapter 6 and discussions in Chapter 7. However, to most effectively apply IM, KM and CM models and critical factors, managers need to adjust these for the specific needs of their teams. The study strongly recommends the application of IM, KM and CM theories together for BIM team development, which is one of the main contributions of this study. By applying only CM, IM, KM some of the challenges would not be addressed. This is discussed in Chapter 7. It is also found, as a result of the literature review and the primary data that CM, KM and IM are interconnected – Section 3.5. They are also broad topics, as discussed in Chapter 3, and this study helps managers by summarising key points and identifying critical factors from these theories. Being pragmatic, this study also provides practical means for the industry practitioners, in Chapter 6, that provide detailed insights on managing BIM team development in the industry. This contributes to the body of knowledge, as current journal articles and books do not provide such details when it comes to resistance to change and learning with BIM. An additional benefit is for the industry professionals to understand how to apply IM, KM and CM theories as these theories are not well-known among the AEC and BIM professionals.

8.4 Methodological contributions

This study finds that by applying models of IM, KM and CM and theoretical, conceptual factors identified in this study, it was easier for the researcher to discuss challenges in practice and to analyse the case study data in Chapter 5. The study achieves this by using the Framework Analysis, which has been mostly used by other disciplines, such as psychology and social sciences, as explained in Chapter 4. As a contribution, future studies can implement similar methods to achieve an in-depth analysis of the qualitative data. As explained in Chapter 4, this method is suitable both for individual researchers and teams. The steps are presented in Chapter 4 and further in Section 5.2.

Additionally, in terms of research methodology, this study contributes by applying a dominantly qualitative approach, which is used less in current studies on BIM. By having only tables and matrixes, it was found difficult to establish the role and value of factors. Several topics had the potential to be explored and having fixed variables and relying only on the quantitative data would not allow new suggestions and ideas to emerge from the data. The qualitative data enabled obtaining detailed answers, explanations from experts in the field and enabled comparing results with established theories. Furthermore, results show interconnectivities between the factors, as another contribution of this study. This was demonstrated through maps and diagrams that illustrate connections and show what enablers (mechanisms) and the benefits of each factor are (see also concluding Figure 6.33). All the matrixes and maps, including the final figures in Section

6.26.1, were created based on qualitative findings, where quantitative results were used to check and confirm the qualitative results.

8.5 Areas for future studies and limitations

In Section 8.4, it has been identified that future studies can further explore the topic of people engagement in the AEC teams. Secondly, a recommendation is for future studies not to investigate the project or organisational teams as ‘fixed’ units. This study finds that in the AEC industry, to develop BIM skills, the team becomes flexible and cannot be ‘fixed’. As a result, a new critical factor on external team collaboration (F26) emerged. This aligns to the literature on KM and Nonaka’s concept of *ba* and is confirmed in Chapters 3 and 7.

The final recommendation is for future studies to apply critical factors identified in this study in different AEC teams and present these results. This can be achieved through an action case study or quantitative surveys. Initially, this study attempted to create an action case study; however, due to practical reasons, this was not achievable. The author could not implement this in practice, not being a manager in an organisation. Large-scale quantitative testing could be organised by the Government agencies or other large organisations, that have the power to contact a high number of experts in the field. While these were limitations that determined the research methods in this study, as presented in Chapter 4, the study applied other methods to address these limitations and find better methods to achieve the aim of the study. As explained in Section 8.4, principles established in Chapter 4 and Section 5.2 on conducting an FA can be used for the benefit of future studies. Finally, the principles of this study could also be transferred to a teaching environment.

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Appendix A: Certificate of Ethical Approvals

Ethical Approval P73060 is presented at the beginning of the thesis.

Ethical Approval P53162

Coventry University

Certificate of Ethical Approval

Applicant:

Nada Milivojevic

Project Title:

Interviews data collection

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

24 May 2017

Project Reference Number:

P53162

Ethical Approval P48040

Certificate of Ethical Approval

Applicant:

Nada Milivojevic

Project Title:

Case study data collection

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

18 December 2016

Project Reference Number:

P48040

Appendix B1: Interview guide for BIM management professionals

Interview questions

	Questions
1.	Could you describe your current position in your organisation?
2.	Please describe your experience with BIM projects briefly.
3.	In your opinion, what are the key components to successful BIM implementation? (Additional) Could you give me an example of how was this achieved on one of your projects?
4.	What was the greatest change for your team while you were adopting BIM practice?
5.	a) Could you give me an example of some initiatives which helped BIM development process in your organisation and your project team? b) In your opinion, are there any other solutions which could help BIM team development?
6.	What has been your most valuable learning experience relevant to BIM working practice?
7.	a) Which training approach did you use for the staff development? What other training solutions could benefit the BIM project team? b) What is your opinion on the trial-and-error learning?
8.	a) Could you describe the communication strategy on your BIM project? (Additional) How does communication occur in your team? b) Could you propose any other communication solutions which would help meeting your project BIM objectives? c) Does your team have open meetings to brainstorm what has been achieved and what could be improved?
9	a) In your opinion, which approach is the best route to BIM implementation, top-down or bottom-up? b) Which approach was deployed in your organisation, top-down or bottom-up? c) What is your opinion on having a shared leadership or decision making on a project.
10	Finally, in your opinion, how should an effective BIM project team look like? For example, in terms of culture, roles and responsibilities, team structure, skills, vision, leadership or control.
11	Should BIM implementation be radical or support the existing practices? May I ask why that is your opinion?
12	What challenges did you face during the BIM implementation?
13	How did you overcome some of these challenges?
14	There are a few other barriers I would like to discuss in-depth. What is your experience with and what could be a solution to: a) Lack of commitment; b) Lack of clarity; c) Lack of trust; d) Communication challenges; e) Resistance to change.

15	Could you explain your organisational BIM objectives briefly?
16	What elements of BIM are implemented on a project you are currently working on?
17	What are your BIM project objectives?

Thank you for your help and your responses.

Appendix B2: Case study interview guide

Interview questions

	Questions
1.	Could you describe your current position in your organisation?
2.	Please describe your experience with BIM projects briefly.
3.	In your opinion, what are the key components to successful BIM implementation? (Additional) Could you give me an example of how was this achieved on one of your projects?
4.	What was the greatest change for your team while you were adopting BIM practice?
5.	c) Could you give me an example of some initiatives which helped BIM development process in your organisation and your project team? d) In your opinion, are there any other solutions which could help BIM team development?
6.	What has been your most valuable learning experience relevant to BIM working practice?
7.	Please choose between a and b: c) Which training approach did you use for the staff development? What other training solutions could benefit the BIM project team? d) Which training did you attend to develop your BIM skills? Is there any other training you would like to attend? e) What is your opinion on the trial-and-error learning?
8.	d) Could you describe the communication strategy on your BIM project? (Additional) How does communication occur in your team? e) Could you propose any other communication solutions which would help meeting your project BIM objectives? f) Does your team have open meetings to brainstorm what has been achieved and what could be improved?
9	d) In your opinion, which approach is the best route to BIM implementation, top-down or bottom-up? e) Which approach was deployed in your organisation, top-down or bottom-up? f) What is your opinion on having a shared leadership or decision making on a project?
10	Finally, in your opinion, how should an effective BIM project team look like? For example, in terms of culture, roles and responsibilities, team structure, skills, vision, leadership or control.
11	Please choose between a and b: a) How was BIM implementation achieved in your team, to support the existing practice or was it a radical change? b) Should BIM implementation be radical or support the existing practices? May I ask why that is your opinion?
12	What challenges did you face during the BIM implementation?
13	How did you overcome some of these challenges?

14	There are a few other barriers I would like to discuss in-depth. What is your experience with and what could be a solution to: f) Lack of commitment; g) Lack of clarity; h) Lack of trust; i) Communication challenges; j) Resistance to change.
15	Could you explain your organisational BIM objectives briefly?
16	What elements of BIM are implemented on a project you are currently working on?
17	What are your BIM project objectives?

Thank you for your help and your responses.

Appendix B3: First, structured interview draft

Extract from the interview draft

Background questions

- What is your role in this organisation?
- Please describe your experience with Building Information Modelling (BIM) projects briefly.

Additional questions:

- What is the experience with BIM implementation and development in your organisation?
- How was the implementation managed and what were the challenges?
- How was the training managed? What were the objectives of the training?
- What are the future goals with BIM implementation and training?

Main questions (extract from the original draft, example for the first four factors):

Topic	Main questions	Additional helpful questions
1 vision	The change management literature talks about the importance of establishing one common vision for the entire team or organisation. This vision should be one sentence, which briefly explains organisational BIM goals. When it comes to BIM implementation and BIM team development what is the vision of your team? How important is it for everyone to be involved in the process of creating one common vision? Less relevant / relevant / very relevant How was the vision established and communicated to your team?	How can aligning vision help BIM team development?
2 Identifying future actions / strategy	Do you discuss and plan your future actions as a team? How would you rank the importance of this? Less relevant / relevant / very relevant	When it comes to BIM development, how would you suggest a team strategy?
3 Ensuring top support	How important is it for you to have the support of the top management? Less relevant / relevant / very relevant	As a manager, how would you ensure this on a BIM project? (for managers) How is this achieved in your organisation? (for others)
4 Clarity about change management program	When it comes to BIM change and development strategy of the company, how important is it for people involved in BIM projects to clearly understand all aspects of it? Less relevant / relevant / very relevant How is this clarity achieved in your team?	May I ask why is that your answer? How clearly do you understand the BIM development program of your organisation?

Appendix C: Expert interviews framework analysis - example

An extract from the 'preliminary analysis' is presented below. Only a part is shown, as the original, full document had around 40.000 words. The text includes the first, preliminary conclusions from the interviews, it also:

- Contains new titles for factors which emerge from the interview data,
- Contains the summary, comments, quotations and conclusions,
- Coding: e.g. I1 means 'expert interviewee 1'.
- Colour coding system shows the importance of the factor; red – high importance, amber – important, green – less important.

Factor 1. Aligning vision

Participant code	**Name of the factor** Preliminary analysis findings
I1	**Aligning vision – clear, common vision** Creating and having a common vision. The vision should be clear to everyone and be a common idea, agreed between parties. Having clear 'information requirements' was mentioned with F1, as it can help to enable the vision (ref: I1 00:10:25, 00:27:44). The clarity of requirements should come from the top management (00:27:44). F1 is about setting up strategical and tactical goals (00:07:28) that will benefit the team. Everyone should have a constant understanding of the vision (00:16:49).
I2	**Clear, common vision** The importance of vision is recognised as one of the key factors. Although it is always important to distribute it to a team, it is not always "agreed as a team", I2 explained. A sub-factor recognised is 'clarity of requirements', a critical sub-factor mentioned multiple times. Vision means showing the benefits, changing people's perception to be less fearful.
I3	**Clear, common vision** It is recognised that teams should have a vision. This vision is decided top-down with the engagement of the team, then it is clearly distributed to the team. This interviewee also recognised the importance of having clear requirements which can go under having a 'clear vision'. 'Vision' also means showing the benefits and changing people's perception.
I4	**Aligning vision, clear outcomes (new emerged title)** The importance of vision is recognised as one of the key factors. It is also mentioned several times that it is important to find - "why are we doing this", "what are the benefits", "what are the outcomes". This is, at first, between project representatives and the client, then is distributed within the team. A sub-factor is 'clarity of requirements' and it is a critical sub-factor mentioned multiple times (e.g. p.6, p.17). It is also important to show requirements in terms of the level of detail and the level of information. Showing people benefits was the main technique used to address fears and resistance to change. 'Educating the client' can go under this factor, or it can become a separate factor as "showing project team and the client benefits and educating them".

This is an extract from the preliminary data analysis. The full transcripts and the preliminary interpretation cannot be published due to its length and the confidentiality of the data.

Appendix D: Observational reports – additional data analysis

As explained in the research methodology, the researcher developed a framework that helped to write a diary on what has been achieved and observed each week in December and January. Same reports were written again but for the whole period of June-August. This was due to the limited access to the company. An example of the transcript is presented below. The researcher here also presents the part of the analysis of those transcripts (the initial analysis had around 7000 words). This is later compared to interview findings, as interviews were conducted after observations.

Case study weekly diary transcript example

Observational report 5-9th of December 2016

This report is confidential and its exact content shall not be shared with external parties - anyone who is not part of my supervisory PhD team or anyone who is not in the management team of (the project team). *Therefore, an extract from it is abbreviated and presented in this Appendix.* It is written for the purpose of:

- Collecting the case study data;
- Comparing the data weekly and monthly.
- Developing general conclusions about the case study;
- Developing principles of change management best practice;
- Further modifications of theoretical factors.

And for the purpose of effective project delivery:

- Understanding project vision;
- Understanding project and team goals;
- Mapping challenges and opportunities;
- Developing potential solutions and strategies to those challenges.

Week 5-9th of December

Project goals:

Although all parties have the same project vision, there are different specific goals depending on a party. Some people are interested solely in transferring the data from the site to the project team (in any format), simply documenting the fieldwork. Some people are interested in transferring the data from the site to a BIM model. Other parties are interested in sharing the data (mainly drawings) from the design team to the site and marking.

This is an extract from the data. The full transcripts cannot be published due to the confidentiality of the data.

Framework analysis findings

	Factors * Not included in the list of factors	Category	Explanation X – means no findings
1	Aligning vision (agreeing on a common vision)	Common vision	There should be a unique common vision on the project. I have to understand parties and their perspective more, but the first impression is that parties are willing to collaborate, share

			information but not necessarily share the same objectives and vision. The vision and goals should be aligned.
2	Planning future actions as a team	Culture and planning	There is a practice of involving a number of parties in the decision-making and action planning, which should produce the best possible ideas. There is a room for improvement in terms of involving some other parties and teams.
3	Establishing top-support	Top support	X
4	Clarity about the change process	Change management vision - objectives	There is little clarity on what are exactly change management goals, but this observation could be wrong and subjective as the observer is just starting to understand the project and the team. The preliminary findings are that the team aims to: • Change tools, • Improve tools, • Learn new tools, • Change behaviour in terms of how to utilise the tools: "without downloading everything".
5	Ensuring an open culture	Culture	There is already an open environment to an extent. There is an idea and willingness to have a "virtual open culture" and share the data online as well, but there are technical limitations (questions around the interoperability, who is responsible for organising this environment virtually and how to manage the access, what are tools, what are limitations). There are huge opportunities in certain software tools. The management has the idea to create one database for all members to see it (on-site and from the office). The access to this is currently limited, but this could be beneficial because parties can get just the right amount of information to support their needs. Too much information could be confusing, hard to manage and create unnecessary data storage.
6	Diversity in the team (e.g. skills, roles)	Team building	X
7	Communication digital and non-digital information exchange	Communication	The good practice is that parties are trying to understand each other's perspectives, needs and explaining their own needs and concerns. Communication is enhanced with referencing to other familiar tools which contribute to better general understanding. There are technical limitations in terms of interoperability of applications which might reduce the information exchange. It is currently not known how the information will be shared between applications to support everyone's needs.
8	Enabling access to information	Communication	Ideally, the drawings would not have to be downloaded but accessed through an app. This is important because portable devices do not have enough storage capacity.

This is an extract from the observational report data.

Analysis of observational transcripts - example

The text below is an extract from the original analysis of observational transcripts. A part is presented due to its word count and the confidentiality of the data. The key findings are presented in Chapter 5.

1. Aligning vision– a very important factor

The initial understanding of this factor: For this, specific, project team, the vision should briefly explain why and how they are implementing BIM. It should explain what they are trying to achieve with BIM tools and BIM working practice.

In December, parties were willing to collaborate and share information, but they did not have the same objectives and the same vision (O1). They had several meetings to discuss what can be achieved, what are the opportunities. Therefore, they were working towards the creation of the same BIM project vision, but this process was very fragmented. 'Fragmented' means that they were discussing multiple topics around BIM, or software tools separately, without discussing the overarching goals and vision.

- New understanding of the factor: Defining BIM vision is a process of consulting a number of relevant parties, mainly middle and senior managers for the project, to achieve a consensus of what they need and what can be useful for them. This process has the potential to bring the team together, but it also has a challenge, regarding the difficulty to involve all parties.

This is an extract from the data evaluation.

5. Ensuring an open culture

This means having an open culture in the project team.

It was not clear from observations if an open virtual environment and the use of CDE improved the open culture in the team. Although now the project information was being stored and shared with different parties within the internal and external team, the access was limited and controlled, as suggested by the industry standards. Not all information was available to everyone. The conclusion was:

- There is little information about the state of open culture in the team. While managers are trying to inform others more on decisions, there is still resistance to share the information.

This is an extract from the data evaluation.

8. Enabling access to information

The project team was working since December to employ the best technology to support the information access. The ability to access information was one of the main criteria in the choice of software, as well. They were trying to avoid any solutions where drawings or models needed to be downloaded. They were trying to make them accessible from the site using portable solutions. Other software solutions enabled them to access the model, through the browser rather than through a software which would demand a download, computer capabilities and software licenses. The licensing was an issue, because software providers did not cover the entire team, therefore the number of licenses was very limited. Another reason why they wanted an access through a browser is because the portable devices do not have large storage capacity. Another issue was Wi-Fi on-site (O1-8). Particularly for the site management, they were looking for solutions where they can view the model and drawings and add comments, photos, checklists and access simple documents easily if possible (O1-8), without downloading the full model.

There is a connection between this factor and the integration of the team. An effective information access also affected the decision-making process. *The remaining text cannot be published due to the sensitivity of the information.*

Main conclusions were:

- Effective information access means enabling people to access the right amount of information they need, to deliver the project successfully. It also means providing the technical support to enable this.
- This is a significant factor. It is strongly connected to other factors such as action planning, decision-making and team integration. It improves the challenge - lack of clarity.

This is an extract from the data evaluation.

This is an example of FA of the observational transcripts. The final results of observations, the documentary data and interviews enabled results in Chapter 5.