AN INQUIRY INTO THE ADOPTION PROCESS OF BUILDING INFORMATION MODELING IN ARCHITECTURAL PRACTICE

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ABSTRACT

AN INQUIRY INTO THE ADOPTION PROCESS OF BUILDING INFORMATION MODELLING IN ARCHITECTURAL PRACTICE

Architectural practice went through various changes in time to adopt emerging technologies. Current and developing Building Information Modelling (BIM) technologies enables the integration of project partners in early phases of a project life cycle, differing from traditional project delivery processes. Since BIM impacts people, process, and technology (PPT), the adoption of BIM invites radical transformations in these aspects. The aim of this study is to investigate BIM adoption in small design offices from a socio-technical perspective by focusing on individuals' experiences to analyze the motivation for BIM adoption, the factors in adoption, and the strategies through which BIM is integrated into the architectural design processes. Case study analysis is used as the research method and data was collected through five interviews from two offices. Afterwards, analytical coding was implemented to analyze the data.

Findings demonstrated that the level of BIM adoption is related to the coevolution of PPT. The inefficient workflow of previous processes was found to be the main motivation for BIM adoption. Whereas the impact of people was a major factor in the adoption phases on the strategies for adoption and barriers in adoption were mainly human related. People were a critical factor in making the decision to go through the adoption. Technological aspects, instead, were considered later when the decision on adoption was given. These findings showed that the impacts of BIM adoption factors, PPT, vary throughout the BIM adoption phases. The major human-based issues in early phases of adoption showed that to implement BIM in current workflows a socio-technical approach is essential.

Keywords: BIM; BIM Adoption; Technology Adoption; Case Study

ÖZET

MİMARLIK PRATİĞİNDE YAPI BİLGİ MODELLEMESİNE GEÇİŞTE ADAPTASYON SÜRECİ

Mimari pratiği, ortaya çıkan yeni teknolojileri benimsemek için zaman içinde çeşitli değişikliklerden geçmiştir. Bir trend olarak, Yapı Bilgi Modellemesi (YBM), bir projenin tüm paydaşları için geleneksel proje teslim süreçlerinden farklı olarak proje yaşam döngüsünün erken aşamalarında proje ortaklarının entegrasyonunu sağlayan ortak bir 3B dijital çalışma ortamı sağlar. Bu nedenle mevcut çalışmalarda BIM hem bir teknoloji hem de bir süreç olarak görülmektedir. YBM'nin insanları, süreçleri ve teknolojiyi (PPT) etkilemesi nedeniyle, YBM'nin benimsenmesi bu yönlerde radikal dönüşümleri davet etmektedir. Bu çalışmanın amacı, YBM'yi benimseme motivasyonunu, benimsemedeki faktörleri ve YBM'nin farklı mimari tasarım süreçlerine entegre edildiği stratejileri analiz etmek için bireylerin deneyimlerine odaklanarak küçük tasarım ofislerinde YBM'nin kabulünü sosyo-teknik bir bakış açısıyla incelemektir. Yöntem olarak vaka çalışması analizi tercih edilmiş ve veriler iki ofisten beş farklı katılımcı ile gerçekleştirilen röportajalar yoluyla toplanmıştır. Daha sonra verileri analiz etmek için analitik kodlama uygulanmıştır.

Bulgular, YBM'nin benimsenme seviyesinin PPT'nin birlikte evrimi ile ilgili olduğunu göstermiştir. Zamana dayalı bir bakış açısıyla, önceki iş akışının verimsiz süreçleri, YBM öncesi aşamada benimseme için ana motivasyonu olarak analiz edilmiştir. İnsan faktörü, benimseme aşamalarındaki stratejiler üzerinde önemli bir faktörken, bu aşamadaki engellerin de esas olarak insanlarla ilgili olduğu görülmüştür. İnsanlar, YBM'yi benimseme kararının verilmesinde kritik bir faktör olarak ortaya çıkmıştır. Bunun yansıra teknolojik faktörler, YBM'nin uygulanması kararı verildiğinde ve ofislerde YBM'nin benimsenmesi kabul edildiğinde daha fazla dikkate alınmaya başlanmıştır. Bu bulgular, YBM benimseme faktörlerinin (PPT) etkilerinin YBM'yi benimsenme aşamaları boyunca değişiklik gösterdiğini göstermiştir. Benimseme sürecinin erken aşamalarındaki başlıca insan temelli sorunlar, mevcut iş akışlarında YBM'yi uygulamak için sosyo-teknik bir yaklaşımın gerekli olduğunu göstermiştir.

Anahtar Kelimeler: YBM; YBM Benimsenmesi; Teknoloji Kabulü; Vaka Çalışması

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LIST OF ABBREVIATIONS

AEC	: Architecture, Engineering and Construction
AIA	: American Institute of Architects
BIM	: Building Information Modelling
CAD	: Computer Aided Design
CADD	: Computer Aided Drafting and Design
CPIC	: Construction Project Information Committee
NIBS	: US National BIM Standard
PPT	: People-Process-Technology

CHAPTER 1

INTRODUCTION

Architectural workflows are constantly challenged today due to emerging technologies and their adoptions. The architectural practice went through a series of changes from traditional workflows to innovative approaches (Saka and Chan 2020). Each technology creates a new way of design communication, workflow, and process which as a result leads designers to modify their *"way of doing"* and know-how. Building Information Modelling (BIM), a common virtual 3D work environment supporting collaboration of all stakeholders throughout a project's lifecycle, has created an innovative change in the entire construction project process in terms of working habits both within a team and among teams. While it affects the working culture at the individual level, it also appears as a multidimensional radical change as it also affects the whole project process at the organizational level. The traditional design-bid-build project model is being replaced by Integrated Project Delivery model (IPD) that involves all stakeholders in the project design period at a much earlier stage (Kensek and Noble 2014). One of the challenges of Integrated design is that participants need to unlearn their way of doing. The routine workflow in architectural practice is challenged through integrating all project partners to the design processes. Therefore, the traditional "way of doing" of an architect throughout design phases is challenged in socio-cultural and socio-technical aspects (Sackey, Tuuli, and Dainty 2015, Deutsch 2011, Oraee et al. 2017, Arayici et al. 2011). One of the common remarks on BIM is that it encourages collaboration among project stakeholders (Deutsch 2011, Eastman et al. 2011, Azhar, Khalfan, and Maqsood 2012, Oraee et al. 2017, Park and Lee 2010). Although collaboration among people seeks to increase performance and efficiency in the project life cycle, it's outcome in practice necessitates many changes at different levels and in different dimensions (Deutsch 2011), which is a complex transformation in a social environment with people from various disciplines. The challenges involved in adapting to changes arising from BIM implementation is radical in the sense that the adoption is regarded as an unlearning process rather than building upon already existing body of experience and knowledge.

The definition of BIM itself is a research area in the BIM literature (Mandhar and Mandhar 2013, Alliance 2012) (Table 1).Various studies indicate that BIM does not have a commonly accepted definition (Latiffi, Brahim, and Fathi 2014, Migilinskas et al. 2013, Jernigan 2008).

Table 1. Definitions of BIM in literature.
(Source: Mandhar and Mandhar 2013, Alliance 2012)

Definition of BIM	Authors/Scholars/ Researchers/ Organisations
Category A) Process /Technology/New way of working	(Building Smart, 2010:1)
"Process of generating and managing data about the building, throughout its entire life cycle"	(Smith, 2011)
"A collaborative process of design, procurement and building operations''	(NBS, National BIM report, 2012)
'The process view' with three categories as Intelligent representation of data – authoring tools, Collaboration process and a facility lifecycle management.	(National Institute of Building Science, 2007)
"A disruptive technology" as it will transform many aspects of the AEC industry.	[(Eastman et al, cited in Sabongi, J.F) (Davidson, 2009)]
Category B) Product/Digital model with information structured and shared in a 3D / 4D / 5D right to 'nD'	(Building Smart, 2010:2)
"Digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition"	Joint definition by (RIBA, CPIC & Building Smart for the UK Construction Industry)
Category C) Intelligence Migration from 2D to 3D and creating intelligent and multi-dimensional building models.	(Ready, 2007 cited in Sabongi and Kymmell, 2007:31)
"Intelligent simulation of Architecture" exhibiting the following six key characteristics : digital, spatial (3D), measurable, comprehensive, accessible and durable.	(M.A.Mortenson Company); (Eastman et al, 2008:13)

People and users in the Architecture, Engineering and Construction Industry (AEC) are creating their own definition of BIM based on their use or experience with the technology. This makes it difficult to create a consensus on what BIM is and obstructs to have a common understanding of BIM in the industry (Abbasnejad and Moud 2013). BIM, which covers the process from the early design phase to the demolition of the building, has different uses for different team stakeholders involved in this process. For a design team, BIM can be regarded as a physical 3D representation of design elements depending on various parameters, while for a contractor, BIM can be defined as a technology that simulates the construction phases step-by-step and reveals the process based on time before it is implemented in the field (Abbasnejad and Moud 2013). These various understandings among users on the concept of BIM makes it difficult to benefit from the technology effectively, to have the right expectations and to get precise answers about what will be encountered with the adoption of BIM. Consequently, these uncertainties might obstruct and create difficulties in the adoption of BIM in architectural offices and this process might be significantly easier or difficult given the nature of architectural offices. In this study, this is proposed as an assumption to be further inquired through case studies of two architectural offices with different work portfolio and work culture. Here it is assumed that people resist adapting to a new technology and process that contains uncertainty. In the case of the adoption of BIM as a design and representation tool, there are even more doubts given that there are concerns about how well BIM could be implemented in the early phases of design. The designer-based problem-solving practice in early design phase is related to the expertise of the designer in the profession. Because expertise in the profession is gained through experience, designers with this expertise are considered to have a settled work process. This established routine can make it difficult to adapt new tools and processes. Therefore, the integration of BIM into the design processes is assumed to be closely related to the people involved in the design process.

1.1. Research Problem

An architectural design project is a network of collaborative design environment both in terms of design and process starting with the first ideas formed in the early design phase. The design idea is developed through the externalization of the idea with the use of certain design tools. In general, architectural design process is the distribution of information and an external visual representation through tools to support the architects' reasoning, problem solving and a talkback (Dogan and Nersessian 2002). The process is unique to the designer in which it is not searched for a single solution to a certain problem and the tools that are used in this process are in a direct relation with the development of the design.

The complexity of contemporary design problems requires different approaches to the problems than the traditional ones (Haider 1986). At this point new tools and methodologies help architects to deal with these emerging architectural complexities and some of these, such as BIM, are supporting architects to change the methods they use in their professional practice (Kalisperis 1988). With the development of computational technologies and shift from computer aided design tools to object-based 3D digital modeling in architectural practice, the process that an architect faces in both design phases and workflows becomes a significant research area.

This study inquiries into the adoption of BIM, here considered as a process and design tool beyond mere representation of design ideas, in the architectural design. For such an inquiry, it is essential to have a general overview of conventional (sketch, physical model, technical drawing, perspectival drawing, conceptual diagrams) and computer-based design tools (CAD drawings, 3D modeling, rendering, parametric design) in order to analyze the role of tools in architectural work culture.

Kalisperis and Groninger (1994) writing on the integration of computers in architectural practice and the roles of CADD (Computer-Aided Drafting and Design) systems in the architectural practice, discuss the differences between drafting and design. In their research, CADD usage during different phases of design is explored through case studies of architectural firms, which are categorized according to the firm size, similar to the study proposed here (Kalisperis and Groninger 1994). In another study, Hoeben and Stappers (2005) mentioned the early design phase as a nonlinear process and claims that computer tools such as CAD programs are suitable to work on a single document until a final solution comes up in a linear process. As a result of this study, CAD programs are designated as appropriate for final stages of the design process rather than in the non-linear design process in early creative stages (Hoeben and Stappers 2005). As early as in 2001, at a conference workshop in Seattle, researchers and practitioners from various fields, industrial design, software engineering, intelligent systems, including human–computer interaction and design studies, were gathered to discuss how computational approaches could be better integrated with the early phases of design (Nakakoji 2005). The aim of the group was to study on what computers support and how they support.

There is an extended literature on conventional design tools, which can be listed as sketching, technical drawing, physical modeling, conceptual drawing, and on their role in the process (Grigar 2012, Herbert 1993, Suwa and Tversky 1997, Nakakoji et al. 2000). Both in educational and professional practice, the whole process of architecture performed with conventional tools are studied in detail (Akin 1990, Gero and Mc Neill 1998, Goldschmidt 1994, Schön 1992, Rittel and Webber 1973, Saferstein 2017, Nakakoji and Yamamoto 2001). This large source of literature provides a strong foundation to base this study on the interaction of tools, human, and workflows.

In this study, it is assumed that the design idea is developed and finalized through a set of design representations provided by all design consultants and project members. While BIM adoption has certain difficulties regarding how well it is suited to the early phases of design, the work culture of everyone in the design team and of the organization the individuals work in might add additional strains or might ease the process of adoption. While each design team has its own working culture and each member of the contributes to it at his/her individual level, there is also an organizational and operational structure specific to each project. The collaboration of all these professionals in different scales entails certain complexities. Therefore, the question what BIM adoption in practice is, has a unique answer to each architectural project experience.

1.2. Research Aim and Objectives

The aim of the study is to examine the experience of architectural offices in adopting BIM and the impact of the adoption on the architectural practice within the team and between the teams within a socio-technical perspective. The study also seeks to increase awareness on what experiences will offices face during and in the early phase of BIM adoption.

To achieve this aim, the following objectives are determined.

- To understand the motivations for BIM adoption in architectural teams
- To understand the factors in BIM adoption through an approach that focuses on individuals' experiences
- To inquire the procedures through which BIM is integrated into the different phases of the architectural design process

1.3. Research Questions

The study aims to investigate the following research question: *How does the adoption of BIM experienced in architectural practice differ regarding the characteristics of design offices?* In this thesis, the adoption process is investigated by specifically identifying and comparing the features of three phases: The architectural practice of an office before BIM adoption, the architectural practice after the adoption, and the adoption process itself. From that point of view, the research question addresses all three phases and seeks to find answers through understanding each phase regarding its repercussions for people, process, and technology (PPT). Therefore, the research question can be divided in three sub parts. Regarding the phase before BIM adoption (pre-BIM period): *What are the features of a routine architectural practice?* This question aims to understand PPT issues before any BIM adoption. The second sub question is: *How is the architectural practice experienced after the adoption?* This question addresses to understand PPT issues after the change, i.e., post-BIM period, where architectural practice retrieves to a new routine. Lastly, with the adoption process itself, an inquiry into a change process starting with motivation for adoption, strategies, change management on different levels and ending with the new routine is meant. While the previous sub questions focus on architectural practice, the sub question on the adoption process aims to investigate the question in a collective manner, by focusing on the workflow, social relations, communication channels, technological and technical issues, briefly socio-technical aspects, faced in this period. The specific focus at this stage is to study how BIM supports a collaborative workflow between teams, the strategies, difficulties, and innovations during the adoption phase. So, the sub question here is: *What are the strategies, difficulties, and levels of adoption in terms of PPT?*

1.4. Outline

The thesis consists of seven chapters. Chapter 2 introduces BIM literature and investigation of its adoption in architectural offices under five heading. The first heading, Introduction to Building Information Modelling, provides general information on BIM and its definitions in reference to existing literature. The heading concludes with the information on current BIM status of Turkey. In the second heading the global and national definitions of small business are given. Afterwards, the challenges of small firms are explained in the third heading. The fourth heading describes the common phases of architectural practice in small scale offices in Turkey. Lastly, the fifth heading provides insight on BIM adoption and its factors based on existing literature. Chapter 3 describes the research method used in this study and gives detailed information about the cases of the study. The research approach, characteristics of case study, weakness and strengths are explained in detail. The chapter also provides information on data collection and data analysis methods. The two cases analyzed in this thesis are introduced in Chapter 4. The interviewed participants, namely key players in BIM adoption, are introduced under the same section. The super ordinate categories, generated from the findings of analytical data coding, are then presented in Chapter 5. The findings are categorized under three headings in Chapter 5. The results introduced in this chapter are discussed in Chapter 6 under two headings. The critical factors of technology adoption PPT and the relations of the findings to these aspects are discussed in general means. Then, each factor is discussed within a time-based manner introduced in the previous chapter. Finally, the thesis is concluded in Chapter 7 with a summary of the thesis and recommendations for further studies.

CHAPTER 2

BIM LITERATURE AND INVESTIGATION OF ADOPTION IN ARCHITECTURE OFFICES

This chapter starts with an introduction into the term Building Information Modelling (BIM). After that, the chapter explains architectural practice in Turkey including an overview on the relations of team members and relations of stakeholders to understand the social structure of the AEC Industry in Turkey. Finally, this chapter concludes with an investigation on BIM adoption and its relation to technology adoption theories in literature and examines critical BIM adoption factors and their impacts on the adoption phases.

2.1. Introduction To Building Information Modelling

The BIM technology is not new in the AEC Industry. The use of computer systems as a design communication tool with virtual models was first envisioned by Charles Eastman in the 1970s with the name Building Description System (Eastman 1974). The term Building Information Modelling was then used for the first time in 1992 (van Nederveen and Tolman 1992) and the worldwide usage of BIM became common in the mid-1990s with the development of technology and computer systems that can support the BIM technology (Abbasnejad and Moud 2013). According to the report of National BIM Standard-US (NIBS), the wide interest on BIM occurred due to CAD applications' 2D and non-integrated data, which cannot be effectively used as information in facilities lifecycle (National BIM Standard-US (NBIMS-US) United States: The National Building Information Model Standard 2007). Other studies (Abrishami et al. 2014) claim that the adoption of new technology is motivated by the shift into performance-based design in the AEC Industry. So new technologies that support the needs of the change in design intent are preferred to be used in projects.

There are two most used definitions of BIM. The US National BIM Standard defines BIM as (NIBS, 2012):

> *Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (Alliance 2012, 3).*

The Construction Project Information Committee (CPIC) defines BIM as "...digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition" RIBA (2012: 3).

Building Information Modelling is both a technology and a process (Azhar, Khalfan, and Maqsood 2012). BIM, as a technology, allows to create and share a 3D model and its building information which serves as an information database throughout the life cycle of a project. An entire project lifecycle includes design phase, construction phase, operation phase, and maintenance and BIM aims to connect teams, workflows, and model data all along the lifecycle of a project (Autodesk).

CAD tools provide drawings based on the geometries of elements, represented through vectors. With the development of 3D modelling tools drawings become object oriented and enables to share more data of the simulated model elements. Components of the designed object 3D models are intelligent elements based on parametric rules. The elements include information on their behavior such as specifications and energy analysis. Due to the parametric rules of the object, any changes on a component are automatically updated in other related representations of the component. This prevents redundant and misleading information in the model (Eastman et al. 2011).

The Architecture, Engineering and Construction Industry (AEC) experiences a technological and procedural change through BIM adoption (Succar 2009). In a procedural manner, BIM encourages integration of the roles of all stakeholders on a project that provides a simulation for an interdisciplinary collaborative design process enhancing multidisciplinary collaboration. In this study, BIM integration is considered to be essential at an early phase to foster the input of all stakeholders in the design process as early as possible recognizing that this might pose a special difficulty given the ambiguous nature of the early design phases. Additionally, there are socio-cultural issues that need to be addressed. Social interaction is essential where cognition is not only an internal mental process, but also a social process (Saferstein 2017). So, besides the technological adoption of BIM, the process of change also includes a change in the socio-cultural context.

It is essential to understand how a technical data-based design tool, BIM, is shaping the design process of an architect in the early phases, where it is believed that the main decisions of a design are taken.

2.1.1. BIM Status of Turkey

The digital transformation in the construction sector and the change in professional practice has also its impacts on the Turkish AEC Industry. From that point of view, it is essential for this study to understand the particular situation of the construction sector in our country in terms of the use of BIM technology.

The BIMgenius community prepared the Turkey BIM Report to determine the status of the use of BIM technology, which represents a pillar of digital transformation in the construction industry, as a starting point for understanding the opportunities and problems in the case of Turkish AEC. BIMgenius is an interdisciplinary platform aiming to bring together professionals related to BIM and digital design technologies and is a community that seeks solutions to the problems of the construction industry with almost 900 followers (BIMgenius, 2018). The research presented in their report is based on a survey study designed to understand the problems and expectations associated with the use of BIM technology in Turkey. The report shows results on participant profiles, BIM experience and organization size, geographical distribution of BIM Experience, BIM use and awareness, BIM maturity levels, basic software used, document management, coordination and parametric design, educational preferences for BIM platforms, problems with BIM education, awareness of BIM-related standards and concepts, problems

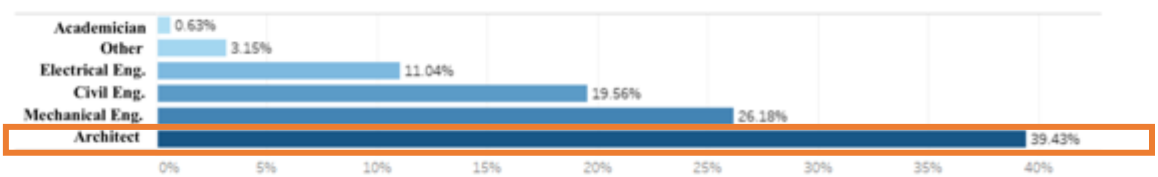

Figure 1. Distribution of survey participants by discipline.

(Source: BIMgenius 2018)

working with BIM and BIM training, the software Training Plans in 6-12 Months, and supplementary user comments on BIM. Report data that will contribute to this study are included. As shown in Figure 1, 39.43% of the participants are architects. Similarly, this study primarily deals with the use of BIM in architectural practice. Therefore, the research findings represented an important set of information for this research.

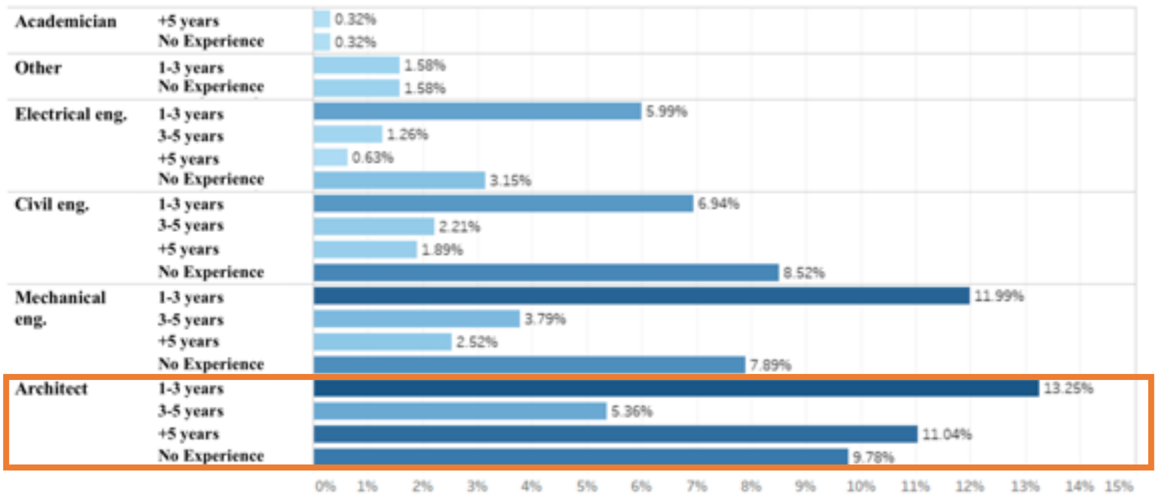

Figure 2. Distribution of survey participants by discipline and BIM experience.
(Source: BIMgenius 2018)

As it is clearly understood from Figure 2, while more than 9% of the architects who participated in the survey claimed that they had no experience with BIM, more than

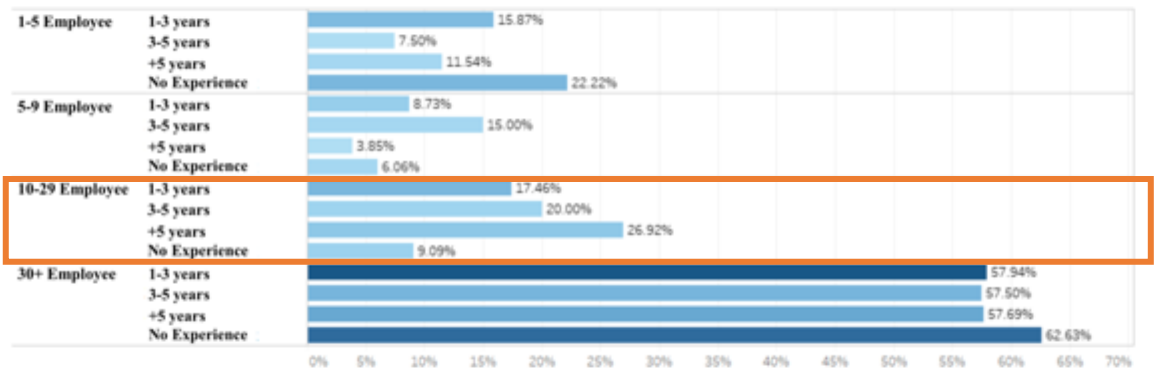

Figure 3. Firm size - BIM experience relation.
(Source: BIMgenius, 2018)

13% of architects, who made up the majority of the participants, stated that they had one to three years of BIM experience. We could conclude from the survey that BIM is becoming more and more popular among architects in Turkey.

The survey results also indicate that there is a relation between firm size and level of experience. From the bar chart in Figure 3, it is seen that firms that have more than 30 employees have a homogenous BIM experience distribution. Almost 27% of firms with 10-29 employees, which corresponds to the category of small business in this thesis, have more than five years of BIM experience and a very small number of the same size firms claimed that they have no experience in BIM. This shows that small businesses are pioneers of BIM usage in the industry.

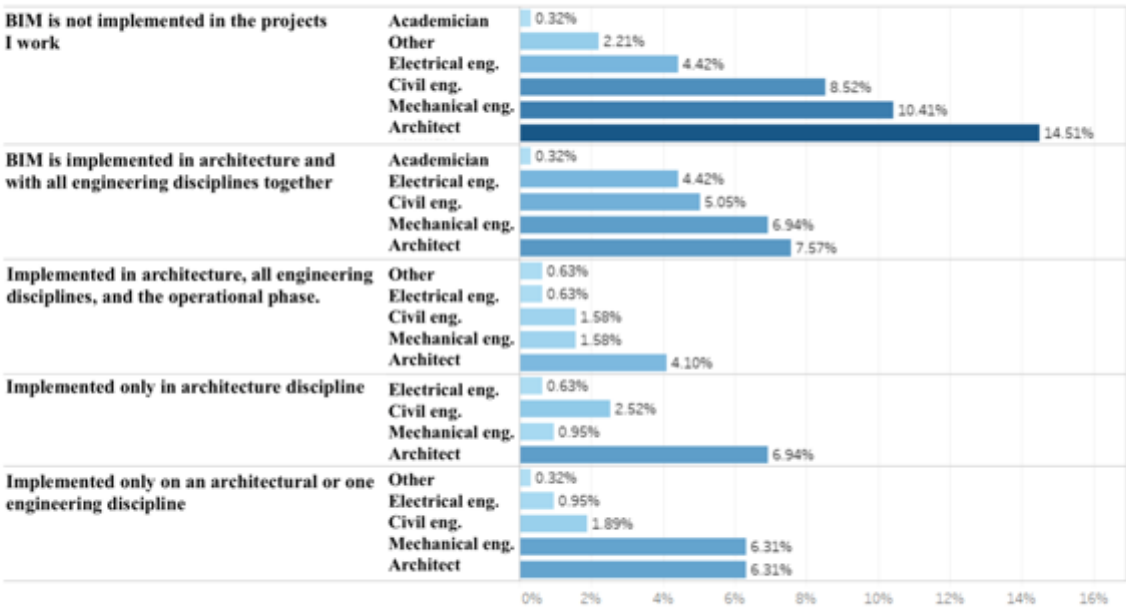

Figure 4. Distribution of BIM maturity by disciplines.
(Source: BIMgenius, 2018)

Another data shows that the use of BIM at different maturity levels is dominant in the architecture discipline. As shown in Figure 4, a high percentage of architects claim that BIM is not implemented in their projects. On the other hand, architects have the highest percentage in saying that BIM is implemented in whether only in architecture, in architecture and all engineering disciplines, or only in one of the disciplines. The highest maturity level of BIM implementation, fully integrated BIM, has the lowest percentage in all disciplines including architecture and engineering.

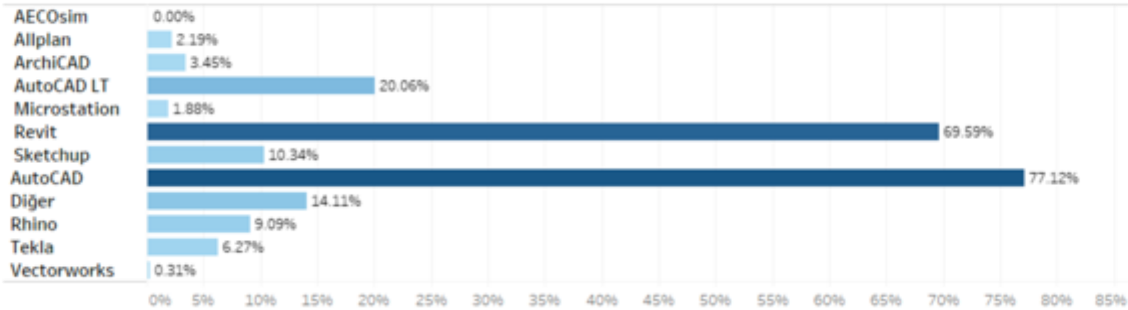

Figure 5. Main software platforms used.
(Source: BIMgenius, 2018)

Software platforms that are used for generating a BIM model are one of the main determinants in BIM adoption. Figure 5 shows that BIM users in Turkey prefer mostly Revit as a modelling software. Revit is the 3D drawing software that is used by the participants of this thesis as well. It is also part of a software package used by a wide variety of disciplines. In another study, the usage rates of the programs included in the existing software used by the participants in the Turkish construction sector are given. According to the survey results the rates are AutoCAD with 91.7%, 3DS Max and Microsoft Office with 66.7%, Sketchup with 50%, Revit at 58.3%, ArchiCAD with 25%, MS Project, Tekla, Bentley, Navisworks with 8.3%. In addition to these, it is seen that programs such as VICO, Allplan, Primevera, Nemetschek Allplan, Vectorworks are not preferred among Turkish AEC firms (Sarıçiçek 2019).

Based on the relation of firm size and BIM experience, it is fundamental to understand what is meant from small businesses and how firm sizes are labelled in Turkey.

2.2. Definition of Small Business

There are a variety of definitions of small business in different sources. According to the Small Business Administration (SBA) in the US, the definition of small business is one with less than 75 employees, while in the data presented by the American Institute of Architects (AIA) firms with less than 20 employees are considered as small business. (AIA, 2014; Klein, 2010). In the classification of Small and Medium Enterprises Development Organization of Turkey (KOSGEB) and European Commission (European Commission, 2015), there are terms such as micro-scale enterprise, small-scale enterprise, medium-sized enterprise, and macro-scale enterprise (TC Official Gazette, 2012). According to these sources, enterprises with less than 10 employees are defined as micro-scale enterprises, enterprises with 10 to 49 employees are small-scale enterprises, enterprises with 50 to 250 employees are medium-sized enterprises, and enterprises with more than 250 employees in a year are defined as macro-scale enterprises.

In this study, considering these definitions, architecture offices with more than 15 employees are defined as small architecture firms.

2.3. Challenges of Small Architecture Firms

Innovations in small firms in the construction industry are different from large firms (Sexton and Barret, 2003). Changing the corporate structure of large firms is much more complex than in small firms, due to both financial and technical capabilities (Haliburton, 2016). Depending on the type of innovations made in the two types of companies, the adoption process may also vary. In some cases, if the cost of innovations in small firms exceeds the firm's budget, the innovation cannot be implemented, and sometimes the small organizational structure helps it adapt to some innovations more easily and does not show resistance to innovation like large firms (Kapısız, 2013; Ademci, 2018).

2.4. Architectural Practice in Turkey

A standard design process has four primary phases. These are early design phase, schematic design, design development phase, and documentation for construction (Park and Lee 2010). Similarly, conventional architectural practice in Turkey takes place in a linear process. In the following paragraphs these four phases of an architectural design process in Turkey will be explained in detail.

In general, the architect takes the overall design decisions in the early design process, either in a team composed of other architects or individually. Afterwards, this design is developed and orthographic or 3D drawing production begin with various design tools. When the design reaches a certain development level in terms of architecture and this design is approved by the employer, architectural drawings are transferred to other disciplines. Mechanical engineers, civil engineers, and electrical engineers produce their own drawings based on the architectural design and transfer them to the architectural team. This process is an iterative process that includes the juxtaposition of drawings, error detection, and corrections. As a result of these drawing exchanges, a project drawing set consisting of architectural and engineering drawings is obtained. An architectural drawing set consists of, respectively, numbering, site plan, land sections (1/100-1/500), plan, section, and façade drawings according to the scale of the project (1/100-1/50), system sections (1/20), detail drawings (1/ 5-1/2) site list, fire resistance values, thermal insulation detail drawings.

In parallel with the drawing phase, a project license process continues with the relevant municipality. At the point where the architectural team matures their first ideas and starts producing orthographic representations, they apply for a pre-approval at the municipality. At this stage, the compliance of the architectural project with the zoning regulations and the zoning status is checked. When all disciplines complete their drawings and make the project drawing set ready, a building permit application is made. In this phase, the compliance of the drawings of all disciplines with the regulation and each other is checked. Approval of the building permit means that the construction process can start. In some cases, the design team's relationship to the project ends at this point. It is not always the architect's duty to provide site control during the construction phase. Depending on the contract with the employer, the designer architect can control the construction site process, an architect other than the design team can be appointed or engineers can undertake this process.

In small architectural firms, the above-mentioned labor-intensive processes involve a single architectural team. The architect produces the drawings at all scales from the beginning to the end of the project and ensures coordination with the teams. In large architectural firms, a team is formed for each architectural design stage. The design team can be defined as the orthographic or 3D drawing team, the detail drawing team, and the visualization team. There is a team leader at the head of these teams consisting of architects and drawing technicians. Team leaders are those who control the drawings of the architects in their team and manage the team rather than producing the drawings. Therefore, the working practice of an architect varies according to the size of the firm and position of the architect.

2.4.1. Project Delivery Methods

Common project delivery method types are Design-Bid-Build (DBB), Design-Build (DB) or Design Construction (DC), Public-Private Partnership (PPP, 3P, P3), and Integrated Project Delivery (IPD).

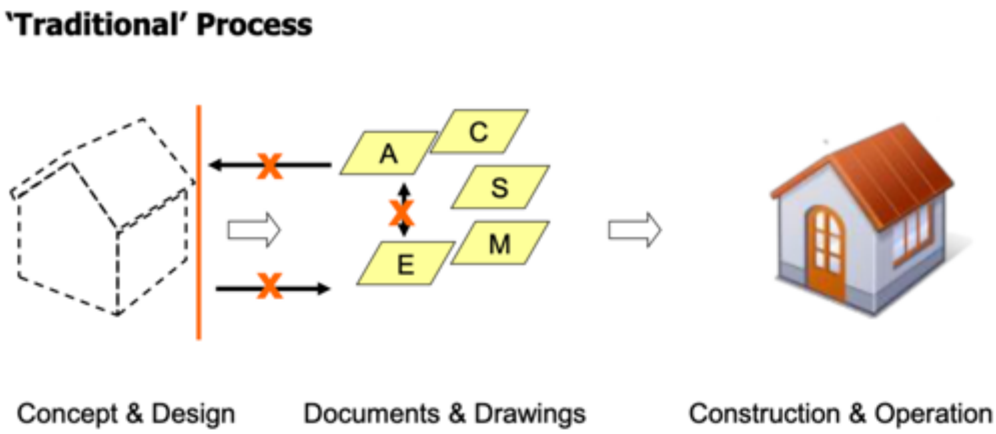

Figure 6. Linear process in traditional project phases.

(Source: Azhar, Khalfan, and Maqsood 2012)

The DBB system was the indicator for the emergence of specialized disciplines such as architects, contractors, and engineers when it was developed during the time of Industrial Revolution. This is one of the common project delivery approaches that has been the standard for project delivery systems for many years. In this model, the owner/client hires a design consultant to develop the project scope and prepare design documents, which then serve as the legal basis for selecting a contractor to build the project according to the specifications developed by the design team. In the case of a public facility, bidding is usually done through an open competition. The contractor who specified price, schedule, and minimum standard. After the construction of the project is responsible for all financial issues similarly as in the DBB approach (Pakkala 2002).

Briefly the PPP method, describes a relationship which divides risks between public and private partners. It is based on a mutual objective between these public sectors and a partner, or in some cases more than one partner, from the private sectors to provide a publicly approved project and or public service. These private sectors can also be voluntary partners in some cases (Grimsey and Lewis 2007).

One of the foundations of BIM applications is integrated project delivery. Integrated project delivery aims to reduce the problems such as outdated projects, unimplementable design, unforeseen problems, inaccurate cost, and time calculations. According to the American Institute of Architects:

> IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction (AIA 2007).

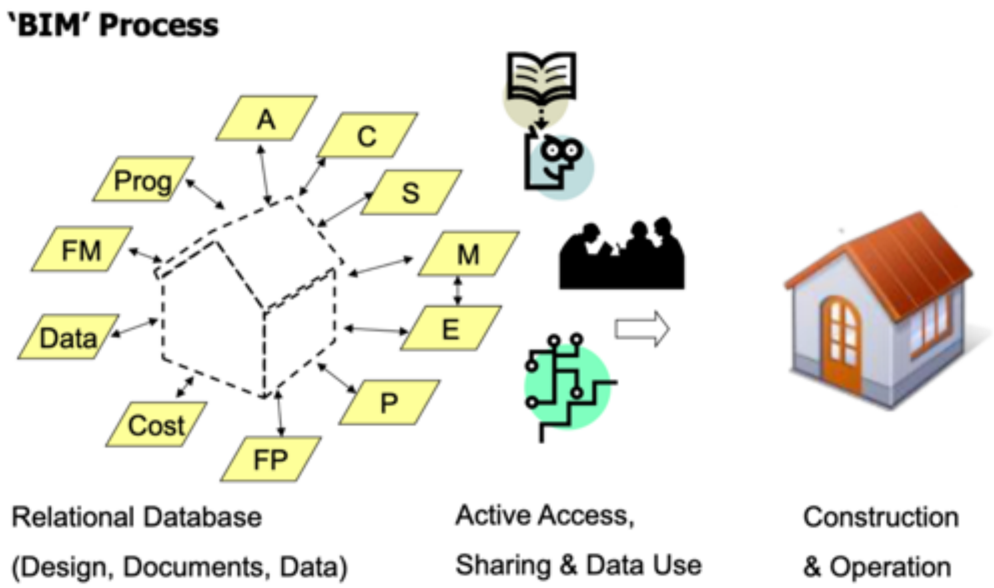

Figure 7. Integrated design process in IPD.

(Source: Azhar, Khalfan, and Maqsood 2012)

2.5. BIM Adoption

The adoption of BIM has become a global issue in the AEC Industry. Increasing BIM implementation has made it more of a survival strategy for the architectural offices to adopt BIM than a choice in parallel with the realization that they will be left behind if they do not evolve with industry (Smith 2014). The survey of McGraw-Hill (2012) on BIM implementation rates in North America show that BIM adoption among contractors increased from 28% to 71% between 2007-2012 (McGraw-Hill 2012).

Smith (2014) analyzed the key factors that were used around the globe to implement BIM successfully. According to his research findings the key factors are: Government and industrial leadership, business case and competitive advantages, national and global standards, national and global BIM product databases and libraries, BIM protocols and legal contracts, project procurement systems-integrated project delivery, quality of the model, BIM maturity models and BIM engagement index, BIM education, training, and research, business changes (Smith 2014). The increase in BIM adoption provides guidance and motivation for the newcomers. The relation of early adopters and pragmatics were explained by Moore and McKenna (1999) as *crossing the chasm* which they described as the most difficult step towards gaining momentum in the market. The chasm is exceeded when pragmatics offer efficient advantages on adopting the technology from the early adopters (Figure 8). They developed this approach based on *the Diffusion of Innovation* theory.

The theory diffusion of innovation was introduced by Rogers in his book named after the theory (2010) which was published first in 1962. One of the aims of the theory was to find a general classification for attributes of innovations (Rogers 2010). The advantages, compatibility, complexity, trialability, and observability of an innovation are used to explain BIM adoption rates in literature.

The literature on technology adoption introduces critical adoption factors, i.e., people-process-technology (PPT) and their relations (Abernathy and Utterback 1978, Kotabe and Murray 1990, Moore 1993, Fritsch and Meschede 2001, Damanpour and Aravind 2006). BIM adoption requires radical changes in PPT, and each aspect is dependent to the other and the adoption of BIM is regarded to be beyond a mere technology adoption. Therefore, the coevolution of these three aspects in BIM adoption is essential to prevent a system breakdown (Kensek and Noble 2014).

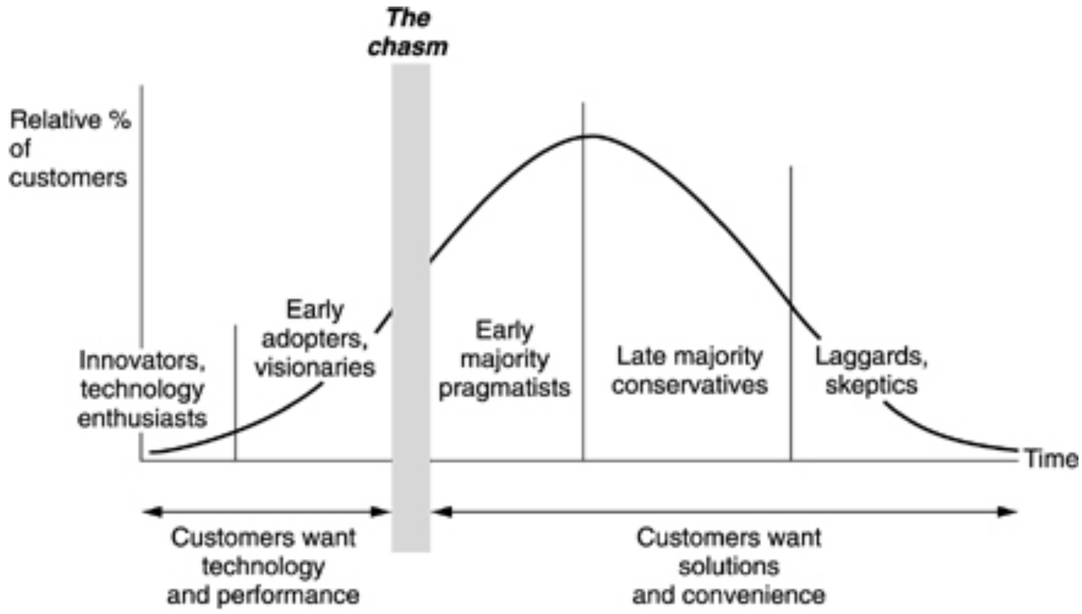

Figure 8. Diagram on crossing the chasm.

(Source: Moore and McKenna 1999)

Studies indicate the barriers and enablers of BIM adoption. Understanding and designating the barriers and enablers of BIM adoption is essential to implement BIM successfully (Table 2 & Table 3). Also, literature provides an important knowledge for developing the efficiency of adoption phases.

Table 2. Literature on barriers of BIM adoption.

(Source: Eadie et al. 2014)

Barrier	Literature Source
Lack of Senior Management Support	Jung and Joo (2011); Arayici et al (2011); Coates et al (2010)
Doubts about ROI/Lack of Vision of Benefits	Arayici et al (2011); Lee et al, (2012); Coates et al (2010)
Cost of Training	Yan and Damian, (2008); Coates et al, (2010); Azhar, (2011); Crotty, (2012); Efficiency and Reform Group, (2011)
Cost of Software	Thompson and Miner, (2010); Azhar, (2011); Crotty, (2012); Efficiency and Reform Group, (2011); Giel *et al*, (2010); Lee *et al*, (2012)
Scale of Culture Change Required/Lack of Flexibility	Yan and Damian, (2008); Rowlinson *et al*, (2009); Jordani (2008); Mihindu and Arayici (2008); Watson, (2008);
Other Competing Initiatives	Cabinet Office, (2012);
Lack of supply Chain Buy-in	Aouad et al (2006);
Staff Resistance	Arayici *et al*, (2009); Yan and Damian, (2008);
ICT Literacy of Staff/Lack of Technical Expertise	Arayici *et al,* (2009); Yan and Damian, (2008); Aouad *et al* (2006);
Legal Uncertainties	Udom, (2009); Oluwole, (2011); Christensen et al, (2007); Race, (2012); UK BIM Industry Working Group, (2011); Chao-Duivis, (2009); Furneaux and Kivvits, (2008);

Table 3. Literature on key BIM adoption enablers.

(Source: Abbasnejad et al. 2020)

Constructs	*Enablers*	*Authors*
Strategic initiatives	Support from top management	(Arayici et al. 2011a)
	User's input	(Arayici et al. 2011b)
	Strategic vision	(Khosrowshahi and Arayici 2012)
	Strategic plan	(Arayici et al. 2011b)
	Stakeholder's analysis	(Arayici, Egbu and Coates 2012)
	Cost-benefit-risk analysis	(Mom and Hsieh 2012)
Change management	Rewards and recognition	(Peansupap and Walker 2005)
	User training and education	(Arayici et al. 2011b)
	Supportive supervisor	(Peansupap and Walker 2005)
	Management readiness for change	(Arayici et al. 2011a)
Cultural readiness	Existence of change agents	(Merschbrock and Munkvold 2014)
	Risk aversion	(Succar 2009)
	Early user involvement	(Miettinen and Paavola 2014)
	Open communication and information sharing	(Dossick and Neff 2009)
Learning orientation	Colleague's help	(Peansupap and Walker 2005)
	System expertise	(Eadie et al. 2013)
	Individual competency assessment	(Succar, Sher and Williams 2013)
	Learning-by-doing	(Arayici et al. 2011b)
	Community of practice	(Peansupap and Walker 2005)
	Learning from past experiences	(Arayici et al. 2011a)
Knowledge capability	Developing knowledge management system	(Arayici, Egbu and Coates 2012)
	Use of communication technologies	(Volk, Stengel and Schultmann 2014)
Network relationships	Inter-organizational linkage	(Homayouni, Neff and Dossick 2010)
	Cross-functional cooperation	(Cerovsek 2011)
Process Management	Setting benchmarking metrics	(Coates et al. 2010)
	Tracking benchmarks	(Giel and Issa 2012)
	BIM maturity assessment tools	(Succar, Sher and Williams 2012)

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes the research method and gives detailed information about the cases of the study. Starting with the explanation on the methodological approach, the chapter includes the characteristics of the method. The strengths and weaknesses of this research strategy are examined followed by detailed information on the designated two cases including issues such as scale of office, organizational structure, workflow among office members and between project teams, and reasons for choosing the cases. Lastly, the strategies for data collection and analysis of the data are explained.

3.1. Research Approach

The research question in the study led to the employment of qualitative research to explore the process of BIM adoption in depth through case study method. As a new and developing field of study, it is important to have in-depth research on individuals' experiences before putting forward any assumptions or hypothesis with regard to the topic of study. In qualitative research, determining the personal experience of the individuals is essential. With this approach, this study aims to build an understanding on the studied topic of BIM adoption in an exploratory way through listening to the participants. Its findings will be unique in that the chosen cases are studied for the first time under the topic of BIM adoption (Yin 2017).

3.2. Research Method

The research method of the study is designated as case study analysis and the definition, characteristics, and strengths and weaknesses are introduced in detail in the sections below. Case study was selected as a method to investigate the study focusing on individuals' experiences and to have a sociological approach to the research problem.

3.2.1. Definition of Case Study

Case study is a qualitative data analysis method commonly used in social sciences. For scientific research, it is fundamental to understand the methodology that is planned to be used, in its whole context. Case study in qualitative research is used primarily in disciplines such as sociology, history, psychology, and anthropology (Merriam 1998, Simons 2009, Mills and Birks 2014).

After the second half of the 20th century, quantitative research methods were prevalent because of the emergence of positivism in science. Case studies were used during this period as a method within quantitative studies (Merriam and Tisdell 2015). The emergence of grounded theory methodology, which "merges qualitative field study methods with quantitative methods of data analysis", created interest into qualitative methodologies and a rebirth of case studies in some disciplines. For recent social studies, the significance of subjective perceptions and discourses that are dominant are emphasized by social constructivist theories.

Different definitions are made for this methodology according to the approaches of the researchers. Here we define case study in general as a case that is studied for the aim of discovering its activity in the frame of determinant conditions (Stake 1995). This method gives the opportunity to explore a phenomenon through various sources of input (Baxter and Jack 2008). It requires a research problem and the proposal of the appropriate solution out of alternative data examination. This examination is made through data, collected from real-life context experiences as a research strategy. Whether it is the analysis of an individual person, groups of people, events, comments, term, policies, institutions, case study is a descriptive and exploratory analysis. Apart from the field of interest, the common aim in a case study is to understand complex social phenomena (Yin 2017).

Case study can be divided in four subcategories which are illustrative, exploratory, cumulative, and critical instance case studies (Becker et al. 1994). Illustrative case studies aim to create an understandable meaning to the reader with descriptive studies. It creates a common understanding about the questioned topic for the reader. Exploratory case studies help to frame the questions and types of measurements that will lead to the main research, but the findings are not aimed to be carried to the final work as a conclusion (Yin 2003). In cumulative case studies, past studies from several sites are used to make a wider generalization about the questioned topic to prevent from extra time and cost and repetition in study. Critical instance case study is suitable for cause-and-effect questions and can be used when the questioned topic is very generalized, or it has a universal dimension. By the light of this information on the types of case studies, the characteristics of the method and steps of developing a case study will be explained.

3.3. Characteristics of Case Study

The elements of case study present the fundamental perspective of the research design. The elements can be listed as the case being studied in a particular context, selecting the case, bounded system, multiple sources of evidence, in-depth study, and the case study design (Simons 2009, Creswell 2013, Flyvbjerg 2011, Bennett and Elman 2007, Miles, Huberman, and Saldaña 2014). Yin (2017) defines the steps of a case study briefly as design, collect, present, and analyze the data. Before starting with the field work, it is advised to do a literature review to define the research question clearly and to have a general overview of existing studies (Yin 2017). The research questions of this study are framed after a literature review of 159 papers related to the study, which are categorized as BIM, BIM adoption, cloud-based BIM, computation and design, design cognition, early phase of design and BIM. After that, the first step to be taken is identifying the objects of the case study which might be a program, individuals, people composition, a social situation, an event, phenomena, or process (Yin 2003). Boundaries in a system can be time, space, or activity (Smith 1978). This is used to apply frames to handle with variables within the context and embraces a system of connections between the case and the context (Harrison et al. 2017). Each context is specific to the case and is significant to understand it (Merriam and Tisdell 2015). In-depth study is used when a deep investigation for a certain task is needed. Determining the case, scope, method, and logic is based on the aim and condition of the research and designates the objects of the case. The case sample can be a single, within case and multiple case. A high number of indexes extends and deepens the research (Yin 2017). For these multiple sources, data collection methods are interviews, observations, groups, questionnaires, and surveys.

3.4. Strengths and Weaknesses of Case Study

Using the case study methodology has both advantages and disadvantages. The advantages of case studies are that we can link abstract ideas to real-life experiences and case studies enable us to link micro details, which can be the behavior of people, to the macro issues, or large-scale context that is specific for the case. By that we can demonstrate an argument how the 'macro' shapes and effects the 'micro' settings. It is a flexible type of method where it allows to start with broad questions and to focus on the core question during the progress of experiment (Becker et al. 1994).

Regarding its disadvantages, case study is criticized as being too subjective, consequently, its results cannot be generalized or tested. This created a concern about the reliability and generalizability of the result. The output of the cases is specific to the study, so the validity of these studies is criticized. In terms of cost, that case studies focus on deep data it needs high investment to do large-scale research.

3.5. Data Collection

The data collection method of the qualitative research in this study is based on semi structured interviews of people who were involved in the BIM adoption process. Interviews are one of the most significant sources in case study research. Interviews allow people to express their opinions, thoughts, feelings about their experiences in their own words (Abdelmohsen 2011). This provides the researcher to document information about individuals personalities and social behaviors in a certain context and to get to know each participant in depth. Interviews can extent from highly structured to unstructured, a range from rigid to fluid conversations. In highly structured interviews, a set of questions are prepared and asked in a pre-planned order. The questions and flow do not change spontaneously according to the course of the interview. An unstructured interview, instead, consists of general topics rather than specific questions and is flexible in terms of flow (Saldana 2011). Therefore, the semi-structured interviews for data collection followed a certain flow, but they were applied in a way that did not rigidly guide the participants and allowed their descriptive narratives.

Interviews in general can be performed in three types: prolonged interviews, survey interview, and shorter interviews (Yin 2017). Prolonged interviews are in depth conversation on the participants interpretation on events and people. These types of interviews can take more than two hours which can be divided in several meetings in an extended time. Survey interviews are basically structured questionnaires. The type of interview implemented in the study was shorter interview which is regarded as semi structured interview that follows a line of inquiry but remains open-ended and is performed in a colloquial approach.

31	A1	A1: Herkes oluyor mesela. Orada ofiste o gün olan ve o projede çalışacak demeyeyim, herkes o toplantıya katılabilir.
32	I	I: Mühendis ekibi var mı ?
33	A1	A1: Hayır, mühendis ekibi yok. Neyse herkes ona katılıyor. O gün hızlı ilerleyebilecek, onu alıp götürebilecek, modelini kuracak kişi ile o iş başlıyor. Ne olarak geliyor, mesela plan kotu olarak geliyor, sizden önce çalışanın çekme mesafesi falandır. Bu verileri çok hızlı görünür kılacak, arazi kesitleri, vaziyet, çevre, trafik gibi... Boşta olan veya o iş için ayrılmış kişi onu başlıyor ve daha sonra yerleşme araştırması dediğimiz süreç başlıyor. Eskizler başlıyor, ilk önce çevrede ne var. Gidip de bir trafik analizi gibi, öyle şeyler yapmıyoruz. Arazi gördüyseniz biraz da ofisin deneyimi içerisinde bu hızlı bir biçimde yerleşme araştırması. İşte kütle nasıl oturur, veriler belli. O başlıyor ve binaya nasıl yaklaşılır.
34	I	I: İlk aplikasyonu Autocad'de mi giriyorsunuz, nasıl yapıyorsunuz ?
35	A1	A1: Bize Autocad'de geliyor. Büyük oranda takılmıyoruz aslında çıktı alaibleceğimiz ortama bakıyoruz. Noktalar geldi ise Revit'te açıyoruz, hızlıca topografya oluşturuyoruz, arazi sınırları ile çıktı alıyoruz. Üzerine leke çalışıyoruz. Autocad'de geldiyse, 3-4 tane nokta varsa, alacağınız zaten bir çizgi var mesela onu alıyorsunuz çıktı, onunla başlıyorsunuz. Bazen, maketini yaptırmanız gerekiyor, Rhyno'da açıyorsunuz. 3D print yapıyoruz.
36	I	I: Çıktı alıp başlıyoruz derken kaç kişi o kalemi masada oynatıyor ? Tek kişi kendi kendine bir eskiz ile...
37	A1	A1: Han Bey. Han Bey ile başlıyor. Onda şey diyemem, alıyoruz biz yerleştiriyoruz. O yerleşme araştırması, Han Bey ile yapılan bir şey. Ama orada masada sen de varsın artık. Çünkü Han Bey'in genel proje yapma şeklinde kapalı bir durum yok. Kapalı bir durumda zaten proje üretmiyor. Yarışmalara proje üretemiyor, çünkü kapalı, kendinsin. O yüzden aslında BIM diyoruz ya, interaktif kısımdan bilgiyi diğer disiplinlerle paylaşmaya Han Bey yatkın. Yoksa siz istediğiniz kadar BIM diyin, interaktif diyin, bu Han Bey'in o duruma yakın olmaması durumunda söz konusu bile olmamaz.Kendimiz kapanıp grafik üreten, iletişim kurmayan... Grafik var, grafik iletişim var. Plan var, iletişimi kurulmuş plan var. Nedir bu, paydaşların bilgisini içeren. Paydaşlar kim ? En başta kullanıcı, daha sonra mekanik, statik, elektrik. Bütün bu bilgiyi içeren veri,isterseniz Revit'te üretin isterseniz başka bir şekilde üretin, mental olarak bu iletişime açık değilse bu çizim zaten ilişki kurulmuyor.56:19 Han Bey eskize başlıyor, lekelere başlıyor. Biz de orda oluyoruz. Sonra dijitle geçirdiğinizde problemler buluyorsunuz. Bu buraya kaymalı, bu böyle olmalı, bu olamadı gibi... Artık sizin ürettiğiniz o dijital ürün üzerinden ilerliyor, tekrar çıktı alınıyor, tekrar bakılıyor.
38	I	I: Revit'e geçiyorsunuz galiba ?
39	A1	A1: Revit'e geçiyoruz, proje ölçeğine göre, biraz da orta ve şey ise Sketcup'ta uzun süre ilerliyoruz. Kesin projeye kadar Sketchup üzerinde model tutuyoruz. Çünkü doğru insan ölçeği ve bir çok hızı ve piyasada çok hızlı ürün üretttirebildiğimiz ortam orası. Revit'in o özellikleri bizim grafik şeyimize yetmiyor. Sketchup o konuda daha vecerikli, daha etkin kullanılabilen. Piyasada o kısımda daha çok kişi çalışabiliyor. Stajerler de çalışabiliyor, alıyor ondan maket yapıyor, alıyor ondan arazi kesiti alıyor, çiziyor. Ama biz şeye takılmıyoruz, özellikle son bir iki yıldır, programa takılmıyoruz. Hangisi bize lazımsa, İzmir projesinde Rhyno kullandık, Revit açmadık bile. Rhyno bizim BIM programımız oldu aslında.57:55
40	I	I: Şimdi herkesin BIM'den anladığı başka bir şey ya, ne kadarını kullanıyorsan BIM senin için o kadardır sonuçta. Mesela sizin ofisin BIM anlayışı nedir, BIM'in içini nasıl dolduruyorsunuz ofis olarak? Yani, müellifler arası iletişim, sizin Central model oluşturmanız, diğerlerini linklemeniz gibi bir ortam mı? Veya 360'ı kullanıyor musunuz? Tam olarak nasıl dolduruyorsunuz BIM tanımını?
41	A1	A1: Aslında bizim bütün paydaşlarımız BIM kullanmıyor, biz BIM'i kendimiz için yapıyoruz. Bir başta şöyle başladık, öyle bir gerçek olmadığını ben biliyorum ama kimseye kabul ettiremedim. Süreden bir şey kazandırmıyor. Yani modeli yapıyorsun kesiti de çıkıyor demek aslında süreden kazandırmak değil. O Revit. Biz BIM'i şöyle kullanıyoruz aslında, kendimiz için. Kendimizin metrajı, kendimizin keşfi, kendimizin analizlerini yapabilmek için. Hızlı veri üretebilmek için. Çünkü şöyle birşey olabiliyor mesela, arazi harfiyat verisi. Son dönemde de öyle hakikatten, çok eğimli araziye proje yapıyoruz ve harfiyat büyük bir konu. Onu Dynamo'dan çekebiliyoruz. Mesela Dynamo'dan maket ürettireceğiz, araziyi hızlıca çıkarıp, önce Dynamo, sonra Grasshopper entegre kullanıp arazi makedi çıkartabiliyoruz. İlk konsept aşamasında da bazı ürünler çıkarmak için kullanabiliyoruz. Daha sonra veriyi yönetmek için, arşivi yönetmek için de kullanıyoruz. BIM'i sadece bir program olarak görmedik, BIM aynı zamanda bir klasör sistemi aslında. Bir isimlendirme sistemi, arşiv sistemi. Önceden Autocad projeleri, tarih ile falan kaydedilirken artık BIM'de informasyon mantığı içerisinde arşivlerimiz, familylerimiz, onların tarihleri, alındığı firmalar, tüm bu süreci, bilgiyi model içerisinde takip ettirebilir oldu. Bu da, kendi hafızamızı tutmak için aslında...clash dedection sadece statiği kendimiz modellediğimiz için kullanabiliyoruz. Elektriği falan modellemediğimiz için kullanamıyoruz.
42	I	I: Statiği nasıl kendiniz modelliyorsunuz ?
43	A1	A1: Geometrik olarak kendimiz modelliyoruz, kolonu, kirişi. Mimarlar olarak biz modelliyoruz.
44	I	I: Sonra kesin hesaplar gelince kesiştiriyor musunuz?
45	A1	A1: Kesin hesaplar dediğimiz, biz geometrisi ile ilgileniriz. Kolon 70'mi 100'mü? Onun içerisindeki donatı ile ben hiç ilgilenmedim, ilgilenmek de istemem.

Figure 9. Sample of interview transcript with BIM coordinator architect (C2-A1).

The introductory questions of the interview were based on the participant's personal information. Thus, it was aimed to learn about the professional experience of the person, the job description, and responsibilities at the place of work, and the level of knowledge about BIM superficially. Apart from that, the interview was structured to consist of three main parts including pre-BIM workflow, adoption process and post-BIM workflow. It was important to gather in-depth information on these topics. Therefore, the questions were not structured to seek a specific answer, but to keep the participants focused on one of the processes and to trigger the narrative of their experiences. Here, the questions were asked as open-ended and mostly evolved during the interview with the participant. In each phase, attention was paid to collect information on people, process, and technology which are discussed in existing literature as the main factors of BIM adoption (Kensek and Noble 2014). To establish the time-dependent relationship of these factors with adoption, which indicates a process, the questions were formed to cover the pre-BIM experiences, post-BIM experience, and adoption phase stages. Therefore, although the structure of asking the questions in the interviews changed, it was aimed to reach sufficient information about the above-mentioned stages in each interview. The questions were adapted during the interview according to whether the information given by the participant was sufficient or not, level of involvement of the person in BIM adoption, and level of knowledge on the technological issues. For instance, to gather information on the collaboration of architectural office with stakeholders, one question is asked to one of the interviewees who is not actively a member of the drawing team and has no experience in BIM software usage as " Do you collaborate with engineering teams?" whereas to one of the interviewees who is the BIM coordinator at the same office, the question is posed as "How do you collaborate with other teams? Do you have a central model to link other teams' drawings?" Here, the feedback of interviews provides information on the collaboration between teams but in different detail levels. Five interviews were performed for the study through zoom meetings. Field observation and face to face meetings were planned to be made for data collection but due to the pandemic all interviews were held in online meetings. Each interview was recorded and were fully transcribed for analytical coding. Even conversations that were thought to be off topic were transcribed for re-evaluation during coding.

3.6. Coding and Analysis

This study used analytic coding for identifying phenomena from collected data. The analysis in this research is searching for meaningful patterns that occur from the coding of the data. The approach for the analysis is grounded theory and followed the steps of initial coding, axial coding, and theoretical coding. As mentioned by Charmaz (2006) "Grounded theory coding requires us to stop and ask analytic questions of the data we have gathered. These questions not only further our understanding of studied life but also help us direct subsequent data-gathering toward the analytic issues we are defining." (p.42).

In a grounded theory approach, the transcribed interviews are read through several times and the researcher becomes more and more grounded in the texts (Bernard 2017). As described by Corbin and Strauss (2014) and Glaser and Strauss (1967), who are the developer of the theory, in grounded theory data is analyzed in a series of steps for a successful theory development which were followed in this study. The first step is the transcription of interviews and close reading of the transcriptions. This iterative process continues with recognizing possible analytic categories through the text, which will generate the potential themes. When these categories are put forward, the researcher starts to generate relations and linkages between these categories by comparing them. A theoretical model is created through the links among these categories. Finally, analysis results are presented with examples of the interview transcriptions and definitions of generated categories related to the part of interview.

All coding steps were done with the qualitative data analysis software (MaxQDA). The software provides organizing documents, coding and analyzing the data, and presenting the outcomes in various formats (Kasali 2013). Below a screenshot of the interface is presented (Figure 10). The interface consists of three windows: coding sets and document system on the left and related transcription on the right.

All interview transcriptions of this study were coded independently as a start for searching categories. The steps of coding are briefly summarized in sections below.

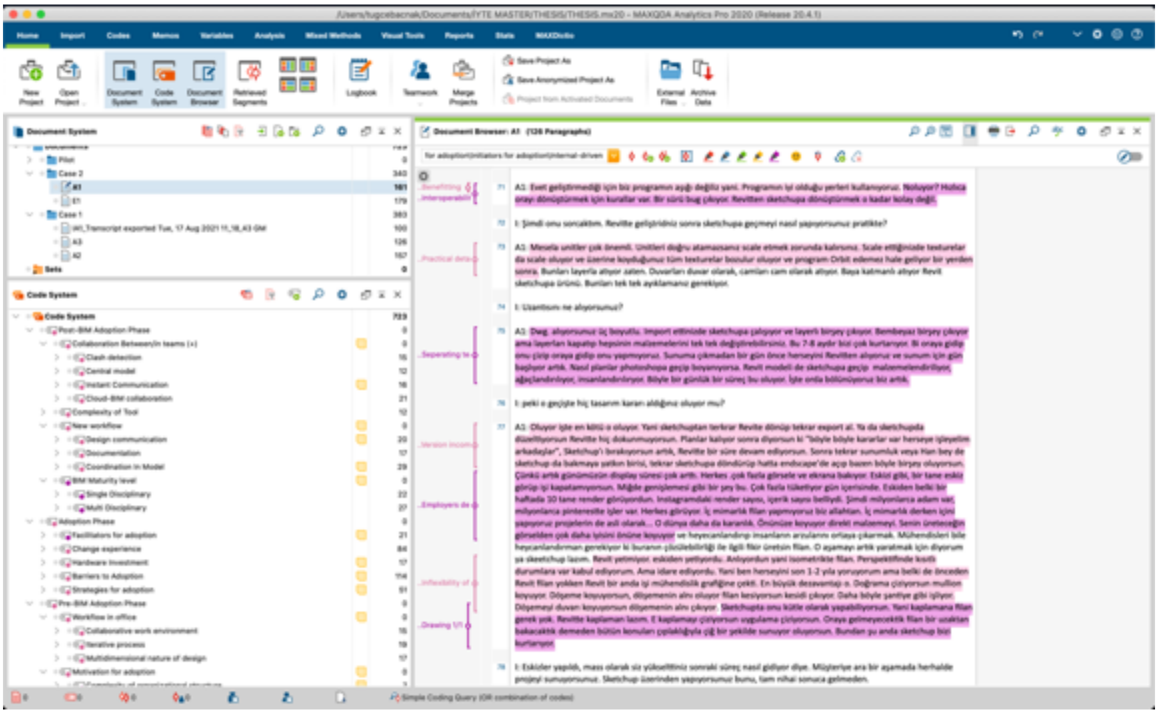

Figure 10. Screenshot from the MaxQDA software interface used in the study.

3.6.1. Initial Coding

The strategy for the initial coding phase was to split the data into small codable parts (Kasali 2013). With that the text was deconstructed and provided a search for obscured subtext and profound meaning (Bernard 2017). The aim in initial coding was to examine any theoretical possibilities. During this phase of coding, it was essential that the researcher was open minded to ensure that new ideas could easily be generated out of reviewed data. This phase is a discovery through existing data to realize any gaps, missing information or unaddressed key points which seem necessary for data interpretation and the researcher does coding that is grounded in the data. Instead of sticking to a single coding method, such as process coding, descriptive coding in-vivo coding, etc. (Saldaña 2021), coding was performed in various methods to analyze the data in depth and in a way that will adhere to the meaning of the coded segment. The transcriptions were coded mostly line-by-line, in some narrative parts as a passage, leaving out only texts that are casual conversations other than the purpose of the interview. The preliminary codes occurred in short phrases rather than abstract words. 769 initial codes were generated for five interview transcriptions.

3.6.2. Axial Coding

In axial coding the split data were reorganized with the intention to group or merge associated codes and eliminate non-relevant codes to find axes of categories (Abdelmohsen 2011). These axes further leads the researcher to the last cycle of coding. While sorting the codes, the number of initial codes were reduced to 723 and 120 of the rest were coded as nonrelevant to the study.

First, initial codes that were distinctively synonymous were sorted into small groups and some of these codes were merged. Later, the small groups of codes were rearranged until the logic of the categorization was established. The process of generating categories was repeated several times before moving forward to selective coding. The creative coding feature of MaxQDA enabled to visualize the direction of the categories.

3.6.3. Theoretical Coding

Theoretical coding was implemented with the aim to cover all related categories and subcategories under an abstract explanatory core category (Corbin and Strauss 2008, 104). The relations between codes generated in initial and axial coding phases have been realized as a time-based abstract core which are categorized under three main ideas: pre-BIM adoption phase, BIM adoption phase, and post-BIM adoption phase. The theory of the core ideas is a modification of time-based information technology adoption research of Karahanna (1999).

CHAPTER 4

CASE STUDY

4.1. Introduction to Cases

To select the cases to be studied in this research first the construction companies known to use BIM in their projects from Turkey were searched on the internet. At the same time, the authorities of CADBIM, the company that is the Autodesk provider of Turkey, were contacted and information was obtained about the construction companies that were currently going through BIM adoption and were involved in BIM projects. With this information, meetings were held with firms and a general idea of the BIM projects available in the Turkish AEC industry was obtained. Afterwards, research was conducted on architectural offices and architects involved in these projects. To communicate with architect's one-on-one, conferences on BIM by organizations such as BIM4TURKEY were attended. BIM4TURKEY is a platform belonging to "Building Information Modeling and Management Association". Its goal is to make the integration of Building Information Modelling and Management (BIM) in the construction sector, higher education, and government organizations easier. They give a platform for all stakeholders engaged in a design and construction project to communicate and collaborate. (bim4turkey 2021). Also, these architects, engineers and partners from the AEC Industry were asked to give other names for snowball sampling. This preliminary information provided an insight on the current BIM adoption status in Turkey. The outcome of these conversations was that firms have an increasing tendency to adopt BIM and that they experience difficulty in full BIM implementation.

Cases were strategically selected from offices known to have gone through BIM adoption at the time the research was conducted. At the same time, attention was paid to ensure that the people to be interviewed were accessible to the researcher. Two cases with comparable office scale and BIM adoption experiences in common are chosen for the research with differences between them in terms of project delivery method, organizational structure, workflow, and project complexity which provided to put out a comparison in their BIM adoption. First, information about the organizational structure of the office was collected to determine the key people, first adopters-BIM championspeople who triggered the adoption, to be interviewed from the offices. Web pages of the offices were searched, and familiar people known to work in the office were asked to collect this information. Questions and protocols following a certain flow were prepared for the interviews to be held with these selected participants. The subject and purpose of the study and interview questions were first conveyed to the participants in writing. Thus, the participants were provided with a preliminary knowledge of the content of the interview. The aim here was not for the participant to prepare their answers in advance, but to be familiar with the structure and flow of the interview. Five interviews with three architects, one interior architect and one mechanical engineer were performed. Each interview took between 60 to 90 minutes. The time differences between the interviews were related to the degree of detail of the information they conveyed due to the speaker's active role in the BIM project (Table 4).

Table 4. Information on participants and interviews.

Participants		Job Definition	Key Role in BIM Adoption	BIM Technology Status	Interview Context	Length of Interview	Date of Interview
Case 1	C1-IA1	Interior Architect / Office owner	Decision Maker	Non-user	Online zoom meeting	01:23:09	14.07.2021
	C1-A2	Senior Architect	First Adopter	Active BIM user	Online zoom meeting	01:44:24	26.05.2021
	C1-A3	Senior Architect	Major motivator / First Adopter	Active BIM user	Online zoom meeting	01:19:01	16.06.2021
Case 2	C2-E1	Mechanical Engineer / Co-owner	Major motivator	Non-user	Online zoom meeting	01:09:20	17.07.2021
	C2-A1	Senior Architect	BIM Champion	Active BIM user	Online zoom meeting	01:36:01	05.06.2021

4.1.1. Case 1

The first case is an interior design office in Istanbul and their experience on a big scale Hotel complex project. The project program includes a hotel building, residences, and townhouses, with more than 20.000 m2 project area. Apart from the relatively large scale, the challenge of this project is that the teams were distributed and were in three different countries. The organizational structure of the project team members and their collaboration is illustrated below (Figure 11).

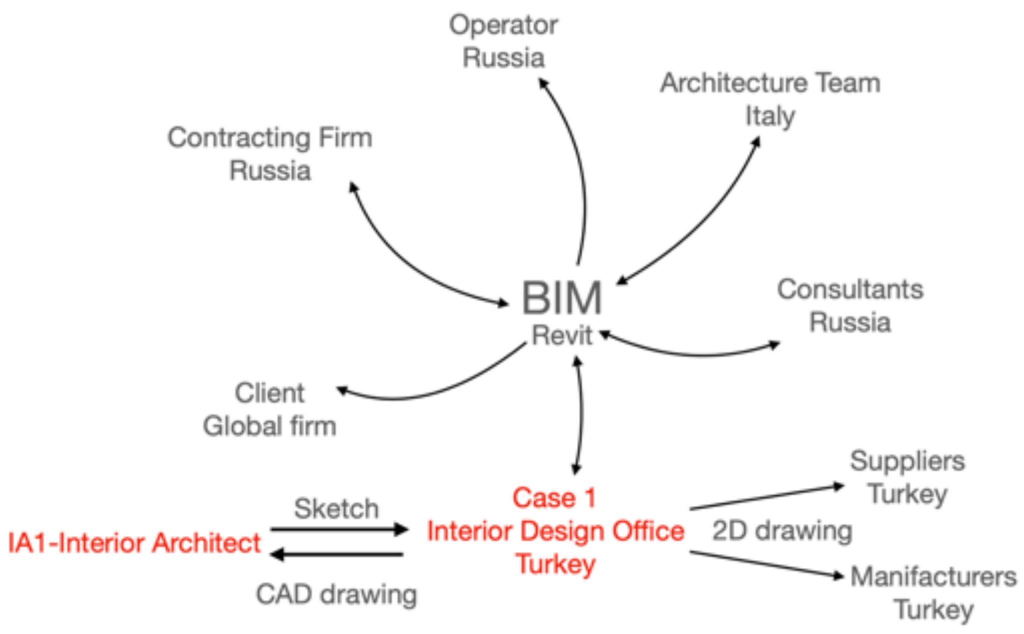

Figure 11. Organizational structure and collaboration links of project members in Case 1.

The office design team consists of 15 people. The owner and manager of the office is an interior architect (C1-IA1) who has 50 years of professional experience in the industry. Apart from the office owner the team members are two senior architects (C1-A2 and C1-A1), six interior architects, one junior architect, one draftsman and one intern architect who work via AutoCAD, and one intern interior design architect. The office was established by IA1 in 1985 and has been in the same location in Istanbul ever since. The office operates on the upper floor of a 3000 sqm furniture factory. Thus, the shop drawings produced in the office are directly transmitted for manufacturing, and in this way, architects can closely follow the entire production process of the drawings they produce. The portfolio of the office includes big-scale hotel projects, museums, lobby areas of worldwide hotel chains, and housings that are mostly outside of Turkey in such locations described by the office president as "crème de la crème".

To understand the daily work routine of the office, the chief architect was asked to provide an office tour during the online interview meeting. The president's office has direct visual contact with the production area and the room is separated by a glass partition from the open office area where all the other employees work. In the open office, an adjacent working order has been created from the desks that were placed next to each other. While some of the employees sit side by side here, some of them work on the opposite side of the table, facing each other and each employee works with two screens.

4.1.1.1. Key Players in BIM Adoption

The Office Owner (C1-IA1)

One of the key people in Case 1 was the owner of the office (C1-IA1) who is a middle-aged interior architect and has more than 50 years of experience in the AEC Industry. He graduated from the State Applied Fine Arts High School, the Department of Furniture-Interior Architecture in 1976 (State School of Applied Fine Arts joined Marmara University within the scope of the Law of Higher Education in 1982). He has experience in various projects, mostly international and large-scale projects, such as resort hotels, luxury chain hotels, public buildings, residential buildings in prestigious locations in cities etc.

IA1 is the person who gives the final decisions in the office and approves the works done as the office owner. Architects working in his office rely on his expertise on detail solutions due to his long years of experience as a professional. He is capable of using AutoCAD in preliminary level for opening and examining .dwg files. Other than that, he produces architectural detail solutions majorly via hand drawings. He is not a Revit user therefore, he is not directly involved in the BIM process. His role in their routine workflow is to produce architectural detail solutions through hand drawings, pass them to the architects so they transfer the design information to AutoCAD and checks the AutoCAD drawing outcomes. He is also the person who communicates with the clients and gets projects through his network.

Senior Architect (C1-A2)

One of the senior architects (C1-A2) graduated from the Izmir Institute of Technology in 2017 and has 4 years of experience as an architect. He started his career as a junior architect in an international architecture office located in Istanbul, which produced large scale projects in residential, commercial, health and education sectors. In that office he continuously worked as a project team member in residential and urban transformation projects with a team of 70 people. Further, he gained work experience in a well-known Istanbul-based architectural firm, established in 1990, and he worked in a shipyard project with a team of 6 members. Together with the team he was responsible of conceptual drawings, project license process, and construction drawings. C1-A2 gained his first professional experiences on Revit in this office. The office owner secured training on the adoption. The training provided knowledge on the software in beginner level, and they did not integrate the use of Revit into their workflow. After these work experiences, he began to work for an interior design office. His first task was to produce drawings on a residential project and to coordinate the whole manufacturing process of the project. He currently continues to work for the same office and is responsible for interior shop drawings and door manufacturing processes of an international and multi-partner Hotel project with an architect team of 12 members.

C1-A2 did not had any experience or practical knowledge on BIM processes but was one of the first adopters in the office. He was motivated to develop his architectural and technical skills and thus could integrate BIM into his workflow. C1-A2 had comfort in using Revit and implementing BIM while the case study was done.

Senior Architect (C1-A3)

The senior architect A3 graduated in 2017 from Izmir Institute of Technology. She started her career in a small-scale architectural office and completed the design and building license processes of a local villa project in Turkey. After that, she was responsible for the drawings of the cafe and restaurant programs of a commercial center project. In the same firm, she also took place in a restoration project of a commercial use project. After leaving that office she started to work in the interior design office, Case 1, as an architect and she was responsible for the drawing and manufacturing processes of furniture in several projects. She is still working fin the international hotel project with a team of 12 members together with C1-A2 and is responsible for interior design shop drawings and implementation process.

C1-A3 has a key role in the BIM adoption process of the office because she was the person who first triggered the idea to go through BIM adoption. She motivated the office owner C1-IA1 and all other team members to start this adoption. She was familiar with Revit software but did not have any practical experience in using the tool. Nor had she experience in BIM processes before this BIM adoption experience.

4.1.2. Case 2

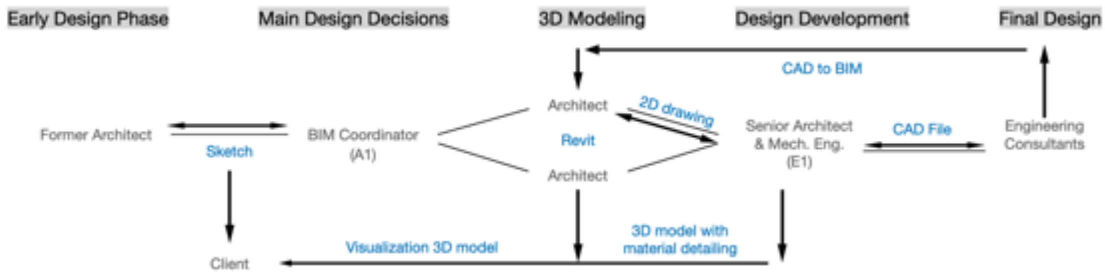

Figure 12. Organizational structure and workflow of Case 2.

The office was found by two partners, one of whom is an architect and the other a mechanical engineer (C2-E1). The team consists of 12 people; founding partners, a senior architect who has many years of experience in construction detailing, a senior architect working as BIM coordinator, four architect and four junior architects. The office has an open-office configuration where all architects' workstations are placed. Only the lead architect and the mechanical engineer (C2-E1) together with the middle-aged senior architect have separate rooms but have visual contact with the open office space through glass separators. The project phases and workflow of the office is illustrated in (Figure 12).

The co-owner and chief architect of the architectural office established his architectural activity in 1986 in Istanbul. He has worked on historical preservation after having completed his architectural education in Istanbul. He has realized projects in Turkey and abroad in countries including the Netherlands, Japan, Canada, the United Kingdom and France. His works were featured in several publications. Selected projects have been published as a monograph by Harvard University Press. The architect has various national and international awards including the Aga Khan Architecture Award. In addition to his professional work, he has also contributed to architectural education since 1992, and is one of the founders and executives of a National Universities' Architecture Master's Program. He is also a visiting professor at three internationally well-known universities. The chief architect took part in many national and international juries and in international architectural events such as conferences and workshops that he personally directed.

4.1.2.1. Key Players in BIM Adoption

Mechanical Engineer/Co-owner (C2-E1)

The engineer partner completed his Mechanical Engineering education in 1985. He has made many mechanical designs in his professional life, prepared construction drawings and took an active role in the construction site management to ensure that his designs are applied as envisaged. He started an engineering company in 2005 and thus took all the necessary steps for the realization of a building and continued its activities in the field of structural engineering and project management, including other engineering disciplines. He continues his professional activity in Istanbul, within the framework of the office that is the subject to this study, by making sustainable projects where architecture contributes to engineering and engineering to architecture, being aware of the cultural and historical responsibility of harmony with nature. He has comfort in using AutoCAD but is a non-BIM user.

The Key role of C2-E1 in this study is that he was the person who decided on the BIM adoption. His role in the process was to motivate and push the team members towards BIM adoption and setting the strategies for the adoption. He did not have Revit skills or any practical BIM experience but was the major motivation during the adoption phases.

Senior Architect (C2-A1)

C2-A1 completed his education in 2014 at the Middle East Technical University, Department of Architecture. He took part in projects of different scales at the office, Case 2, which he joined in 2015. In 2016, he started his master's degree in architecture at Yıldız Technical University. In 2018, he worked as the head of the architectural design studio at FMV Işık University, Faculty of Architecture. He continues his architectural production as a stakeholder in the formation of the office.

Before he joined the team, he did have experience on BIM technology and process through his previous work experiences. When he joined the studied office, he was the only person who had knowledge on BIM and was responsible of diffusing his knowledge and explaining the philosophy of BIM to other team members. In that context, the key role of A1 was to be the BIM champion in the office.

CHAPTER 5

PRE-DURING-POST BIM ADOPTION PHASES

In this study, the process of BIM adoption in architectural offices were analyzed under three main themes, namely pre-BIM phase, adoption phase, and post-BIM phase, to get a better understanding of the nature of the events and perceptions concerning the diffusion of BIM practices. Although these three phases were designated to present analytical stages within the adoption, the field data within this study suggests that there are circumstances where these stages are intertwined in practice and their boundaries are blurred.

In this chapter, a brief presentation of the superordinate categories from the data analysis is introduced. The analysis of the segments in the qualitative data set has led to categories and superordinate categories to explain the phenomena under focus. Later, the three-staged structure of the data analysis is presented with the intention to contextualize the analytical categories within the process of adoption.

5.1. Super Ordinate Categories

Under three main themes, 11 super ordinate categories were developed through the qualitative data analysis. Accordingly, 35 categories -made up of qualitative data segments- were formed to inform the superordinate categories. Each category will be described with parts from the transcript of interviews as results.

All direct texts that are represented were translated from Turkish to English by the author. The superordinate categories and their categories are as follows:

1. *Workflow in office* including the sub-categories of *collaborative work environment, iterative process,* and *multidimensional nature of design.*
2. *Motivation for adoption* including the sub-categories of *complexity of organizational structure, bottom-up motivation, updating drawings, initiators for adoption, complexity of projects* and *lack in coordination.*

3. *Facilitators for adoption* including the sub-categories of *LOD of first model, trust, competition,* and *BIM as a need.*
4. *Change experience* with the sub-categories *of change in attitude, change in team,* and *change in roles and responsibilities.*
5. *Hardware investment*
6. *Barriers to adoption* including the sub-categories of *time constraints, infrastructure, multiple software use, resistance of people* and *software skills vs. expertise*
7. *Strategies for adoption* including the sub-categories of *training*, *"projection project", solidarity, learning by doing* and *BIM champion.*
8. *Collaboration between/in teams* including the sub-categories of *central model, instant communication, cloud-BIM collaboration,* and *clash detection.*
9. *Complexity of tool*
10. *New workflow* including the sub-categories of *design communication, documentation,* and *coordination in model.*
11. *BIM maturity level* including the sub-categories of *multi-disciplinary* and *single-disciplinary.*

5.1.1. Phase 1: Pre-BIM Phase

The pre-BIM Phase refers to the ongoing procedures of architectural production of architectural design offices prior to BIM adoption. This phase is investigated with the intention to present the nature of work environment and workflow in the offices before the adoption and to understand better the context in which the motivation for BIM adoption emerged.

The collected data provide information on the offices design intent, routine work environment in the office, and steps of project development, from start to finish before the BIM adoption. In investigating the workflow prior to BIM adoption, it was aimed to understand where the motivation to switch to BIM use came from and how it emerged and was triggered. In addition, by examining this phase in depth, it was ensured that comparisons related to post-BIM phase could be made.

Workflow in Office

One of the key superordinate categories involves "the workflow in the office" which refers to the particular practices within the "*collaborative work environment", with a focus on "iterative processes"* and "*multidimensional nature of design".* To better introduce the importance of this superordinate category, instances from Case 2 are presented below.

In Case 2, the *collaborative work environment* in the office is supported by an open office configuration. The co-owner and leading architect has a separate room for himself and there is a second room which is used by the mechanical engineer, who is also the co-owner, and shared with the highly experienced middle-age senior architect. All other team members, architects, work in an open plan office environment. Here, the focus is on understanding socio-cultural context in the office. During the interview the co-owner engineer described the lead designer's perspective on working with team members:

> **00:01:31 C2-E1** ...We are not a very big office, actually, don't see it like that. We have not become an office that does huge jobs and does a lot of work. We didn't like to be. XX doesn't like it. He rightfully does not like to do the project that he cannot have a close control over it. He wants to be involved. He always gives an example of a Swiss architect. He had a saying that I don't want more than enough staff to sit at a dinner table and chat. What does that mean, there are dining tables for 10-12 people at most. So, when you sit down, those 10-12 people will see and talk to each other. He will exchange ideas about the project. Therefore, our office was an office of approximately 100-120 m2, take a rectangular section... It's not very big. 120 m2 single-storey.

As it can be understood from his statement, it was important for the owners that the office was able to maintain the working culture they had adopted in years. They keep the number of projects they receive at a certain number of their own will. He mentioned that the office prioritized this collective work culture over financial concerns. We understand that physical togetherness and production in this state of being together was part of the routine working culture of the office. The same engineer adds the following:

> **00:02:58 C2-E1**…He [lead architect] does not like to work by sitting in his room anyway, there is a stool next to each architect at the desks in the open office layout in the middle. There are one or two small stools. He likes to sit on the stool. He is such an architect. He does not sit on a chair with a backrest. He comes and sits next to you during the project.

The co-owner engineer described the relation of team members and the lead architect. According to his statement, the chief architect had a one-on-one relationship with the team members throughout a project lifecycle. All team members were in close contact in the office. Design discussions in the *collaborative work environment* of the office was a routine before BIM adoption.

During design development, collaboration evolves among team members and also between the employer and the architects. The BIM coordinator architect described a step-by-step process in which the early phase of design included discussions on first ideas with the user/employer. This continues until the user is satisfied with the main design decisions, which provides spatial solutions for the needs. When the project reaches a certain level of development, it was transferred to the engineering team to engage in structural solutions. Here, file exchange between the teams was conducted through dwg files send via e-mails:

> **00:02:58 C2-A1**…Here is the case where the architects and the system [clients] and the engineering coordinate with us. Why am I dividing this into three parts? Because it goes like this, relationships with customers, employers, users. "I want my room like this. I want it to look over here" is normal human stuff. S/he has a land. S/he imagines what it will be like on the land. XX is actually the person listening to him/her at the table. He listens and gives a spatial response to those requests. We are trying to bring it to life and make it visible. We are developing and the project is getting somewhere. After a while, the basis of what we can do now has to be linked to engineering.

In Case 2, an *iterative process* between the architecture team and engineering teams are described by the participants. According to their reports, after the project is transferred to the engineer, the engineer works on the project and transfers the file back to the architectural team so they can check situations affecting the architectural design. Until this stage, the architect team avoids making any design changes on the project. Any change at this point, causes teams to produce a solution over an outdated drawing. The incoming static project is juxtaposed with architectural project drawing and clash detection is made by architects. The architectural team makes revisions according to the static project or requests a revision from the engineer. In this process, the project has an *iterative process* between the engineer and the architect. Simultaneously, the user is informed about the changes made during the process and his/her approval is obtained. When the interdisciplinary process is completed, the architect team begins to produce detailed solutions on a larger scale. Here, a project delivery process is described, in which the user is included in the process at critical points, and the production between teams is not simultaneous, but awaits and follows each other, and progresses linearly in *iterative processes.*

Motivation for BIM Adoption

"Motivation for Adoption" is one of the key superordinate categories which focuses on the "*initiators for adoption", referring "Bottom-up motivation", and* focusing on negative factors triggering motivation which are *"Complexity of organizational structure", "complexity of projects", "lack in coordination"* and "*updating drawings"*. The superordinate category is introduced in more detail with several instances from Case 1 and Case 2 below.

There are *initiators for the adoption* of BIM that are *market-driven* and *internal-driven*. With market-driven what is meant is any initiations that were caused other than by the office members. So, any effects of AEC Industry partners on the adoption, except the cases studied here, are labeled as *market driven*. In Case 1, the project delivery method and LOD for BIM model was determined in the contract. Therefore, the first thing that triggered this adoption process and a change in this office, which was established in 1984, was these contractual obligations of the project they took part in.

> **I:** Then I think we can move on to the BIM process. Where did this first BIM adoption come from? From the employer contract?
> **C1-A2:** Yes, this motivation actually came from the contract. In other words, since the contract was made over BIM, we switched to BIM together.

According to C1-A2, the team was already a part of the project before the adoption. So, the architect C1-A2 was asked on this working period in depth. His statements showed that their first reaction was to get integrated in the project by producing AutoCAD drawings as they used to work. These drawings were transferred to the BIM by an external team. The difficulties experienced in this process, which will be explained in depth thereinafter, caused an *internally driven* motivation to join the Revit team due to these negative experiences of distributed drawing workflow of teams. The architect of the office, i.e., the BIM champion, explains her first attempt as following:

> **C1-A3:** …So xxx firm was transferring the interior drawings to Revit. Xxx firm is in Russia, productions are made in here [Istanbul]. Since communication from Russia to Istanbul is difficult, they wanted the interior design project to be drawn in Istanbul, and their communication with our office would be easier. Then I said to my boss, "We are making a proposal for manufacturing, let's also prepare a proposal for the Revit drawings of the interior design." I said, "let's draw it here" because we had a lot of difficulties with it, it is very difficult to control it when the drawings are produced elsewhere.

When she made this offer to the office owner, she had no experience in Revit or BIM. She did make that offer because she knew that the other teams, they work with are contractually obliged to work as a BIM team and she foresaw that the difficulties mentioned above will continue throughout the project. It is understood from the interviews with C1-A2 and C1-A3 that they, as employees, were motivated for BIM adoption. The strategy of change in this case, therefore, is a *bottom-up motivation* process in the office. The office owner, who is interior architect C1-IA1, mentioned that they had no interest in BIM adoption up until then and added that the desire to adopt BIM was internally driven. According to him, the office was not in need for the adoption. The reaction of the office owner was analyzed as a *barrier for adoption* and will be presented in the following parts in depth.

In Case 2, the office collaborated with a prestigious, well-known architectural office in the US for an architectural competition. The owners of the office in Turkey were able to visit the office in the US and observe the working environment there. The fact that the team in Turkey was using AutoCAD for design drawings was an obstacle for the US office that was using the Revit software. The co-owner, C2-E1, told us that at this point he realized that there is a tendency in the world to use this program. The engineer stated that he envisioned that a *market-driven* change will force offices into BIM adoption in the near future. This was the first trigger for BIM adoption motivation mentioned by interviewees of Case 2 during the interviews:

> **00:12:03 C2-E1**...We would be happy to do such a job, we would like it. But they said, "What are you working with? What is your system? Can you draw with Revit?" I had heard of Revit before but 8-10 years ago... we said “no, we use AutoCAD.” He said, "How are we going to work then how are we going to do it?" The man is American... He said let's talk about it, he said let's discuss. Because then he said that it will be difficult for them. It's hard for him…

C2-E1 stated that he was impressed from the collaborative work environment between architects and engineers that they observed in the American office. He stated that the redundant iterative drawing process between architects and engineers caused a waste of time and labor. The example of an office that can work collaboratively between teams created an *internal-driven* motivation to make a change in this direction. According to his statement, the whole process of adoption has progressed because of his personal motivation and efforts from an engineer's point of view:

> **00:12:05 C2-E1**...I went there, there is a model workshop in the middle, a very stylish one. Their open office is also big, but it has everything in it. So, there is also the engineering team. They do not receive external service for engineering either... Mechanical and electrical all work there in the open area. There are a lot of models around. Well, let's not prolong it. That did already excite me, my engineering side outweighed a bit. XX doesn't like this at all, he likes to draw sketches. He has nothing to do with this. It would be impossible for our office to undergo such an adoption without me. So, it's hard.

According to his own words in the interview, the first idea to go through a change in their work habits came from the co-owner C2-E1. He is one of the two people on the top of the hierarchical structure in the office as being one of the owners of the office. So, in this case, differing from Case 1, the adoption strategy is a top-down motivation. Another issue on the top-down motivation that C2-A1 mentioned is that the lead architect's understanding of architectural practice as a collaborative effort already made the adoption process easier and more possible:

> **00:56:18 C2-A1**...He does not produce projects for competitions, because it is closed, you are with yourself. That's why we actually call it BIM. He is inclined to share information interactively with other disciplines. Otherwise, call BIM as interactive as you want, this is out of the question if he were not inclined to that situation.

Another issue that C2-A1 and C2-E1 in Case 2 addressed, and both agreed with, was that the *curriculum* at universities was a trigger in this change.

> **01:17:58 C2-A1**...That's where the motivation comes from. It's also about keeping up with the times. Why do you need to adapt? Everyone who hires you is the most up to date... Do you know what lies behind this? Universities. Whether the graduates of universities communicate with something other than Revit today, everyone has to keep up with it. Universities actually set this rule.

The BIM coordinator C2-A1, mentioned that the software used in the industry is designated by the new graduates' skills. He also points out that this relation works in both directions. The need of AEC industry influences the curriculum at universities.

A motivation for adoption both in Case 1 and Case 2 was the problems experienced in *updating drawing*s or lack of up-to-date drawings. When asked in more detail on the exchange of drawings between Revit-AutoCAD conveyed by C1-A3 in the above paragraphs for Case 1, it is stated that this caused outdated drawings to go back and forth between the teams. C1-A2 mentioned that this problem of outdated drawings occurred also among their team members.

00:34:01 C1-A2...But, for example, it happened like this, the detail came to us, for instance, a door was drawn. The cross-section and plan of the door did not match, in AutoCAD drawing.

They experienced loss of time and labor while trying to fix drawings. A similar statement was made by:

00:08:09 C2-E1…As it changes, the second architect picks up where the first architect had left off. S/he is making it something. You look at the juxtaposition, the project in your hand... it's an old one. But the architect says it hasn't been updated, for instance. Because AutoCAD doesn't have such a feature. So, you drew it. You changed one side, but the site plan or something is still the old one.

He mentioned that this problem required them to go back in drawings and try to fix these contradictions again and again. In Case 2, it is stated that this workload was not always possible to handle with due to time constraints of project delivery. C2-E1 reported that he was observing this inefficient work process over time. He stated that, before starting to work at this office, he examined that these inconsistent and outdated drawings between the architect and the engineer was hindering the process in his individual engineering jobs.

In Case 1, architects C1-A2 and C1-A3 explained how they coordinated with the other teams in the project. They mentioned that there was a *lack in coordination* between teams. They gave examples on different solutions they found in time to exchange information on drawings with other teams. It was necessary to contact and inform stakeholders whenever there were inconsistencies between the drawings. C1-A2 explained this *lack of coordination* with a real-life experience:

I: So how often did you have to communicate? I mean, if there is a revision that affects them, or the situation of reporting once a week, etc...
C1-A2: No, we only communicated when there was a situation that affected their drawing. Yes, only in cases that concern them. For example, there is a socket on the floor, after getting the information of its location, I said "ok" and if I wasn't going to change the place of it, I was just constructing my own drawings around it. If I'm going to make any change, I contact them. I did always get in contact when there was a problem. Actually, we were accumulating problems. When the problems increased, we were going to Russia. When they arrived in Turkey, we were discussing those issues in long meetings that lasted all day.

5.1.2. Phase 2: BIM Adoption Phase

The adoption phase corresponds to the process that starts from the first decision to adopt and continues until the new workflow after BIM adoption became the new routine in the studied offices. The interview findings that implicate this period are on how the offices managed with the *changes* and *barriers* at different levels, the *strategies* they used for the adoption and the *facilitators in BIM adoption* that was mentioned by the participants. This section provides information on the categories: *barriers to adoption, facilitators for adoption, strategies for adoption, change experiences regarding change in teams, change in attitude and change in roles and responsibilities,* and *hardware investment.*

Barriers to adoption

Barriers to adoption is one of the superordinate categories that include the categories of "*Resistance of Team Members"* and "*Software skills vs. Expertise*" mainly concerning issues related to people, categories "*Multiple Software Use*" and "*Time Constraints*" concerning the process, and the category "*Infrastructure*" focusing on technological issues. The superordinate category is introduced below through instances from Case 1 and Case 2.

Barriers to the implementation of BIM have impacts on each other. Information gathered from the interviews provide insights on the barriers caused by people, the process, and technology which are all related to each other. When going through the adoption phase of BIM in. both cases, there were significant *resistance of team members:*

> **00:18:57 C2-E1**…Anyway, that was the biggest problem. The resistance of the guys who work with us for a long time. Because they knew AutoCAD for years and you force them to learn something new. And they refuse, they ignore it. They are blocking it somehow."

The words of C2-E1**,** presented above, showed that people were not comfortable in changing their design routines. He stated that the employees claimed it was mandatory to return to AutoCAD in order to finish or make progress in the project and so he was forced to accept their resistance. He expressed that when they decided as two partners to go through this adoption, they aimed to implement it together with the existing team of architects in the office. However, current employees showed a high level of resistance and refused even to learn the program. C2-E1 mentioned that only one of their team members accepted to learn Revit. But, although that architect adopted the new design tool, he later left the job because he had difficulties in the work process. Other than the resistance of employees, the lead architect did show some resistance against the implementation. The resistance of people, therefore, occurred at different levels in the team. C2-E1 described the attitude of his partner as:

> **00:27:07 C2-E1**…He's [lead architect] making fun of it, too. And he's the one that does the most damage. 'Now, will you work with Revit? ha-ha'. It's spoiling the guys too because we are all in the same environment.

The resistance of people, including both team members and the boss, was similar in Case 2. The office owner, who is the interior architect, did not believe that the change was necessary for the office. This is evident in the following excerpt:

> **01:07:35 C1-IA1**...I have some strict rules while drawing. I use AutoCAD with technical drawing logic. I'm definitely putting the front views side-by-side. I place the plan under each facade by turning it according to the position of that facade. I'm in control of everything. So, there's no way I can skip something. ...Everything is obvious. Let's see, when you say 'draw a line there', you immediately see people screwed up. Therefore, it [BIM] is of no use to me clearly in terms of manufacturing. But it's good for everyone I guess, other than me…

He mentioned that he believes the process would progress the same if they had worked with their conventional methods. Architects working in this office initially refused to learn BIM. C1-A3 clearly stated that all their existing teammates refused the adoption of a new tool. C1-A2 and C1-A3**,** who pioneered the change, reported that even though they tried to support their teammates in learning Revit to get involved into the BIM team, they were not very enthusiastic about learning. Before this project, the office was involved in a project that was developed through 3D design tool other than AutoCAD. C1-A2 states that one of the architects who refused to adopt BIM also showed resistance in that previous project. C1-A3 mentioned that, for their resisting teammates to somehow be included in the team and not fall behind in the process, they gave them tasks that they could handle through AutoCAD.

The architect and the interior architect who manage the team in both offices are professionals who do not use Revit and are not practically involved in the BIM team and use sketching for design communication with their teams. Another barrier for BIM adoption was the dependence of employees on team leaders during the design process. This is analyzed in the study as the *software skills vs. expertise* of people involved in architectural design team. C2-E1 explained this barrier through an office that he knew went through BIM adoption:

00:48:01 E1...A lot of people are working in that office [the American office which they visited]. There are engineers among them, but they could not adopt BIM. It is impossible for them to do. You can't find an architect in the market that knows Revit for 10 years. Just knowing Revit doesn't work. A good architect must know Revit. It's something that takes time.

He adds:

00:48:03 E1…You… I mean the age group you represent. That's why I say you, I mean you. Well, life is not like that, sir. When the master puts the document in his/her hand, he will produce a project accordingly. Is s/he going to do the project from a painting? There is no such thing. That's why you have to be a good architect, you need to be a good architect, you need to know everything. You need to make feasible designs, you should not make things up, you also need to use that method.

By saying "that method" C2-E1 is referring to new drawing technologies that is commonly adopted in architectural practice in BIM implementation. In this case, it refers to the software Revit. He mentioned that the commitment of the young architects, who are comfortable in using the 3D drawing tool, to the architectural knowledge of the lead architect during the design process, who produces in traditional methods, hinders the full transition to the new working culture. The BIM coordinator C2-A1 exemplified situations where the dependency on the knowledge of lead architect occurs. He said that when they encounter a design problem for the first time or when they are not able to come up with a solution to the design problem, they convey the problem to the chief architect. In this case, the chief architect seeks a solution to the problem through sketching, and the 3D model, which is supposed to contain all the building information, loses its relationship with the design process. After the sketch production, the process of re-processing the design decisions into the model begins. Apart from that, both C2-E1 and C2-A1 mentioned that in the early phase of design, the first design decisions are given in several meetings between the user/employer and the lead architect in which they discuss on the first sketches on site plan, mass orientation, architectural program etc. In the workflow of the office, therefore, the 3D model is started to be produced after the early phase of design when design schema reaches a certain level of development. They stated that the process starts with the sketch and then continues with the transfer of the information in the sketch to three dimensions by other teammates who can use the Revit software.

They C2-E1 and C2-A1 mentioned that the production process in three dimensions was interrupted again in the later stages of the design. The middle-aged employee C2-A4, who is among the most experienced architects in the office, makes a hypothetical column-beam layout before transferring the architectural project to the engineers. Thus, when the project is shared with the structural engineer for structural analysis, they try to prevent any clashes that may arise between architectural design and structural design at an early stage.

> **00:42:15 I:** Is it [design communication between the team and senior architect] through the hardcopies?
> **00:42:16 E1:** Of course, he also likes to work like xx [lead architect]. He is not a "Revitist", but he has experience in AutoCAD. Draws something there... Write a note next to it. "We should do something here on the stairs. Otherwise, this or that will happen" etc... Sends it. The guys correct it according to that experience.

As it is understood from his words, the information contained in the 3D digital model is transferred to AutoCAD in the process and the team receives design criticism from this experienced architect via 2D digital design environment. Therefore, the design is transferred from the three-dimensional model to the two-dimensional environment and continues to develop there. The new decisions on design taken at the end of this process, which progresses between three dimensions and two dimensions, are transferred to the 3D model. This dependency on 2D within the team prevents the whole team from taking the process over a single model and is claimed as a *barrier to BIM adoption*. Some critical statements of C2-A1 summarized the issue of *software skills vs. expertise*:

> **00:58:08 C2-A1**…Just as I say, guys [newly graduate architects] seem very well-trained, but they seem to be well-trained to produce. They still don't know how to use this [education on design] information. More experienced people and those who use this knowledge also have significant weaknesses with the technology. The point is to bring them together.

The office owner in Case 1 stated that it is not a possible issue for someone at his age to get integrated into the BIM practice. He points out that he can barely use AutoCAD. The following statements of C1-A3 gives information on the design communication between the office owner and her:

> **C1-A3**…No, he [the office owner C1-IA1] cannot open Revit files. In other words, we need to get him a dwg or pdf printout, so he can check it, he can't enter BIM 360 either. For example, we normally publish to BIM360 as dwg or pdf format, but he cannot open the zip file either.

When asked about the workflow in office, both C1-A2 and C1-A3 mentioned that they rely on the experience and professional knowledge of their boss when there is a problem that surpasses them:

C1-A3…When, for example, we cannot imagine the consequences of the joints, we ask him if he has done this before. For example, a very heavy ceiling will be hung, and we ask him, "Have you done it before?" He suggests a detail accordingly. We get print outs for situations like that. We provide a three-dimensional image for him, so that he can perceive the whole.
I: Are these plans, cross sections, or something?
A3: Exactly, we provide the plan, the section and, if necessary, a three-dimensional visual.
I: Then he sketches on it?
A3: Exactly, he says it can be solved with such a detail. Then we process that detail again as it should be. We're looking to see if it's working or not.

Therefore, communication on the design intent between team members and the lead interior designer is based on the media C1-IA1 conveys. The lack of detailing knowledge of, so to say, “BIM architects”, obstructs them from completing the project production processes in the information shared virtual environment. Therefore, no matter how well they have adopted BIM to their own working processes, at the point where they cannot produce a solution, they mentioned that they had to transfer the information model to the two-dimensional environment where C1-IA1 can work in order to solve the problem. They provide orthographic drawing print outs as a layout for the team leader.

The office owner mentions that he is aware of this lack of technical knowledge in his team. He also states that knowing a program or adapting to new technology is not enough to complete the project delivery process:

00:48:29 C1-IA1…When I ask for details, I ask the BIM team, they don't know anything about details. If they can't solve, then it will come back to me. I'll figure it out, give the details and it will work.
…
00:16:12 C1-IA1 ...now I drew it freehand. Some drawing is coming in front of me, it's a complete cartoon. That's why I have to see it that way. I need to have a look at it too. We will do it this way again in this new project because they have very serious details and as I said, when they encounter a lack of detail, it becomes more difficult to draw Revit model in LOD 500.

According to the statements of C1-IA1, the modeling process in Revit is actually part of the designing process. Therefore, the architect, who makes three-dimensional modeling, is expected to produce solutions for the details that emerge during the modeling process.The contradiction between the level of software skills and expertise and resistance of people to adopt new technologies causes *multiple software uses* in practice. This is analyzed in the case study as one of the barriers to BIM adoption. The architect C1-A3 mentioned communication problems between stakeholders in the project due to multiple software usage. This office, which produced the project in the Revit program as a BIM, experienced difficulties in getting approval for their drawings since the team of the contractor company was preferring AutoCAD for design communication:

C1-A3...Our biggest disadvantage is that the contractor company managing the project does not know anything about Revit. Their reason is exactly the same as ours. There, too, are middle-aged people, even slightly older people. AutoCAD is their safe space. They don't want to get out of there, so they can't control it.

The use of AutoCAD apart from BIM is expressed as a barrier to a full integrated building information modelling in the project in which it was aimed that all partners work and collaborate on a common 3D digital model. It also caused inefficient communication and incorrect drawing distribution throughout the design phase. The interviewees mentioned that this did result with false implementation in the construction site and repeated redundant iterations in process.

One of the barriers to adoption was analyzed as the *infrastructure* that Case 1 experienced initially when adopting BIM workflow. The project team did use a physical server, which was located in the head office of the contracting firm in Russia, as a database and the whole project team established connections through this physical server. All Revit central models from different disciplines were downloaded and linked within this physical database. The network for this data transfer was a Wide Area Network (WAN). The network infrastructure of the office in Istanbul was inadequate since it is located in an industrial zone with weak internet connection. C1-A3 mentioned that the lack of infrastructure caused delays in workflow:

C1-A3…Now. There is a server. In this server there are local files, for example, there are central files of interior, architecture, mechanical, electrical. We were going to work on this project with three people. At first, we needed to access our own local files from the central model.
I: So, the file that belongs to you?
C1-A3: We need to access our files from the central file. This took a long time for us. In Russia it takes 10 minutes. In Turkey it takes one day.

According to the architect, synchronizing their model with other teams took one day. They strategically tried, therefore, to overcome this delay by modelling during workhours and synchronizing the model only once a day at the end of the work shift.

C1-A3…Exactly, for example, I made a revision. My colleague needs to see the revision. I installed the door. She will place that wall according to the door I placed. Normally I synchronize in Revit, she synchronizes, the door goes to her. She places the wall accordingly, it's a very fluid thing. But that was not the case with us. When we pressed sync, it took a day. So, we were working all day so that our day was not wasted. We pressed synchronization at the end of the workday in the evening. The PC could barely process it until the next morning.

Due to the lack of practicality of this workflow and difficulties experienced in terms of collaboration, the office owner invested in a new network infrastructure.

Through this investment the team saved time in synchronization with better network facilities.

Time constraints is a barrier to adoption mentioned by interviewees from both cases. Deadlines of project delivery and workloads of project prevented employees from taking the time to work with Revit and get used to the BIM environment.

> **A3**…During the mockup period, I couldn't learn. I was just hunting for the right information. Someone named xx was doing drawings. I could only view the drawings and was saying, "You've done it wrong. This is the detail." I could only warn. Because we had very limited time. Anyway, our manufacturing drawings were complete. I needed to control the manufacturing process. I needed to check the assembly. That's why I didn't have time to concentrate on Revit.

The architect C1-A3 mentioned that she needed time to get involved in the new workflow because she had to learn various new issues that she was not familiar with. Her ongoing responsibilities in the team caused *time constraints* for BIM adoption.

From another point of view, time constraints during project caused the team to revert to the drawing tools they were used to before adoption. In the given interview example below, C1-IA1 is explaining their routine workflow when they start a new project:

> **00:37:26 C1-IA1**…We do it like this, I first try to understand the project in order to speed things up. I am solving the details in AutoCAD environment. I pass those details [to his team]. If they can't get the job done in Revit in time, they present them as AutoCAD to the others [project teams].

Time constraints were mentioned several times by C2-A1 and C2-E1 from Case 2 during the interviews. **C2-**E1, the co-owner of the office, mentioned his concerns on loosing time while trying to go through BIM adoption as a team. Below is the account of the engineer on that issue:

> **00:20:38 C2-E1**…I tried that a lot too. First, I had our team take trainings. No bro, they don't adapt to, you can't make them adapt. First, they say they are used to it (AutoCAD). "I can't finish with this [Revit]." Then goes back to AutoCAD again. It is a problem in terms of time.

The co-owner explained the reason of time constraints for BIM adoption in the ongoing business process as a financial concern. In the given example below, the engineer explains the balance between time and expenses:

> **00:08:07 C2-E1**…but on the other hand, the office needs to survive, and it needs to make money. So, the project needs to be completed on time and other projects should be done. That balance needs to be well adjusted.

He also mentioned that the delays in project delivery was not tolerated by the client/user of the project. Below, he mentions that the time constraints occur when the time needed to train the staff does not meet the clients' expectations on project delivery schedule:

> **00:08:06 C2-E1**…So that the young architects can develop, and young friends can learn something. But of course, this is not a positive thing from the client's point of view. Projects take a long time and, unfortunately, everyone cannot do their job.

Facilitators for Adoption

Through the data gathered from the interviews with C2-A1, C2-E1, C1-A2, C1-A3 and C1-IA1**,** it is determined that some situations and cases reported by people were *facilitators for BIM adoption.* The *trust* between team members in going through a new workflow during the adoption phase, *BIM seen as a need* by decisions makers, *the LOD of the first model* in which the team goes through the BIM adoption, and the *competitive environment* in office were analyzed as facilitators for BIM adoption.

In Case 2 *trust* was a significant issue from two different perspectives: the trust between client and the office during the whole project phases, and the trust between the owners that enabled the BIM adoption. The two instances below provide information to understand how the office creates mutual gain with the client. After that, the positive impact of trust in BIM adoption is explained with instances from the interview with C2-A1.

C2-E1 explained their initial steps when they take on a new project. The excerpt from the interview with C2-E1 below describes their routine in first meetings with the client:

> **00:03:02 C2-E1**…Anyway, in such a working order, what if we start with the first thing when the project arrives. When a client comes to the meeting because s/he has requested a project from you, our principle is, we listen first, what does s/he say, what does s/he want? What does s/he want to do?

Since this office produces projects majorly for individuals, they are able to establish a one-to-one relationship with their clients. It is important for office owners to understand their clients' wishes, needs, and expectations. Therefore, they give importance to good communication with their clients from the first meeting. The strategies for a healthy communication in which they gain the trust of their client is explained below by interviewee C2-E1:

> **00:03:10 C2-E1**…After that, we say we should prepare a text describing on what we understood. So, to see if we do understand each other. We call it the service description. We make a service description and send it to him/her. What is it in standard architectural practice? This is a definition on the changing scales. Here is the site plan, no matter how big or small the project is, something like that is needed. Layout research of project. Its scales are written next to it.

As the co-owner stated they make sure that client is convinced in that he or she is well understood and that the scope of the architectural practice is well framed at the beginning. The transparency of the project phases enables mutual trust. The architect C2-A1 claimed that, due to the mutual trust between the client and the office, and the clients trust in the architectural outcome due to the prestige of the office, the delays in project delivery during BIM adoption process was more likely to be tolerated by their clients. The positive impact of gaining trust is explained by the architect C2-A1 below:

> **00:05:00 A1**…For example, the reason why I focus on xxx [lead architect] after all, he can gain this time from the client and other stakeholders who we deal with. Normally our projects… If an architectural project in Turkey takes two months on average, it takes one year for us. He can gain this time. We can gain it also financially. We can work on that project for one year, and people [clients] have patience.

The second perspective on trust was among the office owners. Although this type of trust was only mentioned by C2-E1 and was mentioned once, it was considered as a strong facilitator for BIM adoption. C2-E1 mentioned that his architect partners had no doubt when he mentioned his radical decision on BIM adoption.

> **00:16:51 C2-E1**…Anyway, I went back to the office. I had already figured this out. I said to xx, "I'm doing it all over again." He said, “Do whatever you want.”

In Case 1 the interviewees C1-A2 and C1-A3 described several times that they saw the adoption of *BIM as a need* in their practice. The focus point in this section is that the architects tried to relate to their boss that BIM adoption was a need and a solution to the difficulties they experienced in practice. To overcome the resistance of the team leader was possible only through changing his mindset. In the example below, C1-A3 described that 3D modelling and collaboration with other teams was a need to overcome the mistakes in drawings. So, the boss did tolerate the workflow delays due to advantages of clash detection.

00:34:10 C1-A3…My boss complained a lot about this, but before the design, the project is clarified, we can't start production without getting an A [approval]. He actually saw the importance of this. For example, we made a submission, published it without checking it much, and there were a lot of mistakes. A lot of manufacturing drawings went wrong, of course the girls didn't know how the manufacturing drawings would be, so we couldn't get an A and we couldn't start manufacturing anyway. So actually, I had to go into Revit, because I need to check, I need to process the details there. When you create the typical details, for example, you create the wall in Revit, you create the door, you can put the detail wherever it is. So, it was not a waste of time, because there is already an approval process. So even if we were using AutoCAD, we would have experienced this approval process. Only the team would be formed from those who were able to use AutoCAD, now it was formed from those who are able to use Revit.

The earlier experienced difficulties in obtaining backdated project drawings were another reason to see *BIM as a need*. C1-A2 described that they envision that facility managers will demand backdated information on the project detailing in future. So, it became a need that a 3D model is used as information sharing environment.

00:06:09 A2…There is a project that our office did in Russia before. Swiss Hotel in Moscow. For example, the building of the Swiss Hotel was built years ago. I don't remember the exact date. I think it's been over 10 years and some rooms of the hotel, for example, had deformations and the materials were worn out. For example, they will change the material, but there were no drawings left. So, they reached us again. When we went to Russia, for example, they tried to learn information from the person who was included in the project.

The office owner mentioned that 3D design tools eliminate architectural deficiencies by easing the visualization for architects. Criticizing the architectural skills of young architects, he described Revit as a need to be able to communicate with these architects in 3D:

00:04:46 C1-IA1…In this recent period, Revit has become preferred because it brings some conveniences. Because even the most blind man gets the opportunity to see in Revit. I think that's the biggest thing about it.

The office in Case 1 got involved in a project that was already working on a shared Revit model with engineering and architecture teams that were experienced in BIM and had advanced level of BIM knowledge. Interviewees C1-A2 and C1-A3, who adopted the new technology in their practice, stated that implementing BIM for the first time and understanding BIM workflow through a provided model with a certain LOD and established workflow had its advantages. So, the *LOD of first model* was mentioned by the interviewees as a facilitator for BIM adoption.

00:06:09 C1-A2…At the beginning of the project, this Italian architectural office XXX, which I mentioned, had already drawn the project and its first concept drawings through Revit.

He mentioned that all fine details were given in the 3D model as information by the architectural firm in Italy. Also, C1-A3 mentioned that the annotation standards and layers with adjusted line weights were predetermined by the Italian architectural office and that they did not have to deal with these technical issues.

The office owner in Case 1 mentioned that the addition of new team members to the team caused a competitive atmosphere between existing staff and new staff. He stated that this resulted with a positive impact by improvement in performance of team members. *Competition* between people was a facilitator in BIM adoption due to its impact on office work performance.

> **00:52:03 IA1**…We did something like this, there were people who gave goosebumps to friends who came here at different times. Not everyone has the ability to orientate with everyone. Also, for some reason, this place imitated a very competitive environment. Like "I'm doing better than you", "you are doing better than me". It raised a little the temperature here. I didn't do it, I swear. This competitive environment actually produced a very positive result. Because everyone did get enthusiastic. Now I see incredible enthusiasm here. Even I'm surprised sometimes like "wow".

Strategies for Adoption

In each case, interviewees mentioned strategies that their offices put into practice for BIM adoption under five categories. Categories will be explained with instances from the interviews regarding their order of occurrence. These categories are named as: *BIM training*, *"projection project",* hiring a *BIM champion* as a new member, *learning by doing,* and *solidarity* among team members.

In both Case 1 and Case 2 the first attempt in BIM adoption phase was mentioned as providing external *training* on Revit for the existing staff to train them in terms of 3D tool usage. The engineer C2-E1, who triggered the BIM adoption in Case 2, mentioned that he provided training on 3D tool as a starting point:

> **00:19:33 C2-E1**…I thought it will not work like this, so let's get training. Let's see if we can learn this Revit. I started to give Revit training to the core staff.

In Case 1, the first experience with Revit software was with a previous project in 2017 and the first step of the office owner was similar to Case 2 in providing training on the digital drawing tool, Revit:

> **00:05:11 C1-IA1**…There was a project we did in 2017. I first met Revit there. In fact, I hired a lady as a teacher and had my employees in our company take Revit lessons so that they could learn a little.

The architect C1-A3 mentioned that they got support in the adoption process from the BIM manager in Russia. The program license was bought by the contracting firm in Russia. Therefore, the interior design office in Istanbul was not able to get any BIM managing support in Turkey. She stated that the BIM manager clarified the logic of documentation in BIM and taught them how to access local files from the server. Another personal strategy of C1-A3 was to get *training* from friends who had experience in BIM process and from YouTube videos.

In Case 2, the co-owner of the office C2-E1, talked about an innovative BIM adoption strategy, that he personally developed and named as *"projection project"*. He briefly described this as "while a project is being drawn via AutoCAD, simultaneously a team tries to produce the same project via Revit." He explained his impressions on this strategy step-by-step. The first step he took was to provide a physical environment to work with Revit that he called "Revit desk" in the office. One architect was responsible for drawing this projection project at that desk. They first tried to develop small scale residential projects starting from the early phases of design via Revit. Due to being unfamiliar with the design tool, they failed in this attempt. They, then, strategically started with their conventional workflow, meaning sketches, AutoCAD and SketchUp for design drawing. When the project was developed to a certain point and was ready to be shared with engineering teams, the project was handed to the Revit desk to be reproduced in 3D:

> **00:23:06 E1…**Xxx [Lead architect] began to sketch. Then the team did some work in AutoCAD and SketchUp. The project has come to a point, so now the engineers will start working. It has reached that stage. At that stage, I handed the project to the Revit team and said "take the project and transfer it into Revit now." They took it and the team started to redraw it. I said to the others, "Check over them from time to time with a side eye. Let's see the difference. It is neither easier nor more difficult."

The co-owner C2-E1 in Case 2, after his strategy on training the existing staff, he hired a new team member who had the required technical skills and theoretical knowledge on BIM, namely a BIM champion. As C2-E1 stated, the expectations from the BIM champion were that he leads and guides the teams to enhance their BIM adoption process. C2-E1 narrated the previous work experience of C2-A1 before he started to work in their office.

> **00:17:10 C2-E1**…It is like what we were trying to do with the Americans, there is an architect who prepared the concept, and someone else will do the implementation. They don't do architecture. Well, if there are three good architects, the firm gives the concept to them, they take it to the firm. It's like a sausage factory. On the other hand, they concentrated on getting the job done. It's that type of a firm. C2-A1 was also working in that office…Well, let's not prolong it. He was also working there. He graduated from METU and found a job there. He had already internalized to use the Revit software.

The expressions of C2-A1 supported his role of being the BIM champion in the office. He stated that he first started with teaching Revit to the staff. Later, he established the BIM system in the office:

> **00:17:10 C2-A1**…There are already rules. Our file systems. Here [their office] was a girl from New York before me. She had set up the system of AutoCAD. I did set up the BIM system. There is a library, which is developing. We have a common graphic language for instance.

Another strategy during BIM adoption phase that was mentioned by interviewees was *learning-by-doing*. In both cases, it was stated that adaptation was an experience gain based on learning-by-doing in the process. They stated that they took action in progress without having sufficient or any technical-theoretical knowledge on BIM and its implementation. In Case 2, C2-E1 stated that he attempted to draw an implementation roadmap for the team to initiate the implementation without having the knowledge. He explained the reason for his own attempt as having difficulty in finding BIM managers at that period.

In Case 1, the office owner stated that the whole team learned issues throughout the project phases through difficulties and mistakes. Due to the bad network infrastructure in their neighborhood, the office had difficulties in synchronizing their model with other teams in Russia and Italy. In time, they found out that they could handle this location-based delay problem by creating, uploading, and downloading the model partially. Another issue that C1-IA1 mentioned was that due to the large Revit file sizes, the architects failed in switching between applications on their desktops. So, the owner realized in the progress that using two screens would be a more accurate work environment in which the Revit model is always open on one screen and the architects can use the second screen for any other needs. He reports as follows:

> **01:04:23 C1-IA1**…Everyone works with two screens. It gets much easier. Because it is difficult to open and close Revit. It takes a long time because the file is very loaded. Revit is open on one side; we jump to the other screen and continue from there. That's how we learned things. We learned all these lessons from our mistakes.

The statements of C1-A2 clearly shows that the learning process was examined in time through negative experiences. He claimed that they overcame the problems by finding solutions by themselves. He mentioned that despite the few trainings on Revit in his previous job, he improved himself on BIM in the learning-by-doing process in this project:

> **I…** So now you have taken the hotel as a reference for this [model].
> **C1-A2:** Yes yes. The hotel is the reference now. The hotel itself had actually become something that progressed organically. As problems arose, we found new solutions in Revit and systematized it.
> **I:** How did you determine these parameters? So how did you identify these needs?
> **C1-A2:** Actually, we didn't have a "BIM manager" in the beginning, but still don't have one. Therefore, these parameters were not determined in the beginning. In our project, our problems were determined as they emerged. For example, the layouts we made started to become too many. For thousands of instances, we found the "project name" annotation and that sheet number thing in order to be able to separate them from each other.

When the architect C1-A3 was asked how she started to get involved in the BIM workflow, she answered that she acted immediately and developed her skills and knowledge in time. She stated that their office was drawing the interior shop drawings in AutoCAD and another office in Istanbul was transferring their drawings to Revit model to ensure that the final detailing is integrated to the shared 3D model through which other teams in the project collaborate. Due to the complications that occurred during this information transfer, which was mentioned earlier, C1-A3 decided to learn Revit to be able to get in direct communication with stakeholders. Below are her statements on how she experienced this learning by doing process:

> **00:33:50 I…**Then you two, who use Revit, joined the team and then you switched to Revit gradually? Or how did it happen?
> **C1-A3:** I switched directly. I said I have to leave everything and try, since the production had not started yet. I went straight in and said, "give me a job, I'll try". They gave it to me, for example, they gave me the doors, I started with learning how to make a door family. I had a lot of difficulty.
> **I:** Did you learn by yourself by tinkering on the computer?
> **C1-A3:** Exactly, I learned it by observing and tinkering. Then, sometimes we were calling on skype or something, they were guiding me to see if what I was doing was right. That's how I learned Revit.

In Case 1, an organically emerged strategy to overcome the unknown issues of the new workflow and new technology adoption was *solidarity* among team members. The architect C1-A2, mentioned that during the BIM adoption process team members were more likely to help each other. Which in fact also made itself visible in the office arrangement.

00:45:22 C1-A2…It was like this before, we learned the project through Revit, not everyone knew Revit. The newcomers didn't know either. None of the newcomers were familiar with Revit had drawn a LOD 500 model. That's why we were asking each other a lot of questions. "How are you going to do this?" there was actually a rapprochement between the members of the Revit team. The seating arrangement was also the same. Everyone started to sit closer to each other. There was such a differentiation. But it was partly because of the solidarity caused by ignorance.

Also, according to the statements of C1-A2, there was solidarity between the teams. Two new team members with Revit skills moved to Russia to ensure that the office in Istanbul and the head office in Russia could coordinate better. The lack of Revit knowledge among people in the head office was to be minimized in that way. Later in the interview, the architect mentioned the positive impacts of this solidarity between teams. C1-A3 also supported this statement in her interview. She mentioned on the support of engineering teams during their BIM adoption phase, which were very experienced in BIM projects.

Change Experiences

The new technology and BIM process adoption caused changes in experiences during this adoption phase that were mentioned by interviewees from both studied offices. The experiences of participants on change were categorized as *change in team members, change in attitude,* and *change in roles and responsibilities.*

According to the statements of participants from Case 1, the office experienced a major *change in team members* during their BIM adoption. Because of the resistance of people to the adoption of BIM technology and workflow, new team members were hired, and the people of the previous team resigned in time ending with a major change in staff. C1-A2 mentioned that they tried to coordinate the new and conventional workflow in office to incorporate staff that had difficulty in adapting. They transfered partial details of the project, such as specific door detailing, to their AutoCAD skilled teammates. He stated that they managed to work together for a while in this way, but later, because of the lack in coordination between the BIM model and the AutoCAD drawings, those people also left the office over time:

00:13:39 C1-A2…He [BIM adoption resisting teammate] was solving the hotel doors via AutoCAD. Because of that the Revit model was constantly being updated, he also had a coordination problem. I provided export files for him. The electrical, architectural... For instance, I was sending our interior architecture file to him on a monthly basis, for example, or on a weekly basis, if needed. He was actually linking files offline and he was going to examine the project. Where are the doors? What are the changes in the current project? He could not adapt. He couldn't.

> The project has changed constantly, but his drawing has always remained the same. Then he left the project.

He also mentioned that the number of employees increased in time during this adoption phase. C1-A3 also talked about the increase in employee numbers during BIM adoption and that she was only responsible for the traffic in office within that previous team of six people. She stated that with the end of the projects that progressed with conventional methods, her teammates working in those projects could not be included in the BIM team and quit the job. She explained that the change in team started with searching for new team members with BIM skills to predict the cost of the BIM team when placing a bid for their BIM services. Her expression on this period is given below:

> **00:00:00 C1-A3…**No, then this happened; you need to set up the team before you bid, so we posted a job vacancy. We invited those who had Revit skills for an interview. Because to prepare the proposal, I had to determine the number of people in the team. I had to determine what the salary would be per person. I had to calculate the license fees of the program, the people going to Russia, the ticket fees, the hotel costs of their stay there, office expenses, all of them. There was also a concern whether we could find someone, so we wanted to advertise a job posting and we did.

The office owner mentioned that no one in the previous staff had BIM experience nor Revit skills. So, his first attempt was to look for architects with these skills. This period was described by him as a long haul. C1-IA1 pointed out that an intern architect with Revit skills was an essential contribution to the team during this change in team. He emphasized the importance of curriculums in universities on digital drawing skills and its importance in architectural practice as detailed in previous sections.

> **00:41:11 C1-IA**…In principle, of course, we worked hard until we settled the staff and got efficiency. I beat the guys a lot. I only didn't get a stick in my hand. Because I compare my drawing speed and thinking speed with theirs, they're very slow. Hardly did we establish a format. But in the meantime, we constantly expanded the staff. When it was two, it became four, then six, then eight, then 10. Some of the previous staff joined. So, now we are 14 people.

Similar to Case 1, in Case 2 due to existing employees who were showing resistance to change, the office opened a job posting to recruit new staff with Revit skills. The required skills in the job advertisement included having Revit skills so the team experienced a change also in terms of skills of people. With the addition of C2-A1, the BIM champion, and tendency of newly graduates to new technologies the transformation of the team accelerated. He described this change in team members and change in skills among people as an issue of the era:

00:00:00 C2-A1…When I joined the office, no one had Revit skills. I started by teaching everyone Revit. That subject evolved after a point. It came to a point…We are now gradually starting to include those with the Revit skill. Afterwards, no one came from schools without Revit skills.

In Case 2, there was also a *change in attitude* at three levels. First the attitude of clients changed within this adoption period towards demanding more service than expected due to fast consumption of visual materials. Second, the attitude among team members changed in a positive manner due to the reduced iterative drawing workload. C2-E1 stated that the demands of clients on drawing updates were no more causing chaos and stress among the staff:

01:06:15 C1-A1…First, we don't create tension anymore. We used to be overwhelmed by the slightest change. It was reaching the level of suicide. You just finished and the man changes something, and everything changes. You know what the perspective is right here now? You are smiling as an architect. Ask for what you want. It's easy for him now. When he suddenly changes everything, he sees that it can't happen and says, "Look, it doesn't happen. Then it happens just like this".

Last, according to the interviews, it is observed that the attitude of office owners/team leaders towards employees changed towards demanding more than usual. In Case 1, the office owner C1-IA1 stated his expectation on employees to extend their working hours due to the inefficient workflow during BIM adoption phase. The adaptation of architects to the new tool and workflow caused delays in project delivery. Therefore, the office owner motivated his employee to catch up on the schedule through extra work hours.

C2-E1 stated that he expected from the new team members to be skilled in BIM and to be able to generate solutions to architectural problems. So, he was requiring technological and technical skills from newly graduated architects joining the team. He believed that the era of senior architects sketching and afterwards handing the design sketches to the architect team that transfers these sketches to digital environment will come to an end soon. He envisions the new workflow as one in which there will be a single person who delivers the project from the beginning to the end, working individually.

01:08:10 C2-E1…In the future, your generation will produce sketches plus drawings themselves. It will work with Revit. S/he will talk to the employer with the sketch. The future will immediately model and draw it on the computer. S/he will do it himself. S/he won't need anyone else. "Here, turn that into what." That generation will end. This will be the generation. OK? It will use different arguments. S/he will show it. It will be a one-person army. It's that simple.

The delay in workflow due to the adoption of BIM, which was mentioned above, caused *change in roles and responsibilities* in Case 1. When complaints came from other teams about the delay, they held a meeting with the whole team and sought a solution to this problem. The office owner stated that they started to work in a more coordinated way by creating working groups within their own teams. He mentioned that they divided the three-dimensional model into parts according to locations, material, and specific elements, such as doors, rooms, corridors, marble, and reassigned the responsibilities to the people in accordance with these. Regarding the statements of C1-IA1, while senior architects C1-A3 and C1-A2 were responsible of the coordination in team and between teams, they joined the above-mentioned work groups to speed up the development of the BIM. Since the majority of these work groups were composed of recently joined architects, each group was led by one senior architect. To coordinate with stakeholders, each member of the team was responsible of getting in one-to-one contact with a different stakeholder. C1-A3 stated that they made a workload distribution according to the project needs. As the process progressed, she stated that she delegated her responsibilities related to programming, communication, and problems regarding Revit model to another teammate due to the intensified production pace, and that she took more responsibility in the manufacturing process.

The senior architect C1-A2, mentioned that the role and responsibility of the office in the project has changed with their BIM adoption period. The office was responsible of providing service in production of interior design elements. They produced shop drawings via AutoCAD and communicated for production with the producers and workers through print outs. To embed this detail information into the BIM, their final drawings were converted and transferred to the 3D model by an external office with Revit drawing skills. With the transformation of the office, the responsibility of the office extended into providing both the production of interior fixed-furnishing and updating the BIM with information in LOD 500.

C1-A2…No, xx construction is actually a construction company, they mostly do rough construction. They bought this project from xxx, but actually hired us as a subcontractor along with its interior design.
I: Well, there was no talk about BIM at the stage they hired your office, right?
A2: No, it was not talked about in the first mockup stage. After the drawings were gone through CAD, this BIM issue was discussed when we bid on the whole project. In this process, they gave us the entire project of the hotel, xx Yapı was only a contracting company, in fact, we were also the manufacturer. However, xx Yapı also received the interior design project from the employer. Therefore, they asked us to draw the interior design project. More precisely, the employees of xx

Yapı would come to our office. We were going to help them with the drawing process. We are just the manufacturer.

Another change in roles that was mentioned by C1-A2 was the role of the office owner. In their conventional workflow, the office owner was able to be in control of the drawings through AutoCAD and the e-mail traffic between his employee and stakeholders. C1-A2 described that C1-IA1 was controlling every drawing they produced and was involved in the problem-solving process between architects and engineers. That in the BIM workflow design problems are solved in digital 3D environment as the problems occur through synchronizing models, C1-IA1 fall outside of this design process because of his lack of Revit skills:

C1-A2…Actually, there has been a change in our relationship with the boss. For example, in the past, our boss could open AutoCAD files, that is, he could open the pdf and examine. For example, it was like this before: I'm e-mailing last year during the covid period. I'm sending something from home. Of course, I put the employer in cc. He's calling me to say, "That's wrong." He is protesting on the phone. Now, we are publishing in this BIM process. Publishing is made via BIM 360 or we describe something via Revit and send it to Russia. As such, the boss cannot be involved in the process.

The office of Case 2 experienced a major change in roles and responsibilities during BIM adoption. The co-owners of the office were leading and managing the team and projects before BIM adoption. The lead architect was responsible of early design phase, design development and design communication between people. He was holding design discussion for design improvement one-to-one with the staff, each responsible of individual projects. The engineer co-owner was responsible of financial and project delivery issues. He was settling time and cost constraints for the team. With the BIM champion joining the team, the responsibility of the architectural team was gradually transferred to him. As understood from C2-E1's narration, while everyone was communicating and discussing on a project together in the conventional workflow, during the adoption phase, the early design process of the project has started to be carried out only by C2-A1 and the chief architect, and then the project was transferred to the Revit team to be developed by C2-A1:

00:39:13 C2-E1…Then we two [E1 and the chief architect] meet in a common place with A1 with the sketches provided. We meet either at my office, at the place in Ortaköy, or on the other side. The two of them are starting, I do not go into the subject or anything, they are starting to put these [notes from the meeting with the client] conversations on paper. At that moment, whoever XXX [A1] is planning to do the project with the architects in his team... our team is now under his control. I don't even see the guys. We hold a zoom meeting or hold meetings at the office at regular intervals. Sometimes they go to C2-A1's. sometimes they work remote from their homes with the computers we provided. Quite efficient. No problem.

Software-Hardware Investment

In both cases, participants mentioned that software-*hardware investment* was a necessity that they had to face during the BIM adoption phase. In Case 1, the office owner stated that he made a huge investment on hardware for BIM. C1-A3 described in detail what type of improvements they made in the system features of their desktops. Also, she mentioned that C1-IA1 invested in new desktops with much better performance. She pointed out that the office owner did not show any doubt in investing on technological improvement. The cost investment for Revit software was provided by the contracting firm in Case 1.

> **C1-A3**…No, I mean ... The computer is also important for Revit. For example, I had the RAM updated on my computer, a computer with a certain capacity was purchased for those who will join the team, extra support was given to the desktops so that they could run this program.

The senior architect C1-A2, supported the statements of C1-A3 with his statements, given below, on hardware changes during the adoption process:

> **C1-A2**…Well, our office computers had 256GB SSDs. On all computers. Previously, they installed SSDs next to HDDs because the hard disk of the computers was slow. But when we installed Revit, these SSDs were insufficient. Because to run Revit, you need 50 GB free space. Therefore, the hard disks of almost all existing computers in the office was changed. SSD were installed. Some changed completely. It was taken from scratch. But there was definitely a change.

The hardware investment in Case 2 was triggered by C2-E1's observations on their visit to the American office. He mentioned that he was impressed by the high-performance computers in that BIM implementing office. He expressed that they primarily invested in software and hardware for BIM adoption:

> **00:20:30 C2-E1**…It starts with getting the Revit program first. I developed the machines first. I started to renew them. I installed the new server on the computer. I saw the Dells there; I bought the Dells. Serious bucks. Until then, we were always working with add-on computers. "No bro, what's the point, it's price doubles." I said, "Don't step in. I want these." Because I saw it in the Americans. As a matter of fact, all the machines and so on are so fast now.

5.1.3. Phase 3: Post-BIM Phase

The post-BIM phase refers to the period people began to adjust to social and technological innovations caused by BIM adoption and made them the routine of their architectural work processes. This phase is introduced with the intention to present the socio-technical aspects in offices in BIM workflow. In this section information gained through interviews are presented under the categories of *BIM maturity level, new workflow, collaboration between/in teams,* and *complexity of tool.*

BIM Maturity Level

Regarding to the ability to exchange information through the BIM in Case 1 and Case 2 two different BIM maturity levels were realized. Level of maturities in BIMs are categorized according to the level of collaboration and therefore, the amount of information that was embedded in the model. According to the collected data, BIM maturity levels in two offices were categorized as: *single-disciplinary* and *multi-disciplinary.*

In Case 1 the BIM model in LOD 200 is provided by the architectural design office of the project in Italy. All teams included in the project work with the Revit software. The architects of the studied office in Istanbul, develop this Revit model to LOD 500 by integrating construction details of each element. This LOD 500 BIM model is a *multidisciplinary* model which includes information of all disciplines, detailed by the participants as architecture, interior, electrical, mechanical, plumping, piping, firefighting, and acoustic performance. All elements are modelled, or the Revit models of the elements are provided by the suppliers. The model, hence, also entails information on all suppliers. C1-A2 stated that they model 1/1 scale construction detail and layering and according to the statements of C1-A3, the LOD 500 is demanded by the operator company for facility management:

> **C1-A3**…Now in Revit, we also transfer all the information of everything we enter here. The brand, the model, the manufacturer, the website… There is a cost part, of course, but we do not enter that part because they do not want us to enter it. But other than that, it's already demanded. The part that received the most comments in the first sheets we published was "Type the manufacturer correctly, write the description correctly." They paid great attention to them. Because XXX, the operator company, not the contractor, wants to use this Revit model in this way in their hotel business. For example, when a material gets old here, as you said, they want to find all the

information in this project to enter and renew the material there. We proceed in the same way; we enter all the information.

The office owner mentioned that he is satisfied with the maturity level of their BIM that is produced in his office. On the other hand, C1-A3 mentioned that she is unsure of the maturity level and whether the 3D digital model is a BIM or not. She claimed that they do not benefit much from the features of BIM, but only do modeling in detail.

In Case 2, the team models only the architectural project in Revit with detailed information. The engineering teams develop their drawings via AutoCAD and transfer their files to the architecture team. The structural information is integrated into the model by the architecture team. The BIM champion, C2-A1 mentioned that they produce a *single disciplinary* model because their clients do not demand BIM models and that a *multi-disciplinary* model would be possible in their office if it was demanded by the client. He explained that they produce lonely-BIM but with a high LOD in the architecture project. That the information in the model is only used within the team, they develop the 3D model according to their own needs. The co-owner of the office C2-E1, described this lonely BIM as being sufficient and effective in their new workflow.

00:44:20 C2-E1…Advanced architecture final project is ok. The customer is satisfied. We turn back. Our team is processing them in detail on the Revit model again. Then it goes to the structural engineer again. First of all, the structural engineer makes a mold plan. That's what they call it, that's how they start. When the mold plan is set and sent, our team immediately takes that mold plan and models it in Revit. They're doing it fast. It doesn't even take a day.

He explained that they could not go further in BIM, because of the unfair competitive environment in the Turkish AEC industry and that they would not get paid appropriately for building up such a multidisciplinary model.

New Workflow

In interviews participants narrated on their current workflow with innovations in *coordination in team, documentation*, and their *design communication* in model.

The *coordination in model,* is facilitated through model accessibility control as described by C1-A2. When two or more people are working on the same part of the BIM, they distribute the work primarily to prevent conflicts in modelling. He stated that in case conflicts occur during modifying an element, Revit gives a notification on the element ownership, which means that someone is currently working on that element, and that permission is needed for modification:

> **01:40:00 I:** Are there situations in your office where there is another person working on the drawing you are working on for instance?
> **C1-A2:** Yes.
> **I:** How do you coordinate with that person?
> **C1-A2:** We do the division of labor with him. Revit warns us if there is a conflict in the things we work in the same place. Well, like "You both try to edit this element. You don’t have the element ownership. You have to get permission.”

According to C2-A1, in their office the work is distributed by him after a coordination meeting with the team. C2-A1 strategically divided the 3D model in parts such as façade, interior, and architecture to prevent conflicts in 3D modelling. These parts are distributed to architects. He also mentioned that each architect working on the BIM relinquishes ownership of model elements every 15 minutes to make sure that other users can work on those elements.

Participants both in Case 1 and Case 2 mentioned the *documentation* advantages of BIM. They said that it reduces the time needed for project *documentations* and eliminates false information in documents due to storing information in digital form. The office owner in Case 1, expressed his appreciation about easy and fast accessing to work detail information and product specifications. C1-A3 mentioned the advantage of creating easy, fast, and solid schedule or quantity of components in the project.

Participants mentioned on how they perform *design communication* with each other in post-BIM phase. In Case 1, the design communication between office owner and architects did not show major changes than the pre-BIM phase as stated by C1-IA1. He mentioned that he draws a sketch for detail solutions and architects of his team transfer this 2D drawing to AutoCAD. When design decisions are finalized, they transfer AutoCAD drawings to Revit:

> **00:21:17 C1-IA1**…Now I am producing and giving the solutions of the unsolvable parts through sketching. They transfer them to AutoCAD. Thus, we solve the issues by transferring from AutoCAD to Revit.

The design communication in Case 2 between the lead architect and architects in team is similar to Case 1. The sketches made by lead architect in early design phase are transferred to 3D via Revit software by the team members:

> **00:56:19 C2-A1**…XXX [lead architect] starts sketching, starting with bubbles. We are there too. Then when you digitize it, you find problems. It's like: "this should slide here. This should be like this. This didn't work..." From then on, we are moving forward through that digital model that we produced. Print out again. Check again…

Collaboration Between/In Teams

Innovations in collaboration both in team and between teams were mentioned by the participants. This section gives information on the categories of *clash detection, central model, instant communication*, and *cloud-BIM collaboration.*

Clash detection is mentioned as an advantage of collaborative BIM in both Case 1 and Case 2. In Case 2, the office owner C1-IA1 stated that clash detection makes everything more visible for architects who have difficulty in 3D design thinking. Architect C1-A3 was the responsible person in team for the construction detailing and shop drawings of the Hotel project. She mentioned that without the advantages of detecting errors and conflicts between various teams' models through clash detection in BIM, delivering the shop drawings on her own would not be possible:

> **C1-A3**…For example, right now, A2 will join me, but until now I was alone in the production. If it wasn't Revit, I wouldn't be able to deliver shop drawings on my own, it's impossible. In other words, a single person cannot produce a hotel with 65 rooms and an area of 24000 square meters. This has never happened in our office. But the reason for this is Revit. Because I can see the mistakes very quickly there, those conflicts, the things that don't match. Everything is done so smoothly there that I can take it directly from there, have a look, check it, and give it directly down [production area]. It's very fast.

C1-A2 described BIM as a living process through real-time synchronization with teams. When teams reload their projects in the BIM, they can detect clashes and respond to these in a collaborative environment. He shared his negative experiences of working without collaboration in design phase:

> **C1-A2**…I think the most important advantage is that it provides collaboration in a very comfortable way, so interdisciplinary collaboration is a very important issue. For example, in my previous project, it was a hotel project, there were a ton of problems. There was a large conference room in the early design phase. The conference hall span was 36 meters. That's a very serious span with a walkable terrace. This is how it progressed, the project progressed… its location was determined, its foundations are being dug. One day the civil engineer said, "I have solved the trusses here. Its height will be 3.5 meters."…. We changed the floor heights of the hotel because we were thinking more about design, and there was such a huge workload that you wouldn't believe. We did have work nights and days. However, he could have realized it. So, if it was BIM, it could be realized. Because it would be in its modeled form, and he could take a section from there whenever he wanted.

According to C2-A1's statements, in Case 2, *clash detection* was possible for architectural and structural projects because only information on these two disciplines were modelled in their BIM. The architecture team models the structural project in 3D to be able to detect clashes. The co-owner C2-E1, mentioned also that they benefit very much from clash detection in the BIM.

Collaboration among team members is provided through a *central model* in Case 1, in which each member makes a local copy of the centralized model and makes their changes in this local file. When synchronized to the central, all members receive the changes that others have made. The same modelling strategy is used by each team in the project. So, each discipline has its own *central model.* C1-A2 stated that having separate centrals for each discipline is a necessity in big scale projects to prevent the Revit file size to be too large. To collaborate with other teams each discipline links the central files of other teams to their own *central model*. As explained by C1-A2, the 3D *central model* of the interior team has all other disciplines linked to this model. C1-A3 mentioned that in that way they cannot modify other teams' projects but are able to view all disciplines' models together and work collaboratively:

> **00:39:04 C1-A3**…But this happens with reloading. For example, I will deliver, if the electrical were to be changed quickly according to my project, I contact you. I say that I made a revision here. I say that you need to pull your sockets accordingly. So, I synchronize. He reloads my file, quickly revises, and synchronizes that part. I reload it again. And it is fixed.

The same centralized modelling strategy was used in Case 2. C2-A1 stated that they have a central file for each architectural project, and each team member who is responsible in that project work in their local file copies and synchronize the revisions with the central. He also mentioned that due to the Covid-19 pandemic, they part the model in various central models to decrease the file sizes and linked each other's central model to ease remote working and eliminate conflicts due to bad network speed.

Participants of Case 1 and Case 2 mentioned how they realize *instant communication* within and between teams. C1-A2 stated that in pre-BIM phase, they used to communicate with other teams via e-mail, in case of problems. He mentioned that in their current workflow they instantly communicate with the responsible person at the time the problem occurs via WhatsApp or Skype. He added that they were able to quickly solve problems with the real-time synchronization method described above, since they could communicate quickly and practically in this way.

In Case 2, architect C2-A1 mentioned that they instantly communicate online via Zoom and Discord, and he stated that lead architect is not getting involved in these online platforms. They are online in work hours and use screen sharing to discuss design issues.

In Case 2, the team uses online cloud storage, OneDrive, to share and store Revit files. In Case 1, *Cloud BIM* is used for getting approval and comments on their shop drawing deliveries. They used BIM 360 Docs, a part of Autodesk Construction Cloud, for document management including publishing .pdf, .dwg and .rvt files. The team published 2D drawings in .pdf or .dwg formats to get reviews from the design office, electrical engineering team, and business manager group. C1-A3 stated that they need to get an 'A' (approved) on their publishing both from the design office and business manager group to start the manufacturing process. Interviewees mentioned that each team updated their Revit file once a week and that their own team published 2D drawings whenever a change that effects the construction occurred to get reviews from the decision makers:

> **00:39:00 C1-A3**…Official releases happen once a week. Every Friday, all disciplines send their files as Navis, as Revit. They publish it on BIM360.

Complexity of Tool

Participants mentioned some negative experiences on the 3D modelling software Revit, *complexity of tool,* which caused difficulties in their workflow. The office owner in Case 1 expressed his negative observations on working with Revit through one of their experiences. Based on his report, the team was expected to change the radius in the corners of a 3D bench model, which was designed by the Italian architecture office. Despite the team had put much effort in this task, they were not able to figure out how to change the radius which forced them to get some external support. C1-IA1's briefly described opinion on the tool was that even moving a wall was a huge issue. Architect C1-A3, gave an example on furnishings when stating the complexity of the tool. She stated that they were not able to provide layout sheets for technical drawings of furniture because taking sections of furniture was not possible in the Revit software. They either draw the orthographic projections of furniture in AutoCAD, or they convert it to a generic model by duplicating the furniture model, which was a solution they innovated in time. The architect C1-A2, describes the Revit software as "lumpish" when it comes to producing construction details. But he added that it gains meaning to model with Revit when it is a BIM model, due to the ease that collaborative working adds to the modelling task.

In Case 2, the architect C2-A1 mentioned the complexity of Revit during conceptual design development. He stated that the 1/1 scale production in Revit, including every detail of material, which he exemplified with the mullion details in glazing and seeing layers on the front of the slab, is not appropriate for conceptual design visualization:

> **C2-A1**…Revit is not enough. It used to be enough. You understood, from isometric view and so on. I agree that there are limited situations in perspective. But it was managing. I mean, I attribute everything to the last one or two years. Revit suddenly turned the business into engineering graphics. That's its biggest disadvantage. You draw woodwork, it puts mullion. You put a slab, you cut the slab's front, etc., and the cross section comes out. It works more like a construction site. You put the floor on the wall, the front view of the floor appears.

CHAPTER 6

DISCUSSION

BIM was adopted at different levels, through different adoption processes and experiences in both analyzed cases according to the reports of participants. The findings introduced in Chapter 5 are classified into three categories: people, process, and technology, which are the crucial factors in technology adoption (Kensek and Noble 2014). The table of the classifications that resulted from the time-based coding under three categories presented below is prepared for practical insight on interview findings (Table 5). The results of the study will be discussed in two perspectives. Firstly, people, process, and technology aspects will be discussed in general means; secondly, each aspect will be discussed in a time-based manner and compared to each other.

6.1. Critical Factors of BIM Adoption

Table 5. Time-based BIM adoption factors.

		People	Process	Technology
Pre-BIM Phase	Motivation for adoption	• Internal-driven motivation • Bottom-up motivation	• Lack in coordination • Market-driven motivation • Complexity of organizational structure • Complexity of project	• Updating drawings
Adoption Phase	Strategies for adoption	• Training • Solidarity • BIM champion	• Learning by doing • Projection project	
	Barriers to adoption	• Resistance of team members • Software skills vs. expertise	• Time constraints	• Infrastructure • Multiple software use
	IT investment			• Hardware investment
	Change experience	• Change in attitude • Change in team members • Change in roles and responsibilities		
	Facilitators for adoption	• BIM as a need • Competition • Trust		• LOD of first model
Post-BIM Phase	BIM maturity level			• Single disciplinary BIM • Multi dsiciplinary BIM
	New workflow		• Design communication	• Coordination in model • Documentation
	Complexity of tool			• Complexity of tool
	Collaboration between/in teams		• Instant communication	• Cloud-BIM collaboration • Central model • Clash detection

The adoption of BIM goes beyond a mere technological transition because the adoption takes place in a socio-cultural environment. Technology adoption factors, people-process-technology (PPT), are related to each other in such an environment. Despite this distinction, they are not independent from each other, and each factor has impact on or is related to the other.

In a successful innovation adoption, each factor should be realized throughout the adoption. According to Kensek and Noble (2014) in BIM adoption people, process, and product should mutually coevolve in order to establish a new routine (Kensek and Noble 2014) (Figure 13). The product factor is regarded as the technology in this research.

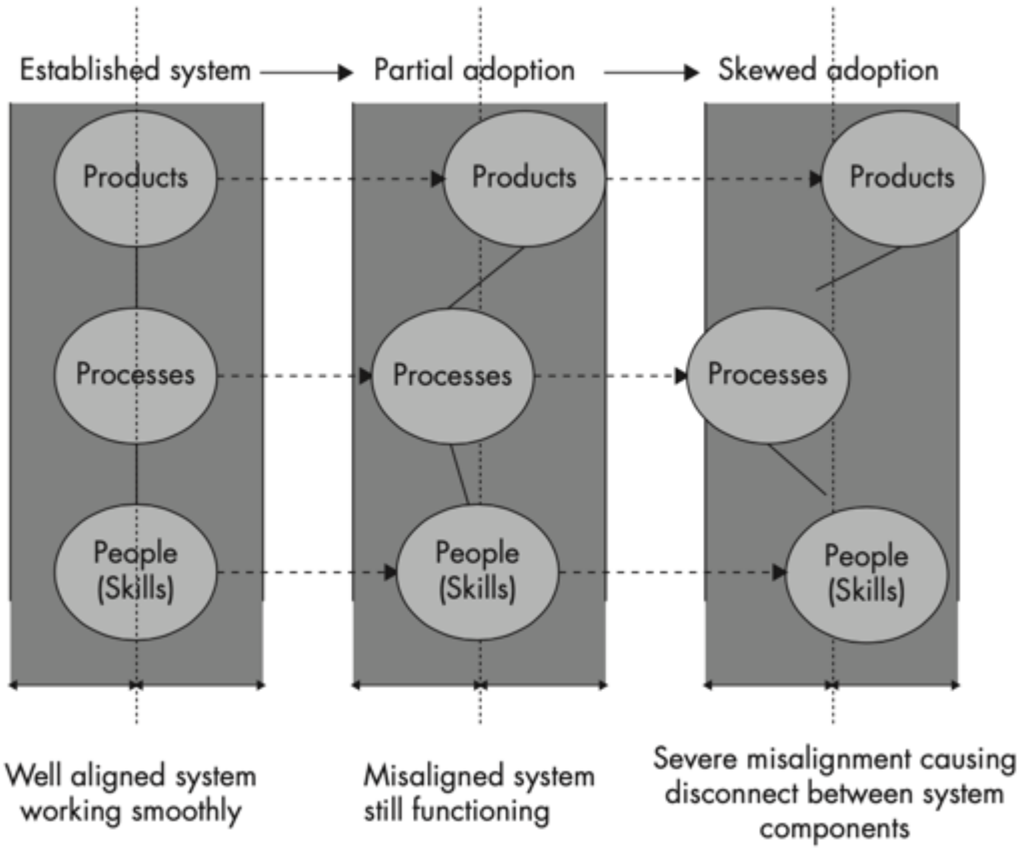

Figure 13. Various levels of adoption through potential coevolution scenarios of people, process, products (technology). (Source: Kensek and Noble 2014)

Findings of this study also indicate that these three factors, people, process, and technology, are addressed in both cases as a factor in BIM adoption. The transition to BIM is different from the transition from paper-based design to the adoption of CAD due to radical changes not only in practice but also in sociological aspects. As a new technology, it required people to learn new skills, roles and to integrate new social relations to their routines to adopt the technology into their workflows. In that sense CAD adoption was a technological transition in conventional architectural practice (Kensek and Noble 2014). With a successful adoption of innovation new conditions are established into a routine in practice. As the results indicate, the adoption of BIM is a radical change in people and technology, and a change in the work process to a certain degree. A radical transition in only one of these three aspects is likely to result with a system breakdown and disruption in workflow rather than establishing a routine (Greenhalgh et al. 2004). According to the findings, both design offices were able to adopt BIM through developments in each aspect but with different levels of BIM adoption due to uneven progress in people, process, and technology. Various levels in BIM adoption is caused by different levels of development or gaps in these aspects (Gu and London 2010).

6.1.1. People

According to Rogers (1983), the decision process of an individual on an adoption occurs in five steps which are knowledge/awareness, persuasion, decision, implementation, and continuation (Figure 14). Rogers describes this decision process as a time-based linear process (Rogers 2010). The findings of the study on BIM adoption in the field of people are highly related to these stages. The findings will be discussed following these stages.

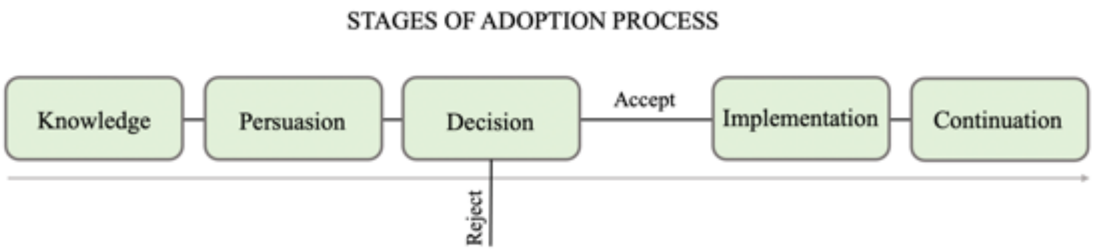

Figure 14. Five stages of adoption process.

(Source: Rogers 2012)

In the knowledge stage, the future adopter gets aware of the innovation but does not have any sufficient information on the innovation. In both cases, adopters stated that they were aware of BIM, and they mentioned that they lacked information on BIM. In the second step, i.e., persuasion, individuals get interested in the innovation and search for initial information on the task. This stage is vague in both cases due to two different reasons. In Case 1, the office was forced to give the decision on BIM adoption to be able to make an offer for the bidding. The office could not gain the time to investigate on BIM before moving forward to the decision stage. But they stated their positive remarks on the technology and process of BIM and that they were aware of its advantages in the architectural practice. The decision in Case 1 was triggered by the architect A3 and the final decision on adoption was given by the office owner. Other employees were not part of this decision stage. According to the reports of participants from Case 1, a majority of team members rejected the BIM adoption. This proves that each individual, apart from the decision process of an organization, goes through these stages of decision process independently.

In Case 2 the co-owner C2-E1 was influenced by a BIM implementing office and was already convinced about the advantages of BIM through his observations. Without questioning the lack of knowledge on BIM, the decision on BIM adoption was finalized with a top-down strategy by C2-E1 which was strongly rejected by team members at that time. One reason for fast acceptance of BIM in both cases relates to the global increase in BIM use providing more and more examples of both its advantages and disadvantages for future adopters. Studies on the global status of BIM adoption that seek to develop global BIM implementation frameworks (Jung and Lee 2015) show that BIM adoption is getting more and more common in the industry. By this means, future adopters gain trust into the new practice and the uncertainties about the adoption process gets diffused through many positive implementation examples which makes it easier for people to decide on BIM adoption. The global acceptance of a technology and its global status has impact on people's behaviors in that it reinforces trust in the technology resulting in a positive attitude towards confronting the difficulties and complexities of the technology. These results are related to crossing "the chasm", gap between innovators and early adopters, in technology adoption life cycle, introduced by Moore and McKenna (1999) as the most difficult phase (Moore and McKenna 1999). In a successful transition a little-known technology becomes a standard in the market. After giving the decision to adopt BIM, the offices move forward to the implementation stage. Abbasnejad et al. (2020) analyzed 80 papers related to BIM implementation. They demonstrated a network of keywords and their relations based on the analyzed literature (Figure 15). The repetition of keywords in the literature is represented by size and depth of color in 25 nodes and

Figure 15. Relations and frequencies of keywords in BIM implementation literature.

(Source: Abbasnejad et al. 2020)

their relations are represented with 147 edges within this Fruchterman-Reingold algorithm, a type of force-directed algorithm that uses splines and nodes as an analogy, layout. From a theoretical perspective these keywords are cited as the key enablers of BIM implementation. A comparison is executed between the theoretical and practical perspective through superposing the research findings with the proposed keyword network (Figure 16).

The keywords based on the analyzed literature in the study of Abbasnejad et al. (2020) and the findings of this research were compared and it was identified that some of

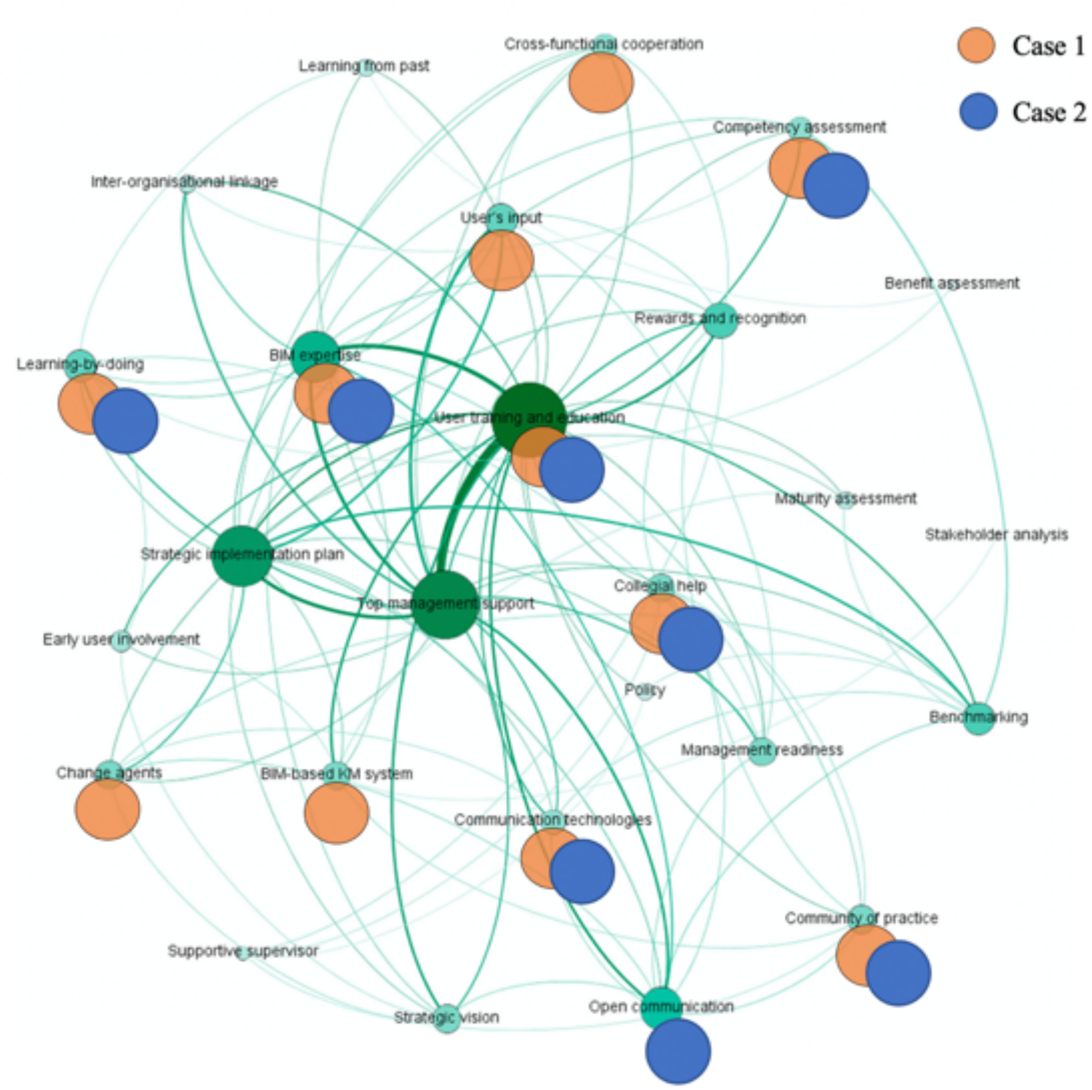

Figure 16. Comparison of theoretical and practical view on BIM implementation enablers.

the BIM implementation enablers expressed by the participants were compatible with these keywords. Competency assessment was done in both cases not at a professional level but verbally through the communication between office owners and staff with the aim to determine the current skill level of staff and thereby to confirm the skill gaps in the team. User training was a strategy facilitating BIM implementation in both cases. Also, the impact of education on enabling BIM implementation was mentioned by office owners, C2-E1 and C1-IA1. Collegial help was stated by all participants as an enabler. The ignorance of staff on BIM caused solidarity among them towards reaching the common goal of BIM implementation. The common interest of office members and their effort in reaching the goal, namely community of practice, was analyzed in Case 1 and Case 2. Community of practice is introduced as the overlap of process and technology by Succar (2009). Learning-by-doing is analyzed as one of the main BIM implementation strategies in cases. The initial approach of people was to learn the innovation through experience. During the adoption phase of BIM, communication technologies were highly used for enabling instant communication between people within the team and people of different teams. Social media and video conference platforms were initially preferred by staff to learn and develop knowledge and afterwards to practically solve problems that occurred in BIM processes which enabled the mobilization of knowledge in a collaborative work environment. This provided the spread of BIM at the individual level. The participation of C2-A1 to the team in Case 2, was a breaking point for the office in terms of BIM implementation. His BIM expertise enabled the staff to implement BIM after several other adoption strategies failed. In Case 1, the early adopters did not have any BIM expertise but had expertise on the digital modelling tool which they benefited from. The expertise on BIM was acquired in a short time due to their personal motivation to develop knowledge on the technology. The project teams in Case 1 were professionals with different technical expertise, such as architect, engineers, constructors, facility managers, IT managers, who enabled BIM implementation through cross-functional coordination. Due to the single-disciplinary workflow in Case 2, they were not able to benefit from cross-functional coordination to facilitate BIM implementation. The BIM champion C2-A1 in Case 2 was the agent for change who diffused the philosophy of BIM and its advantages and disadvantages to the staff. In Case 1, there was nobody in charge as a change agent. Instead, the change was homogeneously managed by the staff. The building information model of the project in Case 1 was used as a knowledge management system by all disciplines. The knowledge was stored and shared through a common system and single file format. That enabled the implementation of BIM in Case 1. The multiple software use in Case 2 to store knowledge resulted in weaker process alignment and was a barrier for BIM adoption. User's inputs were considered by the office owner of Case 1 to decide on hardware system features that were seen as need for BIM implementation by the employees and the office owner held meetings to collect inputs on how they could improve BIM workflow in the office, such as multi-screen usage. On the other hand, in Case 2 the decision on hardware and its investment was done by the co-owner C2-E1 beforehand. Benefit assessment, maturity assessment, stakeholder analysis, benchmarking, learning from past, strategic vison, policy, rewards and recognition, strategic implementation plan, top management support, management readiness, and supportive supervisor were applied in practice by neither of the cases.

The continuity in technology use is essential to understand the degree of adoption, innovativeness, of individuals. Both cases continued to use BIM in their workflows efficiently.

6.1.2. Process

The adoption of BIM leads to a change in the structure of actions. In a fully implemented BIM workflow, the process of architectural practice is expected to be established in an object-oriented digital design environment where all project partners collaborate with each other. Design communications, collaboration, design development, phases of design are expected to adjust to the new process. However, socio-cultural complexities in architectural practice led to divergences from theoretical BIM process definitions in practice. In both cases, apart from the innovativeness of organizations, design process could go through a change at a certain level. The users of BIM adjusted to the new workflow and were able to communicate, collaborate and design through a common shared model. The lead designers instead did not attempt to adopt the technology and continued to traditional CAD-based processes. The dependency of BIM adopters in terms of design solutions resulted in a mixed workflow. This showed that architectural skills and level of architectural expertise has an impact on process change. A successful transition from traditional processes to BIM workflows seem to be possible when BIM adopters are the design problem solvers in practice.

6.1.3. Technology

The motivation for BIM adoption has an impact on the technology adoption process. Case 1 and Case 2 implemented differing technology adoption strategies related to their motivations. The co-owner in Case 2 decided on BIM adoption because he envisioned that the future of architectural practice is BIM and was observing inefficiencies in their current workflow. In Case 2, the technology adoption was a decision of the architectural office made without any pressure from project partners. This internal decision provided the office to be in control of the whole adoption process planning and timing. At the beginning of the implementation process, the co-owner E1 did not reduce the number of CAD workstations initially. Instead, he added one BIM workstation while he ensured that the staff kept using CAD workstations as usual. The office had time and could go through several trial-and-error processes. For a period, the staff developed a project both via CAD and BIM simultaneously to get used to the technology, which C2-E1 named as “projection project”. Briefly, the technology adoption was a gradual transition from CAD to BIM in Case 2. In Case 1, in contrast, the decision on BIM adoption was given to solve difficulties in collaboration in an ongoing project delivery process in which the other project partners were already using BIM due to contractual obligations. The large-scale of the project thereby the amount of data that they were in charge was an essential factor for searching for a more efficient work approach. From a technological point of view the adoption in Case 1 was a sudden and dramatic transition to BIM. Their strategy for technology adoption was mentioned as learning-by-doing throughout the project process. Eastman and colleagues (2011) claimed that in the early phases of adoption it is expected that the work performance of first adopters could be low due to the customization of the software, meaning families, products, material settings (Eastman et al. 2011). The advantage of the office was that they did not deal with these technical issues because of the existing BIM work tradition among project stakeholders.

As mentioned above, considering the collected data from the interviewees, people demanding the BIM adoption were different in Case 1 and Case 2 which had an impact on the level of BIM technology adoption. In Case 1, the client and facility owners of the project demanded BIM in the project contract for facility management after construction. To meet this demand all design teams were integrated into the BIM workflow to ensure that the BIM entails information of all disciplines and sufficient information (LOD 500) to benefit from the model in future facility management. This contractual obligation had impact on the level of technology adoption in Case 1 in that a clear goal was set by an external driver. Therefore, the team adapted a multidisciplinary collaboration in an object-based 3D work environment and adapted to the technical requirements of BIM. The interviewees of Case 2 stated that their clients were not interested in “how” they produce throughout the project lifecycle. The demand on BIM came from the co-owner, C2-E1, to solve some inefficiencies that he was observing in their conventional workflow. The level of adoption or the expectations from the BIM was not set as a concrete goal internally or externally, instead developed during the adoption phase. The office went through this technology adoption without any other discipline sharing this adoption experience because other partners of construction projects were not demanding BIM. These above-mentioned issues caused to a single disciplinary, low level of BIM adoption.

6.2. People-Process-Technology Factors Across Time

The analysis of collected data show that technology adoption factors, i.e., people, process, and technology, have various impacts on BIM adoption over time (Table 5). The inefficient and iterative traditional process in pre-BIM adoption phase was dominantly reported by the participants. The main motivation to go through the adoption came from the disadvantages of the investigated offices' pre-BIM work processes. These results indicate that the process factor has a significant role in the pre-BIM phase in terms of triggering the innovation adoption. In this respect, people were also analyzed as a determinant factor in the pre-BIM phase. The decision to move forward with BIM adoption was internally triggered by key people. The impact of these key people's behavior was crucial in that they were the only source of motivation in teams for moving forward to the adoption phase. Technology was minorly reported as an aspect on BIM adoption in the pre-adoption phase. Despite the existing literature's emphasis on technological aspects of BIM adoption, the findings indicate that the adoption process is a socio-technical issue as also considered in the study of Arayici (2011). The BIM adoption phase is analyzed as a dynamic process in which the apex of transition and transformation takes place. Besides the challenges of a technology adoption, the challenges that the offices experienced were mainly related to people. These findings support studies in the literature. Deutsch (2011) puts a focus on people in his research on BIM and Integrated Design stating that BIM implementation is 90% about sociology and only 10% about technology (Deutsch 2011). Relations, new roles and responsibilities, resistance of people was dominantly stated by the interviewees which prove that moving from adopting BIM to continuity in use without failing depends heavily on social aspect. When reporting their post-BIM phase experiences, participants dominantly stated on technological issues on the contrary of the adoption phase. Getting used to the technology would have an impact on the elimination of social factors. People's efforts focused on the use of the technology and its possible challenges. There is research stating that people's attitudes and behavior changed over the adoption phases (Karahanna, Straub, and Chervany 1999). Improvement in BIM adoption levels would be possible by establishing goals and criteria relevant to each adoption phase. The crucial factors of BIM adoption, i.e., people, process, and technology, would be addressed depending on their impacts in each phase of adoption.

CHAPTER 7

CONCLUSION

This study focused on the BIM adoption process in architectural offices. The aim of the study was to examine the BIM adoption experience of two design offices and the impact of the adoption on the architectural practice within the team and between project partners from a socio-technical perspective. Through the findings of the study, it might be possible to predict to a limited extend what experiences will offices face during and in the early phase of BIM adoption. Three objectives of the study were (1) understanding the motivations for BIM adoption; (2) the factors in adoption through analyzing the data collected on the experiences of individuals; and (3) to inquire the strategies of implementing BIM in different phases of the architectural design process. It was essential to clarify the different definitions of BIM in the literature and its different implementations and interpretations in architectural practice. In addition, the interaction of tools and its users and their influence on workflows was examined to generate the framework for the socio-technical approach of the study. In this context, instead of adding a new technology-oriented approach to the adoption of BIM, which is widely used in the literature, it was aimed to provide a foresight on BIM adoption through examples focused on the experiences of individuals.

Interviews with five participants from two different offices who went through BIM adoption provided data for case study analysis. The semi-structured interview questions had a time-based configuration to collect data on pre-BIM adoption phase, BIM adoption phase, and post-BIM adoption phase. The audial reports of interviewees were transcribed and coded following the steps of initial coding, axial coding, and theoretical coding. In consequence of this analytical coding, abstract categories, and general links within a data pattern was established. Each phase was discussed regarding the three factors of technology adoption, people, process, and technology. Findings demonstrated that the level of BIM adoption is related to the coevolution of people, process, and technology. From a time-based point of view, findings showed that each factor has impacts with different frequencies throughout the BIM adoption phases. In pre-BIM adoption phase, the inefficient workflow of previous processes was the main motivation for BIM adoption as reported by the participants. Whereas in the adoption phase, the impact of people was a major factor on the strategies for adoption and barriers in adoption were mainly human related. People were a critical factor in giving the decision to go through the adoption. Technological aspects instead, were further considered when the decision on adoption was given and the BIM adoption was accepted in the offices. The results from the two offices indicated that the maturity level of BIM is related to the integration of all project partners to the adoption experience. The multidisciplinary BIM adoption in Case 1 resulted with a higher maturity level (social-BIM) than the BIM maturity level in Case 2, which only went through the BIM adoption as an architectural team (lonely-BIM). The major human-based issues in early phases of BIM adoption showed that, in order to implement BIM in current workflows a socio-technical approach is essential.

7.1. Limitations of the Study

Due to the pandemic situations, the interviews were done online via Zoom. Therefore, the researcher was not able to make site observations and collect data from direct observations of the office workflows. The office owner in Case 2, who was designated as a key-player in BIM adoption, could not be interviewed within the time limits of this thesis due to his tight business schedule. Increasing the number of interviewees and the number of cases would have enriched the data and would increase the validity of the results.

7.2. Recommendation for Further Studies

A comprehensive and in-depth literature review was carried out at the beginning of the research in the field of BIM and its adoption. This literature review revealed a very fundamental shortcoming. The adoption of BIM is a human-based phase rather than technological. In this respect, sociological approaches to the subject in future studies will make important contributions to eliminate this deficiency in the literature. That the study seeks to investigate BIM adoption across time, cases presented in this study can be observed and interviewed at certain intervals to analyze the innovativeness and continuation of BIM implementation of offices in post-BIM period.

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