BARRIERS AND ENABLERS OF BIM ADOPTION: PERSPECTIVE AND EXPERIENCES OF TURKISH CONSTRUCTION PUBLIC CLIENTS

by

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ABSTRACT

BARRIERS AND ENABLERS OF BIM ADOPTION: PERSPECTIVE AND EXPERIENCES OF TURKISH CONSTRUCTION PUBLIC CLIENTS

The construction sector is one of the sectors in which technological developments show the least impact. Thanks to Building Information Modeling (BIM), a new era has begun in the construction industry. After BIM usage, it is observed that productivity has increased, the stakeholders have minimized their total efforts and they aimed to maximize their cooperation. This article describes the barriers and enablers of BIM adoption in construction projects in Turkey from the perspective of public clients. According to the literature review, barriers and enablers are listed. These items are divided into three: market, company and project levels. 31 participants from 18 projects which belong to 10 public clients in the Turkish Construction industry were interviewed. According to the results, significant barriers and enablers were determined and the participants were also expected to explain the different barriers that they experienced. After data collection, projects included in this research were divided into two such as: BIM-implemented and non-BIM implemented projects. These two groups are compared by using comparative analysis. It was observed that the unfavorable economic conditions, high costs, and unclear project benefits are significant barriers. Clear advantages of BIM, ease of use, high analysis ability and positive attitude of the company and demand/satisfaction of the clients were considered as the most significant enablers by professionals. The importance of barriers and enablers according to project types were also evaluated. While market level barriers are seen to affect refinery projects at most, company level barriers affect hospital constructions at most negatively. It has been discussed that the barriers at the project level are the most effective in the building projects.

ÖZET

YBM UYGULAMALARININ ÖNÜNDEKİ ENGELLER VE KOLAYLAŞTIRICILAR: TÜRK İNŞAATINDA KAMUDAKİ İŞVERENLERİN BAKIŞI VE DENEYİMLERİ

İnşaat sektörü, teknolojik gelişmelerin en az etki ettiği sektörlerden biridir. Yapı Bilgi Modellemesi (YBM) sayesinde inşaat sektöründe yeni bir dönem başlamıştır. YBM kullanımından sonra verimliliğin arttığı, paydaşların sarf ettiği çabanın en aza indiği ve işbirliklerini en üst düzeye çıkarmayı hedefledikleri görülmektedir. Bu makale, YBM'nin benimsenmesinin önündeki engelleri ve kolaylaştırıcıları Türkiye'deki inşaat projelerindeki kamu işverenleri açısından açıklamaktadır. Literatür incelemesine göre, engeller ve kolaylaştırıcılar listelenmiştir. Bu kalemler üç bölüme ayrılmıştır: piyasa seviyesi, şirket seviyesi ve proje seviyesi. Türk İnşaat sektöründen 10 kamu işverenine ait 18 projeden 31 katılımcı ile görüşülmüştür. Sonuçlara göre önemli engeller ve kolaylaştırıcılar belirlenmiş, katılımcılardan yaşadıkları farklı engelleri de açıklamaları beklenmiştir. Veri toplandıktan sonra, projeler YBM uygulanan ve uygulanmayan projeler olmak üzere ikiye ayrılmıştır. Bu iki grup karşılaştırmalı analiz metodu kullanılarak karşılaştırılmıştır. Olumsuz ekonomik koşulların, yüksek maliyetlerin ve belirsiz proje faydalarının en önemli engeller olduğu gözlenmiştir. YBM'nin açık avantajları, kullanım kolaylığı, yüksek analiz kabiliyeti ve şirketin olumlu tutumu ile müşterilerin talep/memnuniyeti profesyoneller tarafından en önemli kolaylaştırıcılar olarak kabul edilmiştir. Bu çalışmada engeller ve kolaylaştırıcıların proje türlerine göre önemi de değerlendirilmiştir. Pazar düzeyindeki engeller rafineri projelerini en fazla etkilerken, şirket düzeyi engellerin hastane inşaatlarını en olumsuz etkilediği görülmektedir. Proje düzeyindeki engellerin bina projelerinde en etkili olduğu anlaşılmıştır. Bu bulgulara göre bazı önerilerde bulunulmuştur.

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LIST OF ACRONYMS/ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
4D	Four Dimensional
5D	Five Dimensional
6D	Six Dimensional
7D	Seven Dimensional
AEC	Archiectural Engineering Construction
AR	Augmented REality
AVG	Average
BIM	Building Information Modelling
BREEAM	Building Research Establishment'Environmental Assessment Method
BOT	Build-Operate-Transfer
BS	British Standards
CAD	Computer Aided Design
COBIM	National Common BIM Requirement
CSFs	Critical Success Factors
ERP	Enterprise Resource Planning
FM	Facility Management
GC	General Contractor
HSE	Healt, Safety and Environment
IFC	Industry Foundation Class
IPD	Integrated Project Delivery
LC	Lean Construction
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
LOD	Level of Detail / Level of Development
MAX	Maximum
MEP	Mechanical, Electrical, Plumbing

MIN	Minimum
NMIMS	National BIM Standart
nD	n Dimensional
PM	Project Management
PPP	Pubyic Private Partnership
RFI	Request for Information
S	Strength
USBC	The United States Green Building Coun
VR	Virtual Reality
W	Weakness

1. INTRODUCTION

1.1. Background of the Research

Architecture, Engineering and Construction (AEC) industry have some disadvantages for using technological devices in their activities for so many years. So these disadvantages cause a delay in the digitalization. Other industries may be more digital than the AEC industry and AEC industry stayed behind with respect to others. This switch and digitalization affect the ways of doing jobs and even make them easier. In the AEC industry, so many businesses have been made still manually.

The nature of the construction industry and construction projects are very complex. There are so many parties that are involved in the projects. All of these parties should be perfectly communicate with each for successful results.

In recent years, a new concept which is called BIM has gained importance and its importance continues to increase. Construction companies are trying to have a competitive advantage by using BIM (Eastman *et al.*, 2011). Also, by using BIM, they aim to increase their communication and collaboration skills and increase the number of successful projects. The effects of BIM has started to be seen in the countries which started to imply BIM in their projects. For example, their efficiencies started to rise.

Turkey is still far behind with respect to other developed countries in terms of BIM usage. If the Turkish AEC industry wants to catch developed countries in terms of efficiency, cost, and other variables, the companies in the Turkish industry should be interested in BIM developments more.

Some factors prevent and facilitate BIM implementation. Those barriers and enablers should be identified properly for successful BIM implementation. Based on this, this research aims to analyze all barriers and enablers, and finding which of them are significant and which of them are not so significant.

1.2. Determination of the Problems

The evolution of BIM has not completed yet. There is no example of a project in which BIM is completely adopted in Turkey because there are still so many barriers to adoption. BIM implementation can find specific solutions for different problems in the AEC industry. Many developed countries at the global level have started to realize the importance of BIM and have started to apply in the construction project in these countries so much. (Ghaffarhouseini *et al.*, 2017). However, in Turkey, there is a long way to go (World Economic Forum, 2018). In Turkey, there may be so many different barriers that should be solved. The main concern of this research is the barriers of BIM from the public clients' perspective in the Turkish construction industry. Decisions of clients have a very big impact on the design and construction processes. It can be said that they are the major driver for adoption.

1.3. Statement of the Problem

In the literature, there are so many researches that focus on the components of BIM application like, enablers, advantages or disadvantages. Also, some of the researches focus on the barriers for adoption of BIM but there are no many kinds of research that analyze the barriers from the perspective of clients in the developing countries like Turkey.

This study focuses on the barriers and of the BIM adoption especially in developing countries like Turkey from the perspective and experiences of the Turkish public clients. Identified barriers and enablers from the literature are compared with the barriers and enablers in the real cases from the perspective of the clients. .

1.4. Related Studies

There are so many researches in the literature that focus on measuring the effectiveness level of BIM (Mostafa *et al.*, 2018). Because BIM is a relatively new concept for Architecture, Engineering, and Construction industry, so many researchers have tried to make the identification of BIM (Dan *et al.*, 2015).

There are so many researches in the literature that focus on the drivers, barriers, inputs, enablers, advantages, and disadvantages of BIM. Some researches focus on the driving factors for the BIM implementation. For example, Eadie *et al.* (2013) investigated the significance of the drivers and show that the significance of them is related to the experience level of participants. Morlhon *et al.* (2014) have studied the Critical Success Factors that are considered as important for implementation and facilitate the application of BIM. Chileshe and Kikwashi (2014) evaluated CSFs within the concept of risk assessment and management practices. Gichooya (2015) aims to clarify the notion and the difference between drivers and enablers.

However, there are not so many studies on the barriers which are faced especially in developed countries. Amuda Yusuf *et al.* (2017) emphasized that BIM is still immature in Nigeria and he identified the barriers for the Nigerian construction industry. Hatem *et al.* (2018) made researches about the barriers for BIM implementation in other developing countries, Iraq and the most important barriers for the related industry have been identified. Enshassi *et al.* (2017) has surveyed with 270 professionals from different discipline in the Palestinian construction industry for identifying the barriers which prevent the successful BIM implementation in Palestine. Chan (2014) has conducted to design firms in Hong Kong and investigated the barriers for BIM implementation from the perspective of the design firms. Criminale *et al.* (2017) has identified barriers from the literature and classified them as a project or organization level. Koseoglu *et al.* (2019) aimed to identify barriers for megastructures through an airport project. Another problem is the actuality of these studies. It can be said that BIM is a live thing and it evolves continuously. Because of this each year, there may be so many differences and changes. In addition to this problem, it can be said that there is a gap in identifying the barriers from specific parties, such as contractors, designers, and clients and so on.

1.5. Aim and Objectives

The main aim of this research is to identify the barriers and enablers for BIM adoption from the perspective of public clients in Turkey. To achieve this aim, barriers are identified by reviewing the literature and these barriers and enablers are asked to professionals of clients from different types of case projects. To evaluate the results and achieving quantitative data, the Likert scale is used. Findings are expected to reveal the significance of the barriers and enablers. This research have also five objectives. Objectives of this research are listed as follows:

- To conduct an extensive literature review regarding the barriers and enablers of BIM implementation from the perspective of construction clients
- To develop a comprehensive framework for Turkish public construction clients to overcome the barriers
- To evaluate the barriers and enablers with professionals in Turkish construction public clients for real case projects.
- To shed a light on the BIM implementation process and give industry professionals a lead.
- To understand which variables are important in projects where BIM is applied and which variables are important in non-BIM projects by using comparative analysis.

1.6. Research Methodology

To assess and evaluate the barriers which are faced in the construction industry in developing countries such as Turkey, some steps were followed. At the beginning of the study, literature was reviewed carefully. The history, process, and barriers of BIM were listed. In an excel sheet, frequencies of the listed barriers were signed. These barriers were grouped according to their relation like cost, managerial, personnel, culture, and technology. Then, interview questions were prepared to ask them the professionals in the AEC industry. In this step, interview questions are discussed with the advisor of the thesis to finalize them.

In the third step, these questions were directed to the different professionals who are using BIM actively. The professionals are chosen according to their projects. They have answered the questions according to their experiences in the related projects. By asking the interview questions, barriers in the real cases were identified. Case studies are carried out via face to face meetings.

1.7. Significance of Thesis

The best way for the full adoption of BIM to the AEC industry is to identify the barriers and enablers. If these barriers can be identified correctly, true solutions can be also found. Through effective guidance, efficiency in the construction industry increases. If it can be achieved, Turkish public clients become more competitive in the global sector. In addition to this, this thesis may lead to an unexperienced professionals in their work-life to understand the barriers for successful BIM implementation.

This research also shows what is required for BIM implemented and non-BIM implemented projects separately. Understanding the enablers and barriers separately may make finding solutions for BIM implementation easier.

1.8. Scope and Limitations

The interview which is prepared for this study is asked to public clients of construction projects in the Turkish AEC industry. Thus, the results of this thesis may not be applicable to the countries except Turkey. Because the biggest part of the clients in Turkey are the public enterprises and for this research, public clients are conducted, some of the participants are not willing to share the information about the projects such as budget, team and some other confidential information. In addition to this, this research is conducted to professionals from the Turkish construction public clients. The results and required strategy for other parties except clients might be different. Last but not least limitation is that there is no evaluation system in the companies to assess their BIM system and because of this, it is very hard to collect real effects of barriers and enablers.

1.9. Organization of Thesis

There are 6 parts in this thesis. This part can be summarized as in the below:

- Chapter 1 is the introduction part. In this chapter, general information is given, problems are determined and identified. The studies which are related to topics of thesis is discussed. This chapter also includes the aim and objectives of this study.
- Chapter 2 consists of the literature review. This literature review is related to the AEC industry, BIM, barriers for BIM implementation, enablers for BIM implementation, and other BIM-related topics.
- In Chapter 3, the research methodology of this research is discussed. This chapter tells how the appropriate method is chosen and how this method is applied. Also, this chapter introduces how the interview form is prepared which is used for data collection.
- In Chapter 4, findings of the case studies are introduced. The findings are examined according to different classes.
- In Chapter 5 is called “Discussion” and findings are told. Also, findings are discussed in this chapter to understand barriers for BIM implementation in Turkey.
- In Chapter 6, final evaluation are told. The thesis is concluded in this chapter.

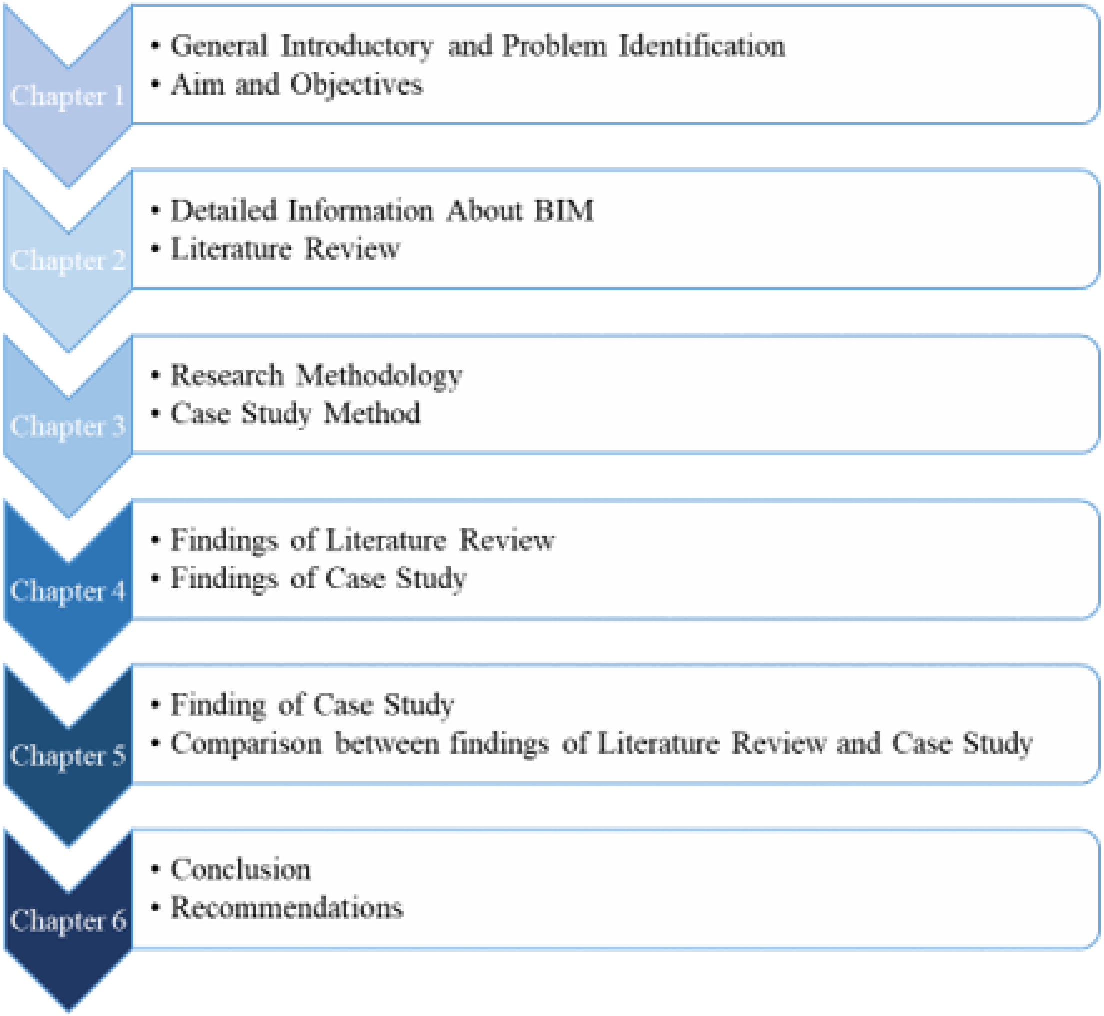

Figure 1.1. Organization of Thesis.

2. LITERATURE REVIEW

2.1. Introduction

In most countries, the construction industry is one of the most challenging industries. There may be so many problems because of the nature of the industry, uncertainties in conditions, adding risks, the efficiency of the employee, and so on. Especially, because of the reduction in productivity, industry professionals have started to look for solutions that increase efficiency. The main reason for this reduction is fragmented nature of the construction projects.

To prevent and solve these problems, industry participants have tried to find some solutions and they are still trying to find more efficient solutions such as digital construction. BIM offers a solution for these problems to professionals in this industry. BIM has risen for approximately 20 years. At first, the benefits were not understood but in time, almost all professionals and different participants of construction are aware about the benefits (Azhar *et al.*, 2011).

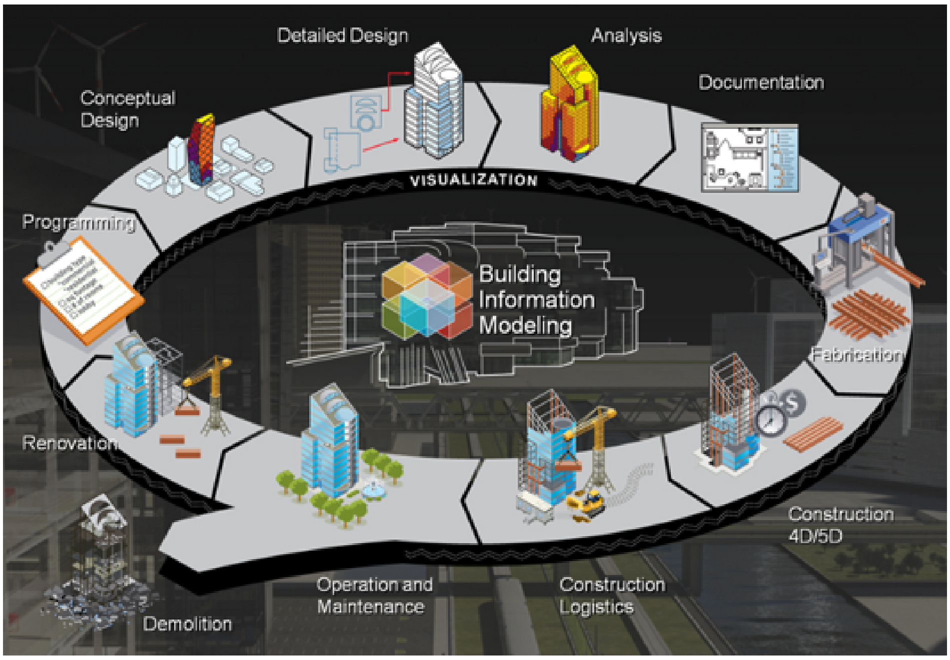

Figure 2.1. Concept of BIM (NBIMS, 2016).

In general, BIM models simulate geometries of the elements, relationships between them, quantities, cost management, schedule of the project, and inventories. BIM brings together all parties involved in projects such as owners, architects, engineers, contractors, and so on. Thanks to this collaboration, parties can work more efficiently and productive. Building Information Modelling is a process, not just software. This means that BIM does not just consist of 3D models, it includes also workflows and some other activities in the project (Moreno *et al.*, 2019).

2.1.1. BIM Definitions

There are so many definitions for BIM. Definitions of BIM are much related to the perspective of the researcher.

According to National BIM Standards-United States (2010), BIM is primarily a three dimensional digital representation of a building and its intrinsic characteristics.

In USA National BIM Standard version 3 (2015), BIM is defined as “business process for generating and leveraging building data to design, construct and operate the building during its lifecycle”.

As we can understood from the difference between the definition of National BIM Standards 2010 and 2015, the definition of BIM has expanded over years and this expansion is going to be mentioned in the following parts.

Dan *et al.* (2015) defines BIM as three dimensional (3D) data in the process of producing and managing building data during its lifecycle, with appropriate building information software to improve productivity in building design and construction.

According to Succar *et al.* (2009) BIM is digital format to organize the appropriate building design and Project data throughout the building’s life-cycle.

Mohandes *et al.* (2012) defined BIM as a Project simulation which consists the three dimensional (3D) models of the Project components by connecting with all the needed information linked to the Project planning, constructing or operating and decommissioning.

Rokooei, (2015) mentioned BIM in research as a reliable, digital, three dimensional, virtual representation of the Project to be built for use in design decision-making, construction scheduling and planning, cost estimates and maintenance of construction projects.

2.1.2. Main Characteristics of BIM

In recent years, as it is discussed, the most significant and promising development is a transition from traditional methods to BIM. By utilizing from BIM, different information is presented, stored and changed. This information is used in cost management, planning, or representing the buildings before they are built. Based on these, reports of a building are automated. Also by utilizing from some characteristics of the BIM like object-based design, the design phase of a project can be coordinated, and computable information can be developed. In the end, thanks to these features of BIM, professionals can develop more sustainable models (Azhar *et al.*, 2008).

If BIM models can be developed properly, all objectives can be obtained by the BIM instead of traditional methods. To develop a proper BIM model, there are some specific features of BIM. These are the game-changers of the traditional methods.

2.1.2.1. Parametric Modelling. Parametric modeling is one of the biggest and important differences between traditional methods and BIM methods in the AEC industry. By utilizing this characteristic of BIM, professionals have a chance to visualize the building and parts of this building from all perspectives. Thanks to this, they can detect the possible problems earlier.

Parametric modeling is used in manufacturing for placing the rules of design, engineering, and manufacturing to their parametric models. For example during the design phase of the Boeing 777, they identify the rules for looks, fabrication and so on. To increase the aerodynamic performance of the planes, they arranged fine-tuned the outside shape.

As a concept, BIM tools are the object-based parametric models that include programmed and predefined object families. Some of the object families which are provided by BIM software are listed in the figure below. These are the predefined objects which can be applied to almost all designs easily. A building model can be identified as dimensionally controlled parametric models utilizing floor levels and so on (Eastman *et al.*, 2011).

Table 2.1. Comparison with respect to base objects between BIM Software.

BIM Tool Base Objects	ArchiCAD V10	Bentley Architecture V8.1	Revit Building V9.1	Digital Project r5.v3
Soild model w/features	X	X	X	X
Site model	X	X (Contaured Model)	X (Toposurface)	
Space Definition	Manual	Manual	Room (automatic)	Room (automatic)
Wall	X	X	X	X
Column	X	X	X	X
Door	X	X	X	X
Window	X	X	X	X
Roof	X	X	X	Custom object

Another alternative is that these might be simple floors, wall lines, or a combination of these. Combination of embedded objects, parametric arrangements, and model configuration identify the instance of building. In addition to base objects which are shown in the figure, some websites provide additional object families.

Parametric modeling is a critical efficiency feature that updates low level changes automatically. Information about buildings are not stored manually, there are dynamic parameters. So if there are changes in the very small part of the project, there is no requirement for very big manual changes because tools make these changes automatically. Each BIM tools differentiate according to included parametric object families, embedded rules, and design behaviors.

This characteristic of BIM is not only applicable for designers, it is also a very useful feature for engineers in the site. They can utilize from the parametric models and information to make proper decisions, increase the quality of the documents and reports, estimate the cost, and schedule the activities and so on.

2.1.2.2. Object Oriented Modeling. Object oriented modeling has started to use in the construction industry with the development of BIM. This term contains a set of parameters and rules. So, designers can develop a model by using element objects. An object means not only geometrical shapes, it also means some non-geometric data such as cost, identification and so on. Development of object oriented modeling results in a transition from 2D to 3D. Thanks to this, the behavior of building elements can be visualized before it is built. Usage of 3D geometry gives a chance for varying dimensions and assigning rules so it can be said that objects gain intelligence with these characteristics of BIM. This feature of BIM allows users to change the height of the objects, representing the relationship between different objects and so on (Jeong *et al.*, 2014).

2.1.2.3. Interoperability. In recent years, BIM has reached Level 2. However, interoperability is still one of the biggest problems and barriers to BIM. Interoperability can be defined as the capability of data exchange between two or more software, system and so on. To make concept and idea clear for stakeholders and make the models useful, there is a requirement for so many software and compatibility for data exchange. This characteristic is very crucial because each party in the construction projects may use different software or tools and there is a need for exchange of these data. According to Froese (2010), there is a requirement for the espousal of more information and communication technology.

BuildingSmart has developed Industry Foundation Classes which is a very good tool for achieving interoperability. So many software are compatible with the IFC, however, some experiments show that there is a long way to go for providing the optimum level of interoperability. It means that IFC is not enough just alone, and there should be some supportive standards such as IDM, MVC, and IFD. If all of them may be utilized, professionals have information about how and when the AEC information is transferred (BIM Experts, 2019).

IFC identifies the method for data exchange. In 1994, Industry Alliance for Interoperability has founded and the journey of IFC has started with this development. The name of Industry Alliance for Interoperability has changed its name as BuildingSmart International. In our days, the ninth edition of IFC is used. IDM identifies answer the questions of which and when. Questions such as which data is transferred and when these are transferred can be answered by IDM (Information Delivery Manuals). Another standard is IFD which is International Framework for Dictionaries. This identifies what the transferred data means. The journey of IFD has started in 1999. IFC can understand whether these objects are the window or not or it can store the material property such as PVC, aluminum. IFD also translate materials into other languages.

In addition to using IFC, another method for mitigating the interoperability problem in BIM is direct links within the BIM software problems. A direct link can be used to transfer the information from a BIM software to another BIM software. Direct links are designed for just two software and only used for data transferring between this two software. This also provides an advantage for example thanks to this, developers have a chance to focus on details in the transfer process and precision of the process. As a result, this method is more reliable than the method of IFC usage (Yousefzadeh *et al.*, 2015).

2.1.3. History of BIM

The journey of BIM has started with CAD application in the 50s and 60s. At that time, in 1957, Hanratty invented the computer aided machining. After that CAD has launched an interface which is called Sketchpad. This interface gives a chance to users for interacting with the program via draft pen, buttons or so on. In 1970, there was a transition from 2D to 3D. This technology has developed by French Aerospace Company. This company had utilized from CATIA for years. However, in the 1980s and 1990s Autodesk has entered to marked with Autodesk, and thanks to AutoCAD, they had become a market leader. At the same time, Bentley which is a rival of Autodesk has launched so many new products. In a very short time, thanks to technological developments, the number of software has increased. These developments have provided a transition from 2D to nD and in this way, professionals in the industry had a chance to find different solutions for the problems. For example, thanks to 4D parties in projects that can manage the resources appropriately and Schedule the activities. After that 5D was developed for cost management. Lastly, for sustainability, 6D is developed and for facility management 7D is developed also. The development of nD is related to the functions. According to Beveridge (2012), 8D is identified for integrated Project presentation, 9D is identified for acoustic, 10D is related to security, and 11D is related to the heat. So, it means that the transition and evolution of BIM continue.

2.2. Understanding the Concept of BIM

2.2.1. BIM Implementation Maturity Levels

There are 4 BIM Maturity Levels which range from Level 0 to Level 3. These levels are Pre-BIM, Object-Based Modelling, Model-Based Collaboration and Integration.

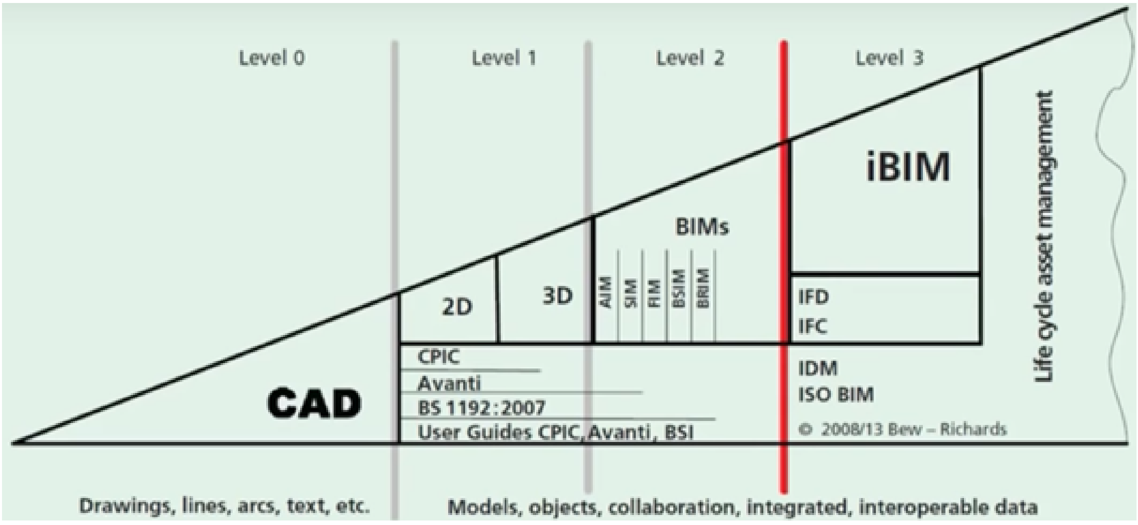

Figure 2.2. BIM Maturity level model (Bew and Richards, 2008).

Level 0 (Pre-BIM): It is related to the traditional methods in the construction industry. At that level, there so many inefficient activities and difficulties. There are only 2D drawings that describes the 3D reality and these Drawings, other documents are not stored in the digital media. Papers or prints are used only. There is no specified formats for data and because of this, finding and using this information is very hard. So it can be said that the usage of this level is very impractical and this level is the simplest form of BIM. Weak building information process causes misunderstandings, lack of functionality, wrong ways, and convergence of the activities (Khosrowshahi and Arayici, 2012) There is no collaboration between the teams that are involved in the projects.

Level 1 (Modeling): Level 1 can be defined as a transition from 2D to 3D thanks to developments in the object, oriented 3D parametric tools such as ArchiCAD, Revit, Tekla, ArchiBus and so on. The parts of the BIM models are shown in correct form. The main format which is used in this level is CAD. Data are managed by incompatible financial management methods (Khosrowshahi and Arayici, 2012) In this level, both 3D and 2D are used. Data can be shared by using a common data environment. However, at his level, cooperation between the components of projects is not still achieved completely. Data exchange has not developed yet at this level.

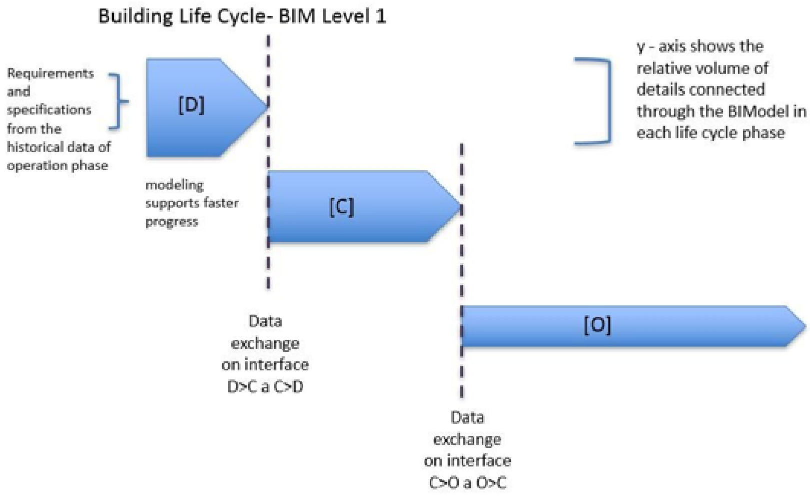

Figure 2.3. Building Life Cycle through BIM Level 1, Linear Model (Nyvlt *et al.*, 2019).

Level 2 (Collaboration): Level 2 has started in 2016. The main purpose of Level 2 is to provide collaboration and cooperation between the parties. Design, engineering, and management processes are very complicated processes and there is a requirement for good communication and collaboration between the parties. Different BIM tools are utilized and also at this level, 4D and 5D BIM are used.

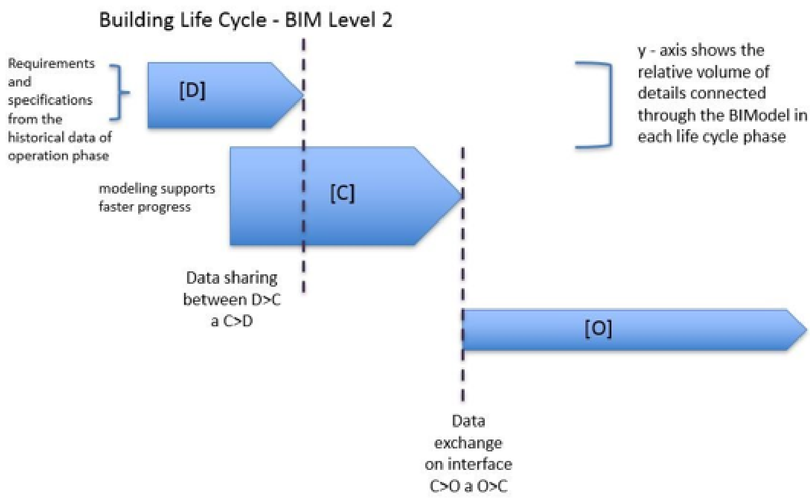

Figure 2.4. Building Life Cycle through BIM Level 2, Linear Model (Nyvlt *et al.*, 2019).

Level 3: This level identified first in UK Government Construction Strategy 2016-2020. However, the definition of this level has not completed. It can be defined as a transition from collaboration to integration. Actually, the main objective of BIM is going to be achieved at that level. Participants of projects are utilized from the virtual process. Virtual and reality come together and are integrated. This level contains scheduling, cost management, and facility management. The data are shared and stored in a source. It also can be defined as “Open BIM” (Infrastructure and Project Authority, 2016); (Hıjazi *et al.*, 2017).

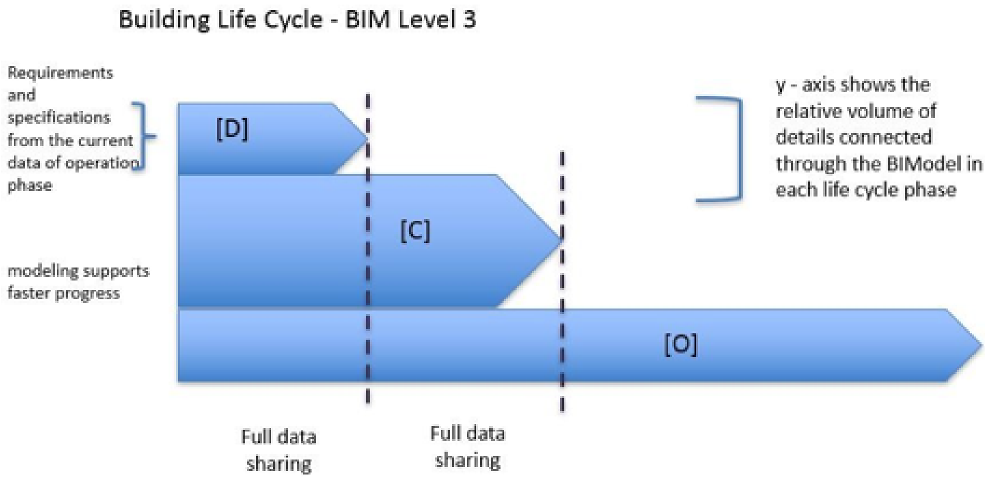

Figure 2.5. Building Life Cycle through BIM Level 3, Linear Model (Nyvlt *et al.*, 2019).

2.2.2. BIM Applications in AEC Industry

Each BIM model may have its specified purposes (United BIM, 2018) According to project complexity, types and stages of the projects, which variables are required are discussed and these variables are included in the model. These additions might be called as dimensions of BIM. Thanks to these dimensions, models of projects become more understandable. In the beginning, there are only 3D and 4D BIM, however, in time, BIM becomes more sophisticated and 5D, 6D, 7D, 8D of BIM have been developed too. Each of them has its own objectives and they are used for specific purposes. These dimensions and their purposes can be seen from Figure 2.6.

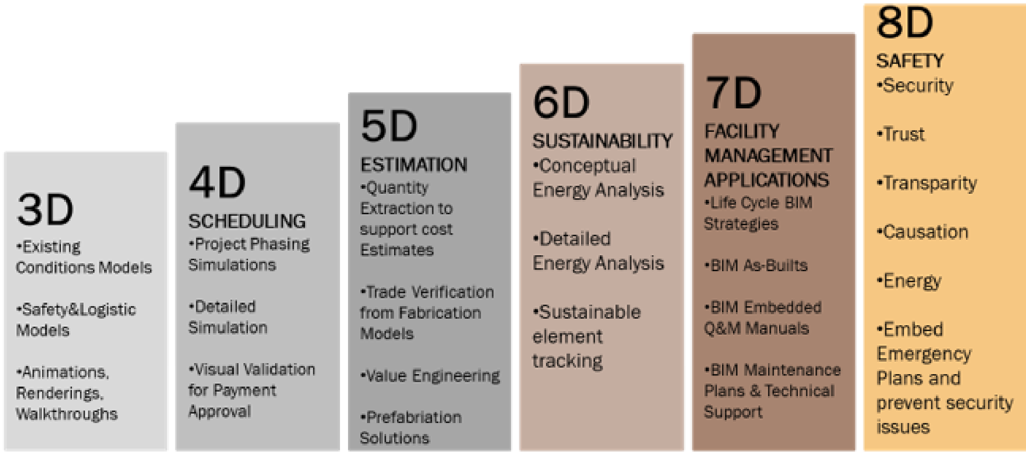

Figure 2.6. Dimensions of BIM (Saleh, 2015).

2.2.2.1. Coordination and Clash Detection. 3D of the BIM may be the most familiar dimension. This is the transition from 2D to 3D. In this dimension, only graphical and non-graphical information can be created and this information can be shared in a common data environment (NBS, 2017). This can be defined as the visible part of the Building Information Modelling model. Thanks to the development of 3D, visualization of the objects are increased. In our days, 3D BIM is used very commonly by architects, engineers and other parties. Thanks to 3D, every participant of the project comes to the same understanding level. Lack of communication has started to decrease with the development of 3D. Complicated nature of the construction industry become less complicated with this development because everyone can visualize the project before the structure is built.

2.2.2.2. Scheduling. 4D BIM provides scheduling and sequencing data as additional information to the project. The sequencing data are combined with the other data during the progress of the construction. This dimension gives an idea about how the Project progress. By using 4D BIM, professionals attain a more accurate Schedule for activities in the projects. These types of data contain the lead time, duration of the projects, and the sequence of the activities and so on. Planners share the information about scheduling in a common platform and thanks to this shared information. Also, thanks to this technology, information which is related to the scheduling can be visualized and it becomes more understandable. If stakeholders, managers, engineers or other parties in the project have a chance to see how the project is going. Preparing a prototype of some elements may give some feedback about possibilities and if there is something wrong, precautions for these can be taken (Borges *et al.*, 2018).

Identifying scheduling and sequencing information is very useful not just for design process also for evaluating whether the programs are applicable or not.

2.2.2.3. Cost Estimation. The construction companies all around the world have recognized that cost management is very crucial for the success of projects and they have also recognized that if cost management in the project is successful, risks are reduced and sustainable profits can be created. At the beginning of the process, the main purpose of the integration of cost management to BIM was creating the correlation between cost data and 3D Model. According to Mitchell (2012), 5D BIM has become the key player for cost management. According to Muzvimwe (2011), 5D BIM gives a chance for simulating the various designs. Kameedan (2015) describes 5D BIM as a model which enables the instant generation of cost budgets and genetic financial representations of the model against time. By utilizing from 5D BIM, time wasted for estimation and quantity take offs can be reduced into minutes. Also, thanks to 5D BIM, the trueness of estimation increases and professionals have a chance to work on improvements (Smith, 2014). Chances and barriers are occurred because of the BIM. As BIM develops, there is a requirement for more sophisticated cost management services.

2.2.2.4. Energy Simulation. 6D contains scheduling, cost management, and sustainability. Sustainability has three components such as environmental, social and economic. The 6th dimension of BIM has focused on environmental sustainability. In these models, users can measure the environmental effects and sustainability performance of different variations. By using the 6th dimension, professionals can compare the environmental and social effects of different design variations, make the decisions easier. To measure the environmental impacts during the construction, fuels and temporary materials should be discussed. In the 4th dimension, the required number of workers was calculated and employment opportunities should be evaluated in the 6D because it can be thought as social impact. For the operation stage, energy should be measured and evaluated. The area of the building is also a very important social impact. In the maintenance stage, demolition and disposal are should be discussed (Pu-ko, 2017).

2.2.2.5. Facility Management. The main focus of the construction industry is costs. If this focus point is switched to another point, the assets where most money is exerted may be understood better. Correspondingly, 7D BIM focuses on facility management. The biggest part of the life-cycle of a building is the operation and maintenance part. If the building is maintained, the lifetime and value of the building can be increased. By this way, efficiency of building increases and management costs can be reduced too. The main objective of 7D BIM is connecting the parties which have contribution to the lifecycle of building.

2.2.2.6. HSE Management. The rate of incidents in the site is very high in the construction industry. Many of the risks are originated from the early design stages. To prevent these risks, the most efficient way is taking precautions in these early design stages which is called Prevention through Design (PtD). However, until 8D BIM, there is no software for managing the relationship between design and safety in the construction site. As it is discussed above, BIM can be used for clash detection, scheduling, cost management, sustainability and facility management but safety is not included. The most important aspect of 8D BIM is including information about the integration of site safety and design decision. 8D BIM is developed for BIM based PtD. PtD includes risks related to the construction sites, methods of design objects, design offers about safety, and measurement of safety. The main objectives of these precautions are reducing the risks, integrating safety devices into designs and so on (Kamerdeen, 2010).

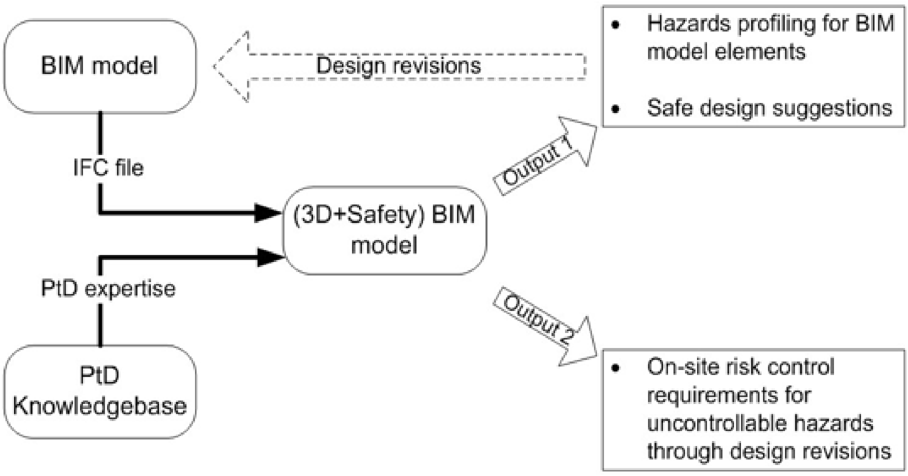

Figure 2.7. Framework for BIM-based PtD (Kamerdeen, 2018).

2.2.3. Details Levels of BIM Applications (LODs)

Level of Developments is reference which can be used for increasing the clarity and reliability of the models that developed by the parties involved in the construction projects. These terms have mentioned G202-2013 Building Information Modeling Protocol Form first. Thanks to the LOD concept, the main users have a chance to identify what their model based on and subusers can evaluate the usability of the model. Level of Developments is related to the problems that occur when different participants use the same models such as:

- In the first stage of the design phase, building systems and components are not clear and in time, there is an accurate definition. In the past, the development level of this model cannot be identified.
- From a BIM model, the user can find some output that the user does not intend. Fundamentally so much information is not reliable, because they are still in design phase. Because of this, the user cannot rely on the other information even they are reliable. By utilizing from the LOD, the user can identify reliability of the information in the models.

- For successful collaboration, the users other than the model editor should know when the information will be available. Thanks to LOD framework, this becomes easier (Latiffi, *et al.*, 2015).

There are six levels that start from LOD 100 and end with LOD 500.

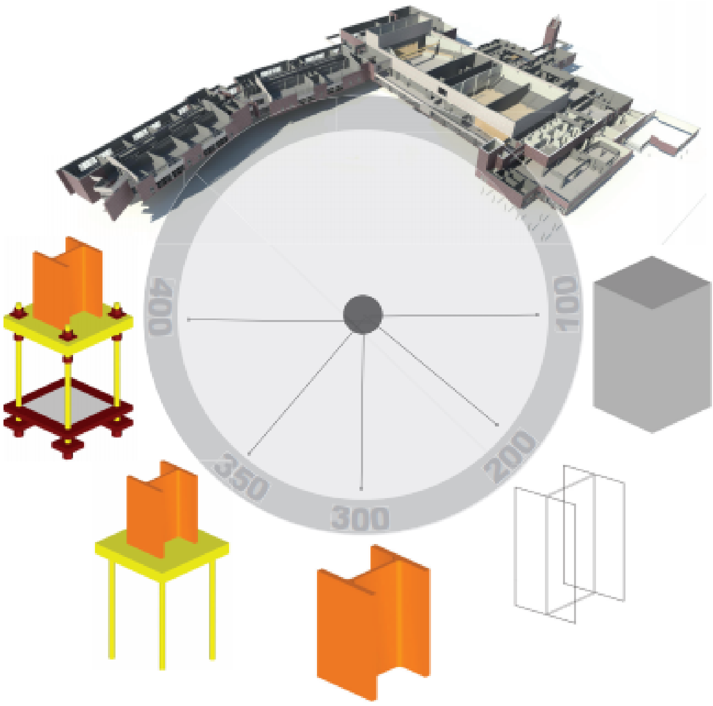

Figure 2.8. An example for LOD Classes (BIMForum, 2013).

<u>2.2.3.1. LOD 100 (Conceptual Level).</u> There is a just graphically representation in the model with the symbol, etc. Requirements for LOD 200 are not satisfied. Cost per square, the tonnage of equipment cannot be identified in this level. 2D drawings are used at this level.

<u>2.2.3.2. LOD 200(Schematic Level).</u> In this level, there are approximate quantities size, shape, location and orientation. Nongraphic shapes or components can also be used in LOD 200 additionally. By using LOD 200, users can estimate the cost, schedule the activities (BIMForum, 2013).

2.2.3.3. LOD 300 (Documentation Level). Quantity, size, orientation, become clearer in this level. As in the LOD 200 level, there may be some non-graphic information. It can be said, the main difference from LOD 200, quantities, shapes and sizes are more accurate than the LOD 200, in this level (BIMForum, 2013).

2.2.3.4. LOD 350. Unlikely from LOD 300, in addition to quantity, size and orientation, interfaces with other building systems are shown in this level. Also, again, non-graphic information can be added in this level (BIMForum, 2013).

2.2.3.5. LOD 400 (Fabrication Level and Assembly). In this level, size, shape, location and quantity are shown in detail. Also, this includes information about fabrication, assembly, and installation. As in the others, non-graphic information may be added (BIMForum, 2013).

2.2.3.6. LOD 500 (As-Built Level). This model includes verified representation in terms of size, shape, location and orientation. Also, LOD 500 represents what will be built for the operation level. Again, non- geometric information may be added to model (BIMForum, 2013).

2.3. BIM for the Different Parties Involved in Projects

Because of the nature of the AEC industry, there are so many parties that are involved in construction projects such as owners, designers, engineers, project managers, contractors and so on. To achieve a more efficient process in the projects, there is a requirement for good coordination and collaboration between these parties. In recent years, for achieving good, efficient collaboration, BIM is very useful and common technique. By visualizing the buildings before it is built, conflicts can be estimated, to prevent these conflicts, some precautions may be taken in earlier stages and misunderstandings between parties can be prevented also. Four main parties which are involved in the construction projects can be defined as:

2.3.1. Owner

In very short, the owner in the construction projects can be defined as an initiator of the project. It may be a real person or private legal entity. The owner finances the projects and makes contracts with the third parties like designers, contractors and so on. It is the decision maker.

2.3.2. Designer

Designer prepares, arranges and modifies the construction projects. Designers can be architects, engineers, interior designers and so on. Drawings, design detail and other can be included in the design.

2.3.3. Contractor

Contractor implements the plans, details which are prepared by the designers in the construction site and manage the activities according to decision of owner and project manager.

2.3.4. Project Manager

Project manager is the professional in the construction field who is responsible for the planning activities, procurement and execution of a project. Project manager prepares reports for owner. There may be different types of project manager such as construction project manager, engineering project manager, and architectural project manager and so on.

Thanks to developments in the BIM technology, these parties come to closer. Thanks to this, costs of projects are reduced, efficiency and productivity is increased and projects become more profitable. To increase the number of these benefits BIM applications should be interiorized by each of these parties.

2.3.5. BIM for the Owner

BIM has so many benefits from the perspective of the owner For example, owner can follow the process of the projects, communicate with other parties, monitor the process of the projects and so on. During BIM design process, a database which provides information about functions and properties of buildings, is developed. Owners can communicate with the designers during the development of 3D models. Before BIM, this is very expensive and long process. On the contrary, owners are included in the process from the beginning of the project through BIM. BIM provides required information to the owners and they can understand easily.

Awareness of owners about BIM is very critical for the success of the project. If they can understand BIM properly, they can manage the stakeholders and select appropriate contractors and designers. Owners can be considered as decision makers in the project and because of this, awareness of owner increases efficiency.

2.3.6. BIM for the Contractors

BIM is very beneficial for the contractors, however, the contribution of the contractors is very small to BIM. Contractors can minimize the risks related to investment, provide coordination better, control the activities, detect clashes in the earlier phases, create and evaluate different alternatives and choose the best, optimum scenario.

2.3.7. BIM for the Project Managers

Because of the lack of engagement and other reasons, project managers have left out the activities on BIM. This situation should be changed because for efficient project management, there is a requirement for BIM applications. If definition of BIM is investigated in detail, it can be seen that the concepts such as coordination, collaboration, communication, are focused and emphasized. Roles of project managers are very critical in development processes which are very critical identification of projects successfully. Project managers contribute to success of the projects. Someone thinks that as BIM develops, responsibilities of project managers decrease however, on the contrary, project managers become more important in the process of BIM implementation. If project managers use BIM properly, there will be some outcomes for projects such as:

- Efficient delivery of project
- Accurate understanding and implementation of BIM
- Improved information sharing and data storage
- Better communication, collaboration
- Better design coordination
- Improved certainty in the duration of the project

Delivery process should be managed a part of project management process. Consequently, project manager should control the delivery process of Asset Information Model in delivery process of project. Because of this, project manager should know how the roles of BIM and project management spread during the whole project life cycle. Some other project manager's BIM role is identified in the table below.

Table 2.2. Roles of Project Managers (Building Information Modelling for Project Managers (RICS).

Stage	**Project Manager's BIM Role**	**BIM Applications**
Briefing, Inception and Pre-Construction	Feasibility Analysis	· **BIM adoption question** · **Challenges to BIM adoption** · Concept-stage BIM
	Value Engineering	Options selection using BIM, Conceptual Estimating Modelling, Energy Analysis, Design Analysis
	Design Management	BIM Information exchange, 5D (rapid cost feedback to design changes), BIM Coordination
	Risk analysis and safety	Simulation, Virtual Reality (VR), and Augmented Reality (AR)
	Scheduling	4D Modelling
	Constructability analysis	4D Modelling, virtual mock-ups, VR and AR
	Procurement (design and construction)	BIM skills and capability mapping, BIM enabled Supply C hain Management, Constraint Analysis
Construction	Phasing and prototyping	4D
	RFIs and issue resolution	BIM Information exchange, BIM coordination
	Change management	BIM information exchange
	Monitoring and control	4D and 5D, Constraint Analysis, Progress Tracking and Production Planning
Project closure	Contract and financial closure	Record model
	Project closure	Record model, Asset Information Model
	Handover	Record model, BIM for FM, Asset Information Management

2.4. Related Concepts

2.4.1. BIM&Lean Construction

Combining BIM and lean construction is a relatively new concept. Because of this, there are no so many researches about this topic. Actually, these two concepts, lean and BIM, is applied to projects separately. Lean construction is related to the reduction in waste. Thanks to BIM, professionals from different disciplines have a chance to work on the same model. By this way, quality of works increases. If lean construction and BIM can be applied successfully, expectations of clients can be understood better. The collaboration of Lean Construction and BIM results in cost reduction (Onyango, 2016). By utilizing the visualization feature of the BIM, resources can be allocated in a planned way. As implementation of BIM increases, Lean construction objectives like waste elimination, rise in the value can be obtained more. If projects in which the BIM is applied but lean construction is not used are investigated, some clues of Lean construction might be observed. So, we can say that BIM application and lean construction cannot be considered as different. Using BIM, structural clash test can be performed, the most suitable design can be selected among the alternatives and energy solutions can be performed (Fred, 2016). Thanks to these, wastes such as time, materials, effort may be eliminated. Customer value can be increase by best result analysis, visualizing the solutions. Cycle times can be reduced by automation material schedules and quantitates, providing accurate information. If tasks and time can be scheduled work flow can be redesigned. Different parties which are involved in Project have a chance to work on a same model and thanks to this, collaboration in the Project is increased dramatically. For success of synergy between Building Information Modelling and Lean construction, starting of the collaboration from the earlier phases of Project is very important. By this way, lean construction can be planned very well. Also, there is a requirement for good leadership in both BIM and Lean Construction (Tauriainen, 2016).

2.4.2. BIM&Smart City

Safe integration of internet and communication technologies can be provided by Smart City concept and this concept has been developed for urban development. The main objectives of smart cities are to provide better, sustainable, and well-connected cities. Smart city projects are very complex projects. There is a requirement for innovative technologies for successful application of smart cities. Innovative technologies should be utilized from the earlier phases of the projects. Energy management, water management, smart infrastructure and transport are included in the smart city concept. In the idea of the smart city, city is managed efficiently by IoT and BIM. For better operation and managing of the city, BIM models can be used (Mgbere *et al.*, 2018) By using these models, energy analysis can be performed. Some factors such as traffic, air pollution, and disaster management can also be simulated. Thanks to BIM, the best way for using resources can be found.

To achieve successful smart city, there should be very good and strong collaboration between different parties which are involved in the projects. By implementing BIM, each party comes to same platform. Wasting time is reduced thanks to this way. BIM implementation prevents information loss and during the design of the smart cities flow is not disturbed. The most important concept for mart cities is connectivity and data. By using BIM, data points are met. By using Digital City which is published by Autodesk, future of the smart cities can be simulated and visualized. Another software which is related to BIM is CIM which is published by Bentley. There is still a long way to go in BIM Implementation for smart cities.

2.4.3. BIM&Sustainability

BIM and sustainability are two of the most important and hottest concepts of the AEC industry in recent years. Because the BIM provides good collaboration and a common platform, sustainability increases. Expenditures and consumption can be reduced after the construction phase thanks to BIM. More innovative and cost efficient buildings can be built thanks to strong collaboration which is provided by BIM. Performance of building and environmental, economic impacts affect the sustainability of the building. Thanks to BIM, green buildings can be evaluated, analysis can be done, and sustainable decisions can be made. To reduce energy and analyze the renewable energy options which provide energy efficiency, energy may be modeled. Energy costs can be reduced thanks to building orientation. Building massing analysis optimize the structure. To reduce the water consumption, water analysis can be performed. Financial impacts can be estimated by BIM (Zhabrinna *et al.*, 2018) These were related with the design phase. In addition to these, there are so many effects of BIM on the sustainability in the construction phase. Some analysis can be performed continuously to understand environmental effects. Noise pollution and environmental effects can be measured. Designs can be detailed thanks to BIM in construction phase such as drawing in 3D. After these steps another important phase is operation of the building. Building performance in terms of water, energy and carbon emission can be measured thanks to BIM. Better decision for improving the results can be made by utilizing from BIM. Reduction of resource and waste consumption may become easier.

Also there are some certification for green buildings such as LEED and BREEAM. These are two of the reputable rating systems. BREEAM has been published in 1990 by the Building Research Establishment. BREEAM rating systems evaluate the building according to:

- Management
- Energy
- Health and wellbeing
- Waste
- Land use and ecology
- Pollution
- Materials

LEED is another popular rating system which is valid all around the world. It has been published by U.S. Green Building Council. Building has been rated according to design, construction, operation and maintenance of the buildings. There are four types of certification in LEED certification:

- Certified (40-49 points)
- Silver (50-59 points)
- Gold (60-79 points)
- Platinum (80 points and above)

To satisfy the requirements of these rating systems, BIM is very useful. According to these criteria, buildings can be designed and analyzed by utilizing from BIM. In design phase appropriate materials can be chosen and decisions are made according to its cost and environmental impacts.

2.4.4. BIM&Innovation

Recently, innovative solutions for increasing the collaboration between parties are required so much because efficiency in construction industry decreases. However, it should be said that innovation is very difficult in the construction industry because of the complex nature of industry. There are so many solutions in the literature for improving the solutions, collaboration and the most important solution for this is BIM.

2.4.5. BIM&Integrated Project Delivery

It can be said that traditional delivery methods are not efficient anymore. Thanks to IPD, integration and collaboration have increased and the context of delivery methods have also changed. Also, IPD provides maximization of efficiency, increase in the value, and reduction in waste and so on. It can be said that IPD is the combination of integrated approach and lean construction (Ilozor *et al.*, 2012).

Key stakeholders can be informed by this method. There is a requirement for so many developments and support systems. If there are problems in these support systems, it fails. If there is inaccuracy in data handling, it has also economic impacts on the IPD team. All parties which are involved in this stage should be informed and this is possible with the BIM. In addition to this, if BIM and IPD is integrated, new alternatives can be found, delivery system or method may become more efficient. For following the development of the data, a track system may be developed and thanks to this system so many data such as aggregate cost data, presents data, saved costs are stocked. Communication among the team members directly effects the success of the project, face to face meetings are not possible very time and it may be expensive, so because of this, coming together the participants of the projects in the common digital platform is the best way and this can be achieved by BIM. In the end, a model that integrates BIM and IPD, cost savings which is the most important barrier for IPD can be achieved (Kent *et al.*, 2010).

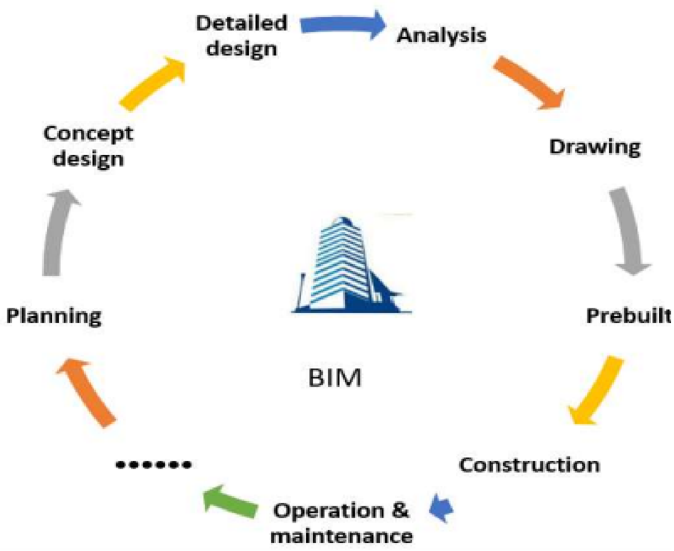

Figure 2.9. The Application Areas of BIM in the Construction (Zhang and Chen, 2018).

2.5. Different Application Areas of BIM

In recent years, application of BIM in other sectors except AEC industry has become very popular. Thanks to BIM, two different tools can communicate with each other. As the features of BIM increases, the number of the application increases too. Different application areas of BIM except the AEC industry are listed below.

2.5.1. BIM in Education

BIM implementation is very common in the education area in recent years. In 2012, BIM is used for teaching sustainable design by Shen *et al.* (2015). Authors claim that thanks to BIM, students can understand how different designs may increase the performance of the structure in terms of energy. Variables in the building can be evaluated thanks to BIM tools. BIM is a very useful tool for teaching design and construction process of green buildings. In 2012, Lee and Dossick shows that BIM can also be used for construction engineering and management education. Virtual design technologies has developed by developments in the BIM tools and correspondingly, quality of education in these areas has increased. It can be summed up as thanks to BIM, learning is improved, people are prepared for practical industry and engagement is increased. In research of Lewis, the studies of the students who have taken course for BIM based energy modelling are investigated. Results show that the study who have taken course about this topic are more successful than the others (Lewis *et al.*, 2014).

2.5.2. BIM in Medical System

Medical system means foundations and resources that are used for delivering health care services. In recent years, the importance of sustainability in health care services and construction industry has increased a lot. There is a requirement for more tools to develop and evaluate the projects in terms of sustainability. There is an expectation for an increase in the lifetime of the projects. All hospital projects are not new buildings sometimes there may be requirement for refurbishment or extension. Existing healthcare facilities are investigated at least one time every 3 years. Energy consumption and reduction of carbon emission are analyzed. To provide safer and enough environment for the patients, facility management dimension of BIM can be very useful tool. Insufficient communication may results in disconnection between personnel in the healthcare facility. This causes some risks for the health of the patients and additional costs. In some researches, some information which are required for supporting facility management activities for whole life cycle of facilities are identified. According to Sebastian (2011), BIM manager is required for some jobs which required some IT abilities. For example, Castro Medical Center is one of the most valuable and expensive hospital and approximately 320 million dollar is expended. During the construction of this hospital, BIM is used for creating value and visualizing. Sebastian proposed geographic ınformation system for integration of energy efficient buildings. New system which is proposed by Sebastian in the same research includes models for all phases of the facilities such as: assembly model, energy model, operation optimizing model and so on. This research aims reduction in accidents, loss of skilled personnel too (Harris, 2017).

2.5.3. BIM in Economic System

The economic system has direct impact on public activities and government. BIM can be implemented to so many economic systems. BIM is identified as new paradigm that visualize the construction projects and simulate them by Azhar et. al. McAuley developed a scheme based on utilizing from all costs of whole life cycle. This scheme is developed by consulting to international methodology for life cycle costing. This gives a chance to user for selection of the best and economical option. According to the results of Thurairajah's and Goucher's research, cost consultants are going to use BIM. Research of Ji *et al.* (2013) propose that economic factors are fundamental drivers for BIM implementation and to promote BIM implementation, the best way is considered as economic incentives by government (Thurairajah, 2013).

2.5.4. BIM in Traffic Control

BIM has been implemented for many years in traffic control. In recent years, researchers have focused on this topic. Managing traffic includes activities such as: prioritization, control, and reduction of the traffic. Schaap and Van de Riet has published a research by implementing psychological insights by using BIM behavioral insight models. Chen *et al.* (2016) shows closed circuit television in public buildings which is technology that facilitate BIM technology (Schaap *et al.*, 2015) BIM model which was developed for mass rapid transit station is chosen to implement to the CCTV. Thanks to BIM, closed circuit television model can be tested in 3D environment. Risks which are related to pedestrians can be reduced by BIM and the safest path for pedestrians can be identified (Shaaban, 2015). Harsha *et al.* (2017) analyzed whole life cycle of road infrastructure. Deng *et al.* (2019), used BIM to noise mapping which shows noise level of certain level. Traffic noise can results in very serious health problems in the metropols (Deng et al., 2019).

2.5.5. BIM in Image Process and Feature Extraction

Imaging analysis can be defined as process of extraction data from images. There are so many applications in imaging analysis such as emotion identification, image analysis, face identification, and image compression. Liu *et al.* (2017) propose a case study where the laser scanner and a camera are used to develop a complete BIM tool. Mahdjoubi mentions about real estate marketing by utilizing from 3D laser scanner and BIM integration. This research reports that automatic procedures to offer faster and better services to customers have been developed. Kim and Anderson developed energy modelling system by using Open BIM standards. The main objective of this research is estimating energy and developing a new method to develop correlation between simulation engine and BIM models (Kim and Anderson, 2013) Sharqi and Koseoglu reviewed the health and safety development by BIM and image identification. This research proposed a method which is based on BIM including searching and retrieving selected time images and so on (Sharqi and Koseoglu, 2013) Image recognition and BIM tools are very useful for producing daily HSE reports.

2.5.6. BIM in Forecasting and Prediction

Forecasting and prediction can be defined as the process of predicting future events. In last decades, so many researchers have published so many papers for this application area. Strzalka (2011) analyzed 3D urban model to predict demand of heating energy in urban area. An urban energy management tool is developed to predict heating energy demand and improve the building standards. Becker *et al.* (2011) focused on correlation between the future trends in construction industry and required education for these trends. This research proposes scientific methodology of researches for prediction and trends. Hwang *et al.* (2012) studied on developing automated cost estimation system. BIM models develop some information and tools for automating process such as procurement, timing and prediction.

2.5.7. BIM in Manufacturing and System Modeling

Manufacturing system includes functions of equipment, human resource, and information, control and support. Steel proposed compatibility in BIM. For modular construction manufacturing, Moghadam *et al.* (2012) suggests usage of BIM and lean base production line. According to Barlish and Sullivan (2012), BIM is very useful tool for semiconductor manufacturing (Barlish *et al.* 2012).

2.5.8. BIM in Social Sciences

There is resistance to change in construction industry and professionals are unwilling to transition to BIM. There is a requirement for common effort of professionals from material sciences, physics and social sciences. Consequently, each parties should work collaboratively by using BIM to provide required integration. Technological developments like BIM offer more collaborative work environment and better information sharing. In tries to adopt qualitative methods to ally work in social sciences might offer more robust information behavior supported by BIM by integrating models in system, communication, and information. These methods give a chance to compare quantitative data with each other. The social, organizational and structural factors that increase performance of building can be understood through BIM. The results of Newton's and Chileshe's study shows that BIM results in advanced visualization, increased efficiency and reduced clashes. Zhang *et al.* (2018) investigated BIM application in Hong Kong. This research focuses on whether BIM change the working style, responsibilities and relations or not. Results show that visualization tools increase the communication between project teams.

2.5.9. BIM and Virtual Reality

In the research of Davood *et al.* (2012) development of BIM tools and technology is considered as a very useful resource for VR simulation. Database is developed through a comprehensive core which includes components of a building. BIM team focuses on developing of 4D/VR prototype simulator. Sampaio *et al.* (2017) developed a model which is based on VR technology to scheduling in the construction. VR technology visualizes different phases of construction and interaction with the construction activities become possible. VR application shows construction process clearly, mistakes can be detected in the earlier phases. To make VR more interactive, to make VR multiplayer in virtual buildings BIM is used actively in VR environment. The multiplayer virtual walk allows real time interactions of remotely located project stakeholders in the same environment, with a shared immersive walkthrough experience. Main concept of BIM is storing consistent 3D data for collaboration of each disciplines. By combining VR and BIM, professionals have a chance to achieve optimum alternative. Developed data analysis methods, multidisciplinary planning, and coordination, access to high quality project results are expected through combination of BIM and VR (Sampaio, 2017).

2.5.10. BIM and Augmented Reality

One of the most significant feature of BIM is visualization. There are so many researches about visualization aspects of BIM. Kim and Kim (2012) have developed model which aims visualizing the phases of the construction by utilizing from the Industry Foundation Classes. Zhang *et al.* (2013) made researches for developing models which can be used for finding solutions by checking the safety requirements. To link BIM and AR, there are three major concepts: BIM model, Data Transferring and AR platform. Some graphical elements are provided by the BIM model. By using data transferring, BIM model can receive and send information about the structure. This information may also be used for developing a link between model and AR platform. Thanks to AR platform, people may use to information which are received from the BIM model and they can visualize the structure (Wang *et al.* 2014). Thanks to this, before construction is completed, people have a chance to see the completed version of the building. This is very big chance for customers and stakeholders too. Customers may have more information about the building and thanks to this, they may be more clear about whether this building is available for them or not and they can decide whether they buy or not too. On the other hand, thanks to link between BIM and AR, stakeholders can see whether their expectations are met or not and they may tell some other will to contractor based on this.

2.6. Barriers for BIM Adoption

The adoption of BIM in construction projects has been very slow. There is not only one barrier that can be handled by individually, even there are so many barriers that can be listed as the factor that makes adoption slower in the AEC industry. BIM adoption is not only related to technology it is also related to human, culture of companies in the industry and so on. One of the most important and fundamental barriers to implementation of BIM is fragmented nature of the construction industry. Because of the fragmented nature of industry, there is requirement for contribution of other parties.

In recent years so many researchers have focused on the barriers that prevent implementing BIM in the construction industry. Each of them has pointed different aspects of barriers. Hamma-Adama has reviewed BIM adoption and its barriers in Nigeria which is one of the developing countries. According to his study, "lack of expertise within the organisations" and "lack of expertise within the Project team" are the most important and impactful barriers. Also, lack of standardization, protocols and lack of client demand are another barriers that prevent the BIM adoption.

Amer *et al.* (2016) have investigated both private and public sector projects. In this paper, weak government efforts to implement BIM, shortage of experts about BIM, weak knowledge of BIM benefits are listed as the most important barriers. The questionnaire that is used in this study is applied in Iraq construction industry.

Chan (2014) has focused on the barriers for BIM adoption in Hong Kong and he has investigated that from the designers' perspectives. The main objective of his study is to identify the needs and barriers of design firms. The main barrier for design firms in Hong Kong is identified as the lack of qualified staff about BIM. In addition to this, lack of training, lack of standards, lack of client demand, lack of government's lead, lack of incentives, etc are other specified barriers for adoption of BIM.

Abubakar *et al.* (2014) have investigated the required awareness level of Nigerian construction industry and factors affecting BIM implementation. According to this research, social and habitual resistance to change is the most important barrier that prevent the implementation of BIM. Legal-contractual issues and high cost of training are in the second and third places according to this questionnaire which is conducted to firm in the Nigeria. Also, this paper has mentioned about the some other barriers such as lack of enabling environment, lack of trained professionals, poor internet connectivity and so on.

Ahmed *et al.* (2013) have focused on identifying the most important barrier for the adoption of BIM by developing relative rank. Relative rank is calculated according to repeating frequency in the literature. Social and habitual resistance to change and traditional methods of contracting are the most frequent barriers for BIM adoption. High training costs and expensive learning curves are in the second place according to this study. Lack of awareness of BIM is in the third place.

Sawhney *et al.* (2015) have tried to identify barriers for adoption of BIM in India by using semi structured interviews. Mindset of the people, lack of skilled workforce, collaboration between different parties that are involved in construction projects, technical issues, cost, lack of awareness and demand, BIM learning difficulty are listed in this paper.

After so many barriers have been identified by different authors, these authors have classified these numerous barriers in some categories. For example, Gu *et al.* (2011) have categorized identified barriers into three such as: people, process and product. Ashcraft-Esquire and Ku-Taeibat have divided these barriers into two such as contractual and personnel. Paper of Gu and London have investigated into three such as technical issues, contractual issues, and process related issues.

2.7. Enablers for BIM Adoption

To reach fully adoption of BIM in the construction the barriers that have been investigated in the literature so far should be eliminated. On the contrary, of course, there are so many enabler that facilitates BIM applications in the industry.

The main objective of the paper which is published by Abbasnejad *et al.* (2016) is classifying the enablers for adoption of BIM. Authors have identified 27 enablers for BIM adoption. They classified these enablers into seven groups such as: strategic initiatives, change management, cultural readiness, learning orientation, knowledge capability, network relationships, and process management.

Amuda-Yusuf (2018), has focused on the critical success factors for BIM adoption for Nigerian construction industry also he has ranked these factors to identify the relations among each other. He has identified 28 factors from literature review and based on these, he has prepared a questionnaire. According to his study, standard platforms for integration and communication is the most important enablers for Nigerian construction companies. According to this study, well education and training, well communication between BIM objectives and top management support are other enablers for adoption of BIM.

Hamma-adama *et al.* (2017) have investigated both barriers and enablers for BIM adoption in Nigeria. They have used online questionnaire for data collection. During the analysis step, they have used reliability test, descriptive statistics, and Relative Importance Index methods. According to results of this study, availability of trained professionals to handle the tools is the most important enablers that Hamma-adama has identified. Proof of cost savings by its adoption and BIM Software affordability are the other important enablers that affects adoption of BIM.

Wong and Lee (2018) have aimed to identify CSFs of BIM adoption. They have prepared a questionnaire and they have shared this with the contractors and architects in Finland, Denmark and USA. According to the results of the questionnaires, willingness of share information among the parties involved in the projects or organizations. Master BIM model team/manager, leadership of senior management, effective collaboration are other important enablers for appropriate BIM adoption process.

Mohammed *et al.* (2017) have tried to identify accelerators for adoption of BIM by utilizing from the previous researches. After findings from literature review, they have utilized from the content analysis. As a result, they have identified seven pillars for BIM adoption in their study such as standard and accreditation, collaboration and incentives, education and awareness, National BIM Library, BIM guidelines and legal issues, special interest groups, research and development.

2.8. BIM Software

In the construction industry, BIM is a very new concept and there is a very long way for full completion. However, its adoption to the activities in the construction projects is very fast. There is so many software related to BIM and each of these has different functions and application areas.

2.8.1. Autodesk Revit Architecture

Revit can be used for modelling the whole buildings and parts of it. Revit is very efficient and useful tool for providing collaboration between the parties which are involved in the projects. Users can find system families (walls, floors, roofs, and so on), loadable components (extrusions, sweeps, etc.) and lastly in-place families (Autodesk, 2020).

2.8.2. ArchiCad

This software is useful for architecture. ArchiCad provides aesthetic solutions during the design phase. It offers a chance for visualization and 2D-3D drawings to architects and engineers. Parametric objects (often called as smart objects) can be used in ArchiCad, many architects can work on the same model thanks to this software, professionals have a chance for remote access, and also ArchiCad is compatible with DWG, DXF, IFC and BCF.

2.8.3. Autodesk Ecotect Analysis

This software is useful for environmental analysis. Designers have a chance to model the performance of building in terms of environment and sustainability (Azhar *et al.*, 2009).

2.8.4. Autodesk Green Building Studio

This software is a cloud-based service and designers can model the performance of building as in the Autodesk Ecotect and optimize the building in terms of energy efficiency. Green Building Studio provides solutions for carbon neutrality (Autodesk, 2014).

2.8.5. Naviswork

By using Naviswork, users can view 3D drawings, and combine them. The main objective of Naviswork is to enhance collaboration in models. Thanks to this collaboration and cooperation project analysis can be made appropriately and construction is simulated. There are so many functions that users can use. 3D drawings and scan formats can be combined. Users can understand whether there is a conflict between the parts of the model or not. Areas can be measured in 2D and 3D drawings, components and parts of the building can be counted and required materials can be estimated. The link between shape and time can be provided and by this way, the building can be modeled. In addition to these, developing an animation in another feature of Naviswork. Naviswork is a very crucial software for the application of 4D and 5D (Autodesk, 2020).

2.8.6. Autodesk Dynamo

Dynamo offers creating virtual logic by utilizing from parametric designs and tasks can be automated. There are so many functions in Dynamo and because of this, BIM can be implemented easily thanks to Autodesk Dynamo. DWG Files can be converted into actual geometries. There is also a filtering feature and thanks to this filtering, objects can be imported (Autodesk, 2018).

2.8.7. Tekla Structure

Tekla Structure is a structural design software and is used especially in steel and concrete structures. The building can be modeled in 3D by using this software. LOD 500 is available in Tekla and this is the most advantageous feature of it. Thanks to this feature, cost so can be minimized. This results in more profitable projects. There is only one tool for all elements and projects, because of this, it can be said that Tekla is very user friendly. Project members and third parties collaborate easily in this platform. Open collaboration in Tekla Structure utilizes model data for fabrication and construction (Tekla, 2019).

2.8.8. 3D Studio Max

By using 3Ds Max, professionals can prepare 3D animations, images and so on. It is generally used by architects for visualizing the projects. In addition to architects, video game developers and TV studios may sometimes use this software. There are some features for dynamic simulation, map creation, rendering and so on (Autodesk, 2013).

2.8.9. Aconex

Aconex is generally used by technical offices. The main purpose of Aconex is to provide collaboration between different parties which place in the construction industry and also documents can be archived. The archive is very practical thanks to Aconex and because of this, Aconex should be used from the starting of the project. For example, if Aconex is started to use after 1 year from the beginning of the projects, some information from this duration might be lost. Aconex can be used in so many different project types such as power, mining, plant, building and so on (BBCT, 2019).

2.8.10. Adoption of BIM

2.8.11. Development of BIM around the World

2.8.11.1. USA. BIM was developed in the USA and the USA is the most important country for the development and implementation of BIM into the AEC industry. US General Administration leads to the application of BIM in the public projects. Also, implementing and using BIM in the project has become compulsory since 2007. However, there is still a need for development, for instance, there is a lack of standardization and public coordination. Approximately 70% percent of the companies in the USA are using BIM software. BIM is not supported by the only the public sector, universities and private organizations also promote BIM implementation (Singh, 2017).

2.8.11.2. United Kingdom. UK is another leading country in BIM implementation, especially in Europe UK is the most developed country in terms of BIM. Participants use National Building Specifications for the description of elements, standards and so on and NBS belongs to the UK. This was developed in 1973 and more than 5000 offices is utilized from these standards. Using BIM Level 2 is compulsory for reducing procurement costs for approximately 20%. If a company is not available for Level 2, this company cannot take public projects (Zigurat Global Institute of Technology, 2018).

2.8.11.3. China. China is still in the beginning stages of the BIM implementation and it can be said that China has stayed back in the BIM relatively. According to China Construction Industry Association, approximately 20% of the construction companies in China have started to use BIM. China has difficulties like cultural resistance and so on. As in the other sectors, they are trying to accelerate the implementation rate of the BIM in the AEC industry (Dodge Data Analytics, 2015).

2.8.11.4. South Korea. BIM implementation rate is very low in South Korea relatively other Asian countries. Although they are known as a very developed countries in terms of other technological developments, they are not very developed in BIM technology. According to a survey conducted by Korean Institute of Registered Architects 75% of the companies have not implemented BIM (Lee *et al.*, 2015).

2.8.11.5. Japan. The Government Buildings Department has prepared "Guideline for BIM Application in Public Building Projects" in 2014. This guideline has identified the standards of BIM usage and implementation. There are so many examples for different types of projects and these examples show how the BIM should imply. LODs are specified and by this way, they aimed to make their AEC industry more efficient. Japan has very high BIM usage rate in procurement management, facility management process (Kaneta *et al.*, 2016).

2.8.11.6. Singapore. There are two main objectives for BIM implementation in Singapore: reducing the number of foreign workers and increasing efficiency. Approximately 30% of the residents are from different countries such as India, Bangladesh, China, etc. Singaporean Government is planning to reduce the number of these by BIM implementation. The main objective of government related to this is increasing the BIM adoption rate to 80% and by this way they also aim the increase efficiency for 25%. Building Construction Authority has prepared "The Singapore BIM Guide". BIM execution plan has been also identified. There are so many plan templates for different types of projects. Singapore BIM Fund has founded in 2012 and main objective is supporting the firms in BIM implementation by training, consultancy and so on (Kaneta *et al.*, 2016).

2.8.11.7. Malaysia. On the contrary, in the Malaysian, rate of BIM adoption is very slow and the evolution of the industry to the BIM is very slow. They conclude that there is a requirement for collaboration between stakeholders in the industry and specific vision about BIM implementation. Supports and incentives of government are very important for success. The biggest problem with BIM implementation in Malaysia is unawareness. However, there is a rising interest in BIM in Malaysia in recent years and this interest increases gradually. On the contrary adoption rate is not increasing correspondingly. Malaysian Public Work and Department has introduced BIM to parties in the AEC industry in 2007. Still, some programs and events are prepared for increasing the number of BIM applications (Memon *et al.*, 2012).

2.8.11.8. India. BIM implementation is in the beginning phase in India and they have stayed behind according to other countries. However, it is expected that the volume of the construction industry is going to increase for approximately 3 times in 2022. And so many companies have projects in India nowadays. It can be said that thanks to this AEC industry in India is going to develop. Of course it is expected that BIM application rate is also going to increase. Also, in recent year government give so many incentives for implementation.

2.8.11.9. United Arab Emirates. In recent years, the implementation rate of BIM in UAE has increased and this increase still continues. However there are not so much standards related to BIM. The BIM is rarely mentioned in the contracts because of this, responsibilities are not identified definitely. The BIM has become compulsory in the Dubai Municipality in 2013. BIM has used in very big projects in UAE such as Opera House, Abu Dhabi Airport. After the selection as host for Expo 2020, the construction sector has become very important industry for AEC. To achieve their goals, they need to eliminate inefficiencies in the industry. Because of this reason, BIM implementation has become more important for the UAE (Croft, 2017).

2.8.11.10. Brazil. In 2017 a committee which is called Strategic Committee for the Implementation of BIM and a Technical Support Group have founded. There are six main strategies for these foundations: providing communication, editing regulation and standardization, developing technological infrastructure, developing BIM platform, organizing the public purchases, and training human resources. Thanks to these strategies, Brazil aims to increase the efficiency in AEC industry, increase the quality of the projects, achieving more accurate schedules, reduction in the number of revisions in the projects. İncreasing the number of qualified personnel. They want to achieve these by creating communication plan, reduction of discrepancies, give incentives, define learning objectives, publish documents related to BIM, and define a framework for BIM implementations (Kassem, 2015).

2.8.11.11. France. Adoption of BIM in France is not compulsory. They have not prepared any law and standards. However, government gives so many incentives. In recent years, the government has recognized the importance of standardization and they have planned Plan BIM 2022. By this plan, France aims to motivate parties in the projects. The main barrier for implementing of BIM in France is that BIM is not compulsory (Dekker, 2019).

2.8.11.12. Germany. In 2013, Germany's Federal Ministry of Transport and Digital Infrastructure has founded. The main objective of this foundation is using the sources of the government for public works in the correct way, improving the reputation of AEC industry in Germany. As a pilot, the Federal Ministry of Transport has given incentives and the amount of these incentives is 3,8 million Euro. They are planning to implement BIM completely in their projects until 2020. There are two standardization in Germany and first one has prepared by the Association of German Engineers which is one of the biggest foundation. The German government expects rise in productivity thanks to better collaboration and analysis (Biblus, 2018).

2.8.11.13. Norway. There are incentives from the Norwegian Homebuilders Association in Norway. Government is responsible from the application and organization of

BIM. Thanks to this conscious, since 2010, BIM is implemented in the AEC industry and companies are using BIM file formats. BIM is utilized during the whole life of the building (Biblus, 2019).

2.8.11.14. Australia. In Australia, BIM implementation is not very common. Although there is a very long way for BIM adoption in Australia, in the last 5 years, there are so many attempts to increase the rate of BIM implementation. There is an expectation for growth by 6,5 billion dollar until 2020. There are three foundations in Australia such as Australasian Procurement and Construction Council, Australian Construction Industry Forum and Australasian BIM Advisory Board. APCC is related with the governmental and ministerial institutions. They are looking for the ways of digitalization in construction. Leaders of the AEC industry in Australia come together in ACIF. This foundation enables the cooperation and collaboration between the parties which are involved in the projects. ABAB is much related with the development of BIM standards. They make guidance for BIM adoption and thanks to this guidance, parties in the projects came to the same level.

2.8.11.15. Netherlands. In 2014, research was published by the University of Twente, Dutch Building Information Council. The main objective of this research was to understand the level of maturity of the companies in terms of BIM implementation. A model is developed to understand the maturity level (Siebelink *et al.*, 2019).

2.8.11.16. Spain. In 2014, BIM guidelines is published in Spanish. This was a revised version of the Finnish COBIM. Spain was affected from the neighboring countries and they have founded the Ministry of Infrastructure immediately. The main objective of this foundation is leading and pushing up the BIM. In 2015, esBIM Spanish Commission was founded. At the end of this process, BIM implementation has become must for the construction companies. After announcement of mandatory, sector has begun to implement BIM. They have given importance to training for BIM. They have organized so many conferences and congresses. BIM professionals have come together with other professionals and share knowledge, experience. In addition to training, creating the right environment for BIM is another important issue and they have given importance to this topic also. EsBIM Commission and BuildingSmart has supported the implementation of BIM, created BIM Implementation plan and identified the BIM Scope. In addition to these, Innovation Plan for Infrastructure and Transport 2018-2020 has published by Ministry of Infrastructure.

2.8.11.17. Italy. The BIM Journey of Italy has started with UNI 11337. BIM Implementation has become compulsory because of the "BIM Decree". This mandatory is related with the big procurement projects, so, small projects still continue with the traditional methods in Italy. In the stage 2 of the process, BIM implementation is going to be compulsory for these small projects. In 2022, at the end of this progress they are planning to implement BIM completely.

2.8.11.18. Denmark. Denmark is one of the biggest supporter of BIM implementation. They have made investments to research and development studies for BIM. BIM implementation has been mandatory by Palaces & Properties Agency, Danish University Property Agency.

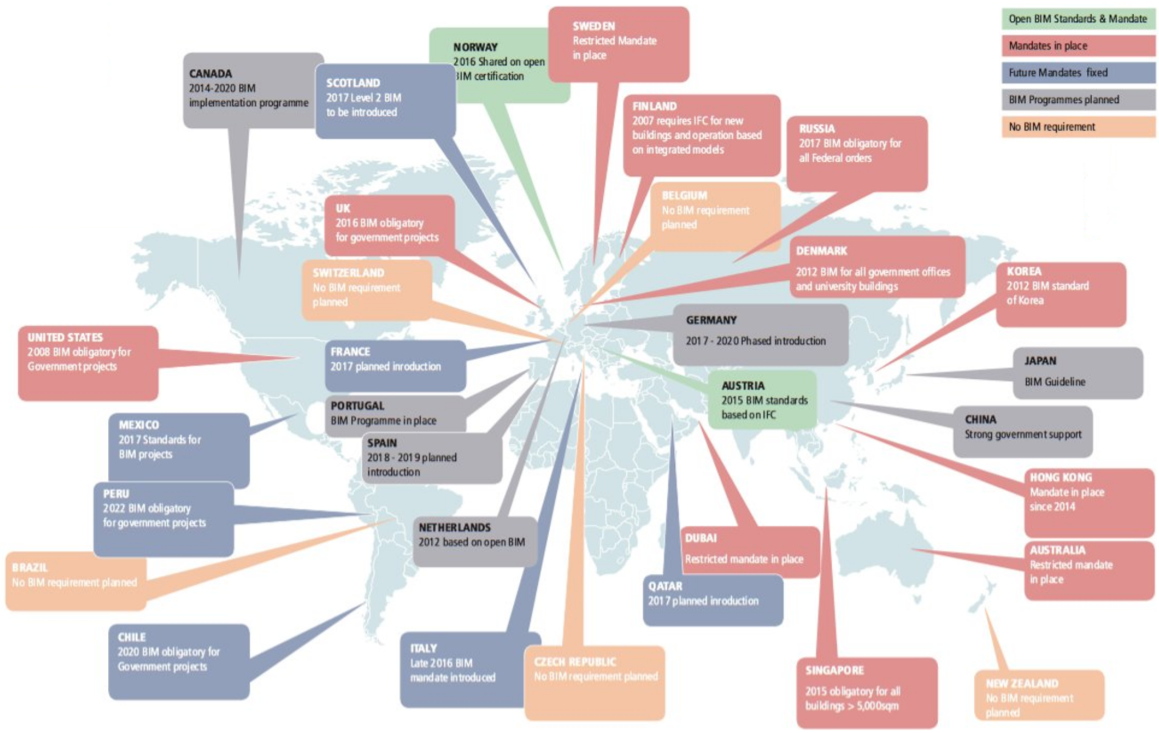

Figure 2.10. Global BIM Adoption (CITA, 2018).

2.8.12. BIM Adoption in Turkey

In Turkey, contribution of construction industry to the growth of the economy is very big and impactful. Construction industry has trigger effects on the so many other industries and it may results in decrease in the unemployment rate. To make the construction industry more efficient, application of new technologies by the Turkish construction companies is very important. If we look at the ENR 250, there are so many Turkish companies as number but the sum of the revenue of these Turkish companies' is still less than a company which is placed in top 10 of the ENR 250. Thanks to application of the new technologies, Turkish construction companies have become more efficient and advantageous according to other countries' companies. If we look at the strategy in the construction industry for Turkey, it can be said that, energy, infrastructure, urban generation projects are going to be more important. Turkish government aims to sustainable growth in the construction industry thanks to these types of projects. In these types of projects, if there are time, cost, quality problems related to lack of communication, the results of these problems may affect very negatively. Because of these, development and application of BIM in Turkey construction industry is inevitable.

In recent years, sustainability and green building concepts have become very important for Turkey. There are some many regulations and legislations about these concepts such as Energy Efficiency Law, Regulation of Energy Performance of Building and so on. Thanks to BIM, carbon footprint can be reduced, material qualities and LEED documents can be computed, and wastes can be reduced (Aktas *et al.*, 2015).

Özorhon and Karahan (2016) have examined the BIM applications and identified critical success factors. The aim of this study was measuring the effects of different factors on the success of the BIM applications. To find and measure these factors they have sent a survey to different companies in Turkish construction industry. According to this research, BIM is applied at most in building sector then office buildings and lastly industrial buildings in Turkish construction industry. Companies prefer BIM in the design and construction phase especially, however, in operation and maintenance phase BIM is not preferred so much. Another finding is related to BIM level. BIM users in Turkey usually prefer BIM Level 2.

Professionals who have more than 5 years' experience on BIM, choose working in a company that have more than 30 employees.

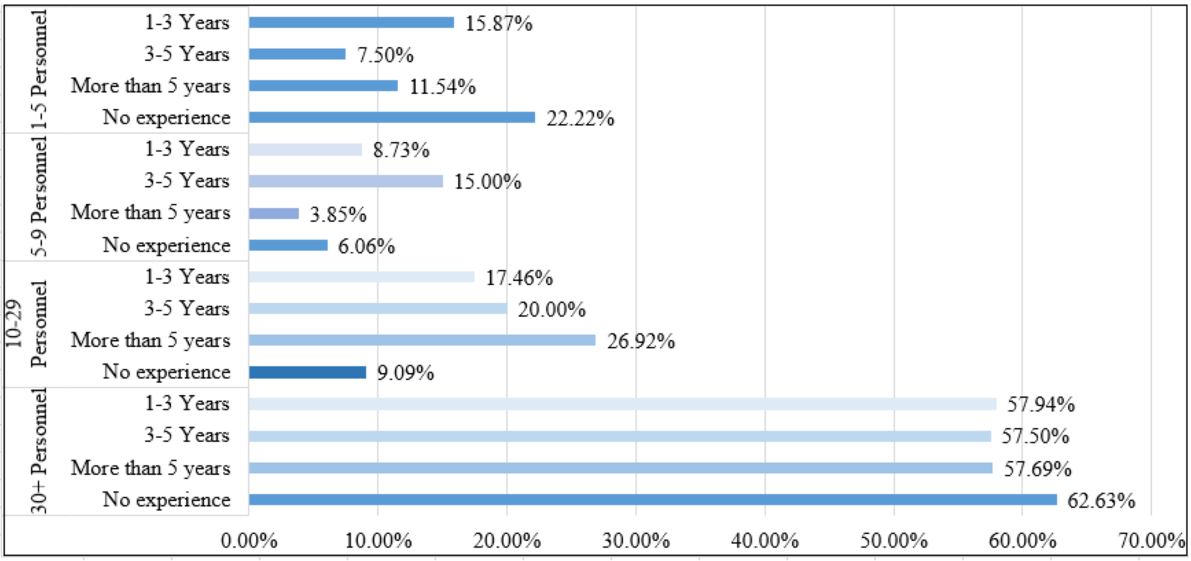

Figure 2.11. BIM Adoption by size of company and personnel experience (Bimgenius, 2018).

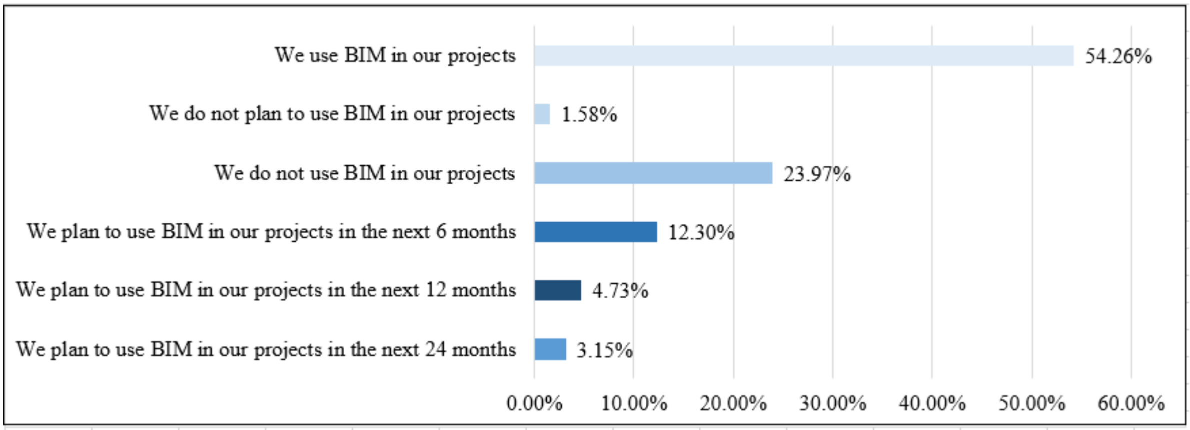

Figure 2.12. Percentage of BIM Usage (Bimgenius, 2018).

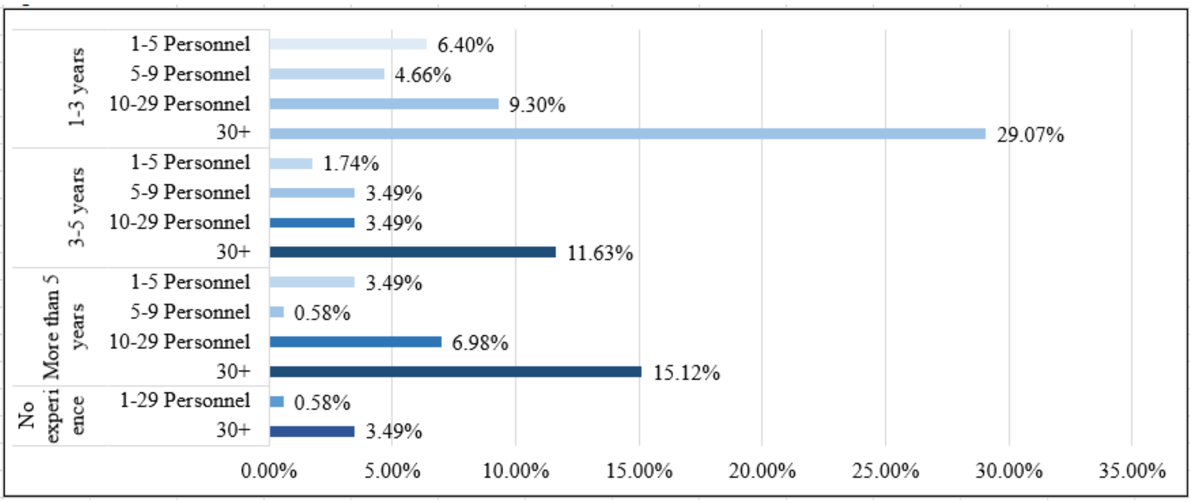

Figure 2.13. Relationship between BIM Usage and Institution Size (Bimgenius, 2018).

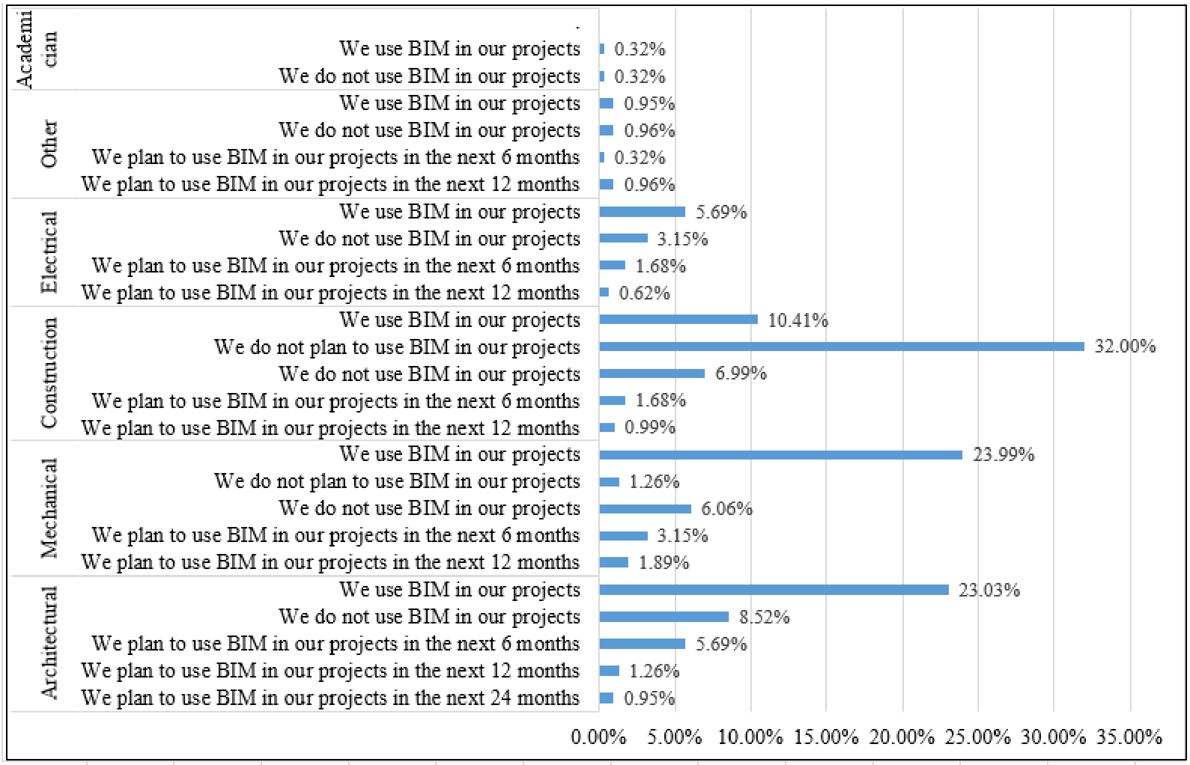

Figure 2.14. Disciplinary distribution of BIM Use (Bimgenius, 2018).

2.8.13. Future of BIM

In recent years, it can be said that BIM development has been the hot topic of the AEC industry and BIM is the future of the construction industry. There has been very big development in the application of the BIM to architectural area, however, still there is a requirement for development to make construction process easier. Choo *et al.* (2019) analyzed the trends in the BIM by utilizing from frequency analysis and topic modelling methods.

After the transition to Level 2, construction industry is going to have so many advantages thanks to BIM. Sharing information is going to be faster and easier. Thanks to this, productivity and efficiency in AEC industry are going to boost. If effective collaboration can be achieved, duration may decrease and new information may be edited easier. If productivity can be increased, it means reduction in the cost (Gao *et al.*, 2016).

Big data can be defined as data which cannot be handled by traditional ways or software and stored in a single machine. Big data cannot dealt properly, fit in a table, and there is a requirement for developed software to handle with these types of data. Data in the BIM gives an idea related to life cycle of BIM such as design, planning, construction, operation and so on. In our days, BIM is used especially for design, evaluation and retrofit. All information in the BIM are fitted into a scheme of the objects such as a Wall, Project, building and so on. This structure make collaboration and sharing easier. Thanks to future developments in BIM, Professional can handle with the big data easier. Working style of the Professional can be changed and become more efficient thanks to effective management of big data (Cobuilder, 2017).

One of the most important facts in the AEC industry is inefficiency in the projects. BIM is very important development for preventing this inefficiency. By utilizing from BIM, new markets which did not have a chance to obtain any tools can be opened and developed very soon. Thanks to advantages of BIM such as fully integration and efficient collaboration, these smaller markets may overcome the barriers which they face at the moment (Azhar, 2011).

Precise data can be obtained and by increasing the precision of data remarkable developments may be achieved in the buildings. More complex buildings that offer more comfortable living places to residents thanks to these developments can be designed and built (Department of Energy, 2015).

Clashes can be detected very easily. Clashes can be defined as the problems that can be face during the construction and design phases. By detecting the clashes thanks to BIM, efficiency in the industry can be increased (BIM United 2019).

There have been so many developments in 3D printing technology. As 3D printing technology develops, professionals in the AEC industry create objects in a very short duration and material waste can be minimized by this way too. It can be said that 3D printing is stretching of the 3D BIM. 3D objects can be produced and during this process digital folder in the BIM is used. Thanks to this technology, structure can be analyzed, then dynamic and efficiency of structure can also be predicted.

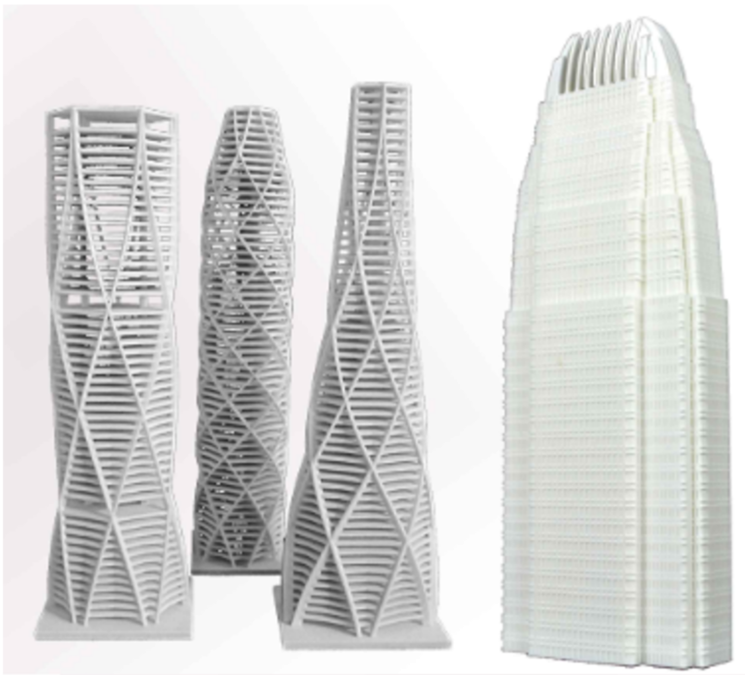

Figure 2.15. Use of BIM in 3D Printing (Piroozfar *et al.*, 2017).

Augmented reality and virtual reality are two of the biggest supporters of the BIM technology. Thanks to AR/VR technology, examining and understanding 3D models become very easy (Sampaio, 2018). In the future, AR/VR technology is going to enhance the BIM technology, because stakeholders wants to see and understand everything clearly in the every phases of the construction. This development is going to affect not only stakeholders but also customers. Because customers have a chance to see their houses before it is built (Piroozfar *et al.*, 2017).

Another expected technology in AEC industry about BIM is usage of drone. Project managers and consultants has started use drones in the construction projects to track and report the progress of the projects. Drones can track and store very big data in a very short time from very large area. BIM professionals can utilize from these data to make their model clear and by this way, their models become more reliable (Vacanas *et al.*, 2015).

2.9. Global BIM Standards

To achieve efficiency rate which is foreseen by BIM, there is a requirement for national and global standards. There is a requirement for well-coordinated approaches and systems. If coordination all around the world can be achieved, there is a success in the world wide. It should be understood that if BIM is going to be applied to all projects in the future, common standards should be adopted.

According to National British Institute, standards which are going to be developed should satisfy these requirements such as:

- Guidelines should direct industry to use BIM protocols which support collaborative design applications.
- Professional should achieve compatible product information which are integrable to project model and fit for purpose.
- Standards should include process changes which are required for all life cycle of a facility such as design, construction, and maintenance.
- It should assist in development of compliance control and development of analysis for performance of building design which is based on object base modeling.

Development of database and library is very important for the application of the BIM. UK government has announced that everyone can connect to their BIM Library for free. Achieving to BIM Library for free is very important development to obtain higher BIM application level.

Another important point for BIM standards is legal issues and protocols. There are so many users in BIM models and information which are included in the BIM models are very sensitive, because of these reasons there are some uncertainties statutory obligations. Although there are some attempts about this topic in some countries, there is a very long way to go. Concepts such as intellectual property right and ownership of data should be focused and investigated. American Institute of Architects has developed a protocol document as a legal model. This protocol links the parties in critical topics.

BIM development level is different in each country. Some of the countries have prepared guidelines and in these countries BIM usage is compulsory. Especially, in recent years, there are published guidelines in United Kingdom, USA, Singapore, Denmark and Finland.

2.9.1. BS1192

If the information about construction are prepared and coordinated very poorly, it results in time extension, and conflicts. So, BS 1192 is prepared to manage the production, distribution and increase the quality. It contains information related to AEC industry which are developed by using BIM systems.

Its first edition is published in 1990 and after that in 1998 second edition is published. Third edition is related to collaboration between the parties in the construction industry such as engineers, architects and so on. Third edition provides an application codes which can be applied to 2D and 3D model based information systems.

It is applicable for people who are responsible from the preparation of the construction information during the design, construction and operation phase. According to The British Standards Institutes, this standard is also applicable for BIM software developer. It provides common methods to create projects, identifying the responsibilities and classify the activities.

2.9.2. PAS 1192-2

Extended version of PAS is Publicly Available Specifications. PSA contains guidelines, application codes which are developed by some foundations and during the development process of PSA, guidelines of British Standards Institutions are followed. PAS 1192-2 specifies the delivery process.

2.9.3. PAS 1192-3

PAS 1192-3 specifies the information management for operational phase of construction projects by utilizing from BIM. It has been published in 2013 by British Standard Institutions and it was finalized in 2014. PAS 1192-3 based on the codes which were identified in 2007 and were related to collaborative production of architectural, engineering and construction information. It is the partner of PAS 1192-2. While PAS 1192-2 focuses on project delivery, this focuses on the operational phases which specifies the method for developing Asset Information Model. The operation facility may be usually very complex. PAS 1192-3 includes possible problems and solutions of these problems.

2.9.4. PAS 1192-4

This standard has been published by BSI in September 2014. PAS 1192-4 focuses on data transfer process. The original version of this standard is COBie UK 2012, however, it was turned into a BS. In 2011, usage of Level 2 BIM has become mandatory for construction projects. In level 2 BIM, there is a requirement for data exchange and PAS 1192-4 specifies the expectations in the data exchange process.

2.9.5. PAS 1192-5

This standard is published for developing models which focus on the security, digital built environment and smart asset management. It is published in 2 February 2015 for commenting by the British Standards Institute. In 23 May 2015, final version was launched to sector and it is developed by the Centre for the Protection of National Infrastructure (CPNI) and BIM Task Group's security working group.

According to introduction of this standard, understanding the problems and ways of controls which are developed for providing safety for assets that are developed digitally and major deficiencies in the security wall becomes easier with this PAS. The main purpose of this is sharing the information safely instead of preventing the collaboration about the BIM and asset management system (BIM Wiki, 2015).

2.9.6. PAS 1192-6

2.9.6.1. PAS 1192-6. 2018 is the latest version. Actually it might be called as a pre standard. It includes full scale list of key documents. This documents are appropriate to BIM techniques which are used in British construction industry. The main objective of this standard is accelerating the transition to Level 2 BIM. This standard focuses on BIM standards about especially health and safety of employee. Its complete name is "Specification for collaborative sharing and use of structured Health and Safety information using BIM which consists 66 pages". The main objective is integrating the HSE rules to the models (UK-BIM Alliance, 2019).

In PAS 1192-6:2018, there are some necessities which are required for sharing the information that are related to health and safety of the employee within the whole life cycle of the projects and assets. In addition to this, each development stages for construction is supported in this standard too.

The PAS provides guidance on how H&S information is produced, flows and can be used throughout the building's design, project management and asset lifecycle.

All information which are required for preventing the health and safety problems of employee might be involved in a single model, PAS 1192-6 includes some information such as participating risks, prioritizing highly risky activities, identifying hazards and so on.

<u>2.9.6.2. ISO 19650 Standard.</u> The introduction part of ISO 19650 mentions about fundamental concepts of project management. BIM serves as a new approach for managing the project where the data are transferred in every steps of construction such as procurement, design and construction. BIM offers an opportunity to manage data exchange and quality. Efficiency in design management can be increased with BIM. Part 1-2 of ISO 19650 is related to design and construction phases of projects. ISO 19650 is used by professionals who are interested in procurement, design, construction of assets and who are responsible from delivering asset management activities.

Part 1 includes concepts and principles for developing BIM processes in an agreement. In the figure below, general information management for operational assets and project delivery and relationship of these are represented. A represent the start of the delivery phase, B represents the phase with progressive development of the design intend model into a virtual construction model and lastly C is the end of the delivery phase.

Figure 2.16. Information management lifecycle as it relates to ISO standards, according to ISO 19650.

Part 2 tells the process for information delivery. This information delivery belongs to design and construction cycles which contains identification of tasks, roles and responsibilities. Process of delivery which is identified by ISO 19650 Part 2 is shown in the figure below.

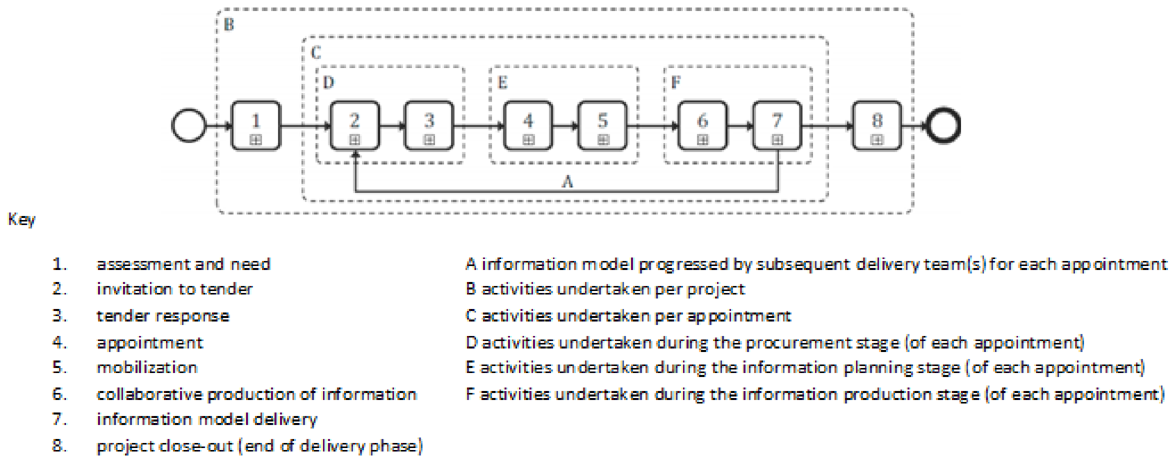

Figure 2.17. Information Delivery Process (International Organization for Standardization, 2018).

2.9.6.3. National BIM Standards (NBIMS). The main audience of NBIMS are software developers, vendors and designers, engineers, owners who implements practice documents. In addition to these, there are so many other standards which are used in other countries such as BIM-Guide for Germany in Germany, National BIM Guide in Australia, National BIM Standard in China, BIM Road Map in France, BIM Standards User Guides and Library Components for Contractors in Hong Kong, Guidelines for Architectural BIM Models in Japan and lastly BIM Guideline Standard in Malaysia.

3. RESEARCH METHODOLOGY

3.1. Introduction

In this chapter, the methodology for data collection and analysis of these data is introduced. To begin this study, reviewing the literature was one of the most significant phases of this research because the following studies uses the results of literature review as a base. If this part can be fictionalized very well, other parts is also going to be more sensible. At the beginning of the process of identification of the process, 50 papers are examined. Not all of them is useful for this study because of this, pre-evaluation phase was processed. After the pre-evaluation, appropriate papers, journals, etc are chosen and totally 41 resources are examined. 9 of them are eliminated because in these theses, BIM adoption are investigated from the perspective of contractors or architects. These might misguide the findings of the research because this research is focusing on the clients' perspective. Each examined paper focuses on different project types in different countries. Some barriers are chosen which are discussed in these sources. Details of the literature review are introduced in the Table 3.1, Table 3.2, and Table 3.3.

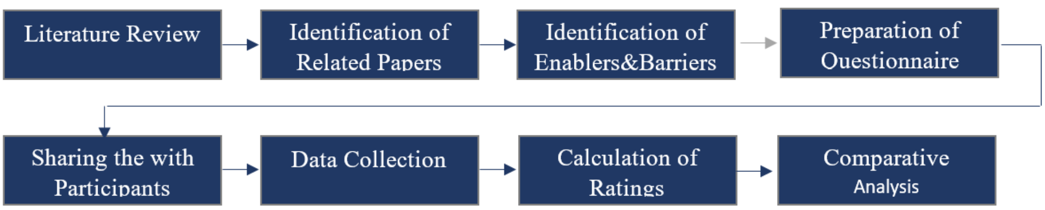

Figure 3.1. Process chart of methodology for the research.

After the selection of appropriate barriers and enablers are selected from the literature these barriers and enablers are asked to professionals from the industry by using appropriate data collection and analysis methods. The process of the methodology which is used for this research can be seen from Figure 3.1.

Table 3.1. Details of Reviewed Literature Sources.

Source	Country	Name of the Paper	Project Type	BIM Function	Data Colection	Data Analysis
1	Nigeria	Barriers to Building Information Modelling Adoption in Nigeria	-	-	Literature Review, Questionnaire	-
2	Iraq	Barriers of Adoption Building Information Modeling (BIM) in Construction Projects of Iraq	Buildings Projects, Infrastructure Projects	2D, 3D	Questionnaire	Central Tendency Measurement, Variability Measurement
3	China	Benefits of Building Information Modelling in the Project Lifecycle: Construction Projects in Asia	Expo Building, Finance Center	-	Case Study	-
4	Australia	Enablers and barriers of building information modelling (BIM) within South Australian construction organisations	-	-	Questionnaire	Mean Variance Analysis, RII
5	Ireland	Public / Private BIM: An Irish Perspective		3D	Literature Review, Questionnaire	
6	Palestin	Challenges to the Utilization of BIM in the Palestinian Construction Industry	-	-	Questionnaire	P-Value, RII
7	Hong Kong	Barriers of Implementing BIM in Construction Industry from the Designers? Perspective: A Hong Kong Experience	-	-	Questionnaire	-
8		Analysis of the adoption rate of Building Information Modeling [BIM] and its Return on Investment [ROI]			Literature Review	
9		Challenges with BIM Implementation: A Review of Literature			Literature Review	Content Analysis
10	Turkey	Challenges and Enablers in BIM-Enabled Digital Transformation in Mega Projects: The Istanbul New Airport Project Case Study	Airport		Case Study	
11	Sweden-Norway	Benefits and Barriers of BIM Implementation in Production Phase	Residential Complex	-	Questionnaire, Case Study	-
12	Finland	Challenges of implementing new technologies in the world of BIM ? Case study from construction engineering industry in Finland			Literature Review, Case Study	
13	Turkey	Building Information Modeling (BIM) Use in Turkish Construction Industry	-	-	Focus Group Discussion	RII
14	Germany	Potentials and Barriers for Implementing BIM in the German AEC	-	-	Questionnaire	-

Table 3.1. Details of Reviewed Literature Sources (cont.).

Source	Country	Name of the Paper	Project Type	BIM Function	Data Colection	Data Analysis
15		A. 2010 Challenges of Interoperable B. BIM in a between organization	-	3D	Literature Review, Questionnaire	-
16	UK	The Issues and Considerations Associated with BIM Integration	-	-	Questionnaire, Case Study	-
17		Benefits and Barriers to the Adoption of 4D Modeling for Site Health and Safety Management	Infrastructure	4D	Questionnaire	
18	Sweden-Denmark	Utilization of BIM from Early Design Stage to facilitate efficient FM Operations		7D	Case Study	
19	Malaysia	Examining the Challenge for the adoption of BIM in Malaysia from Clients' Perspective			Questionnaire	Rasch Analysis
20	Jordan	Barriers to the Adoption of Building Information Modeling in the Jordanian Building Industry		3D-7D	Literature Review, Questionnaire	
21	-	Critical Barriers to BIM Implementation in the AEC Industry	-	-	Questionnaire	Weighted Score
22	Iraq	Challenges and Obstacles of Adoption BIM Technology in the Construction Industry in Iraq			Questionnaire	
23	Mlaysia	Exploring the barriers and Driving Factors in Implementing BIM İN THE Malaysian Construction Industry		3D	Questionnaire	RII
24	Sweden	Building Information Modeling (BIM) Adoption Barriers: An Architectural Perspective		3D	Literature Review, Case Study	
25		Building Information Modelling(BIM): Benefits, risks and challenges	Aquarium Project	3D-4D-5D-6D-7D	Questionnaire, Case Study	
26	UK	Building Information Modeling Adoption: An Analysis of the Barriers to Implementation		3D-4D-5D	Survey	Mean Rank Analysis
27	Nigeria	What are the Barriers and Drivers Toward BIM Adoption in Nigeria			Questionnaire	Descriptive Statistics, RII
28	Libya	Barriers and Driving Factors for Implementing Building Information Modelling (BIM) in Libya	Residential,Industrial, Infrastructure	3D-4D-5D-6D-7D	Questionnaire	RII, Cronbach Coefficient, Pearson Correlation

Table 3.1. Details of Reviewed Literature Sources (cont.).

Source	Country	Name of the Paper	Project Type	BIM Function	Data Colection	Data Analysis
29	Sweden	Study of the implementation process of BIM in construction projects	Campus and Hospital Buildings	3D	Case Study	
30	Finland	Challenges of the expansive use of Building Information Modeling (BIM) in construction projects	School and Residential Projects	3D	Cultural-Historical Activity Theory	
31		Benefits and challenges of building information modeling according to participants of construction project	-	3D-4D	Questionnaire	
32	Fİnland	The challenges and potentials of utilizing building information modelling in facility management: the case of the Center for Properties and Facilities of the University of Helsinki	Library	7d	Case Study	
33	India	Drivers and Barriers to the Use of Building Information Modeling in India			Literature Review, Questionnaire	
34	India	Implementing Building Information Modeling (BIM) At AEC Firms in India		3D-4D-5D	Questionnaire	Inferential Statistics
35	China	Barriers to BIM implementation strategies in China		3D-4D	Literature Review	Comparative Analysis
36	Qatar	Barriers to BIM/4D Implementation in Qatar		4D	Questionnaire	Reliability Test, RII
37		BIM and 4D planning: a holistic study of the barriers and drivers to widespread adoption		4D	Literature Review, Case Study	
38	Malaysia	BIM in Malaysian construction industry: Status, advantages, barriers and strategies to enhance the implementation level		3D-4D-5D	Questionnaire	Average Index, RII
39	New Zealand	The benefits of, and barriers to, implementation of 5d BIM for quantity surveying in New Zealand		5D	Cross-sectional Survey	
40	Australia	Barriers to BIM adoption: Perceptions from Australian small and medium-sized enterprises		-	Questionnaire	Cronbach Correlation, Reliaility Test
41		BIM: Innovation in design management, influence and challenges of implementation		3D-4D	Questionnaire	

3.2. General Information about Data Collection and Analysis Methods

One of the most crucial parts of the research is data collection. There are two main types of data such as primary and secondary data. The type of data can be changed according to its closeness to the event. Primary data is a type of data which is observed, experienced or recorded. Written or published sources are defined as secondary data. The reliability of the secondary data is less than the reliability of the primary data. In Daily life, people record so much primary data from sounds, sights, tastes and so on. There are four types of primary data such as measurement, observation, interrogation, and participation. These types of data can be collected by measuring, recording events or situations by camera, recorder, etc. Consulting to the people's convictions or experiencing. If there is no primary data, it is very difficult to transmit the facts to other people (Kabir, 2016) Primary data may provide information about everything in Daily life. However, there is a requirement for so much time to collect primary data and it is not possible for every time. If data gets bigger, reliability of this data increases also, but organizing very big survey may be very expensive. Secondary data are recorded and published such as information in magazines, newspapers and Internet and so on. The source of the data and presentation form of data identify the quality. If secondary data are going to be used, quality should be reviewed. Data can be controlled by comparing the data from different sources, and if secondary data are going to be used, this is very important (Institute for Work and Health, 2015).

Data can be classified also into two main groups such as quantitative and qualitative data. If numbers are used to track the information about science, this is called quantitative data. If data can be described in words and it contains feelings, judgments etc, these types of data are called qualitative data. Quantitative data are measurable. Population, income, GDP are some examples of quantitative data. Examination, research notes, interviews are some examples of qualitative data.

If data is in the number format, quantitative analysis can be conducted. For choosing the best suited analysis, the levels of measurement such as nominal, ordinal, interval and ratio should be considered and the best method should be chosen. The main objectives of the quantitative analysis are measuring, making comparisons, examining relationships, making forecasts, testing hypotheses, controlling and explaining. So much quantitative data are collected by surveying, however, some of them may be originated from the examination of records. Excel of SPSS may be used for quantitative analysis. To manipulate and make changes in the data, they should be in a readable format. If they are arranged in the readable form, there may be a requirement for the extra arrangements. If the data cannot be read and understood by the machine, they should be loaded manually. Using columns and rows in excel is the most common way. Transferring the data phase is a very boring phase and there are usually mistake during this period. There are two main categories for quantitative analysis: parametric and non-parametric analysis. Descriptive and inferential analysis are examples of parametric analysis methods. Descriptive tests include some information about the shape of the model which shows how the values of a variable are handed out (Walliman, 2017). However, the inferential tests utilizes from an example that are related to a population. Parametric analysis can also be diversified according to the number of variables: univariate analysis, bivariate analysis and multivariate analysis. In univariate analysis, there is only one variable and descriptive test can be utilized in this analysis. In bivariates analysis, the relation between two variables is examined and an inference test can be used in this type of analysis. Thirdly, if there are more than two variables, to examine the relations between these variables, the multivariate analysis should be used. In multivariate analysis, multiple regression, logistic regression and elaboration analysis are used.

If the sample size is very small (less than 30), there are few assumptions about data, data types are ranked or nominal or source of the sample are different from each other non-parametric tests should be utilized. Qualitative analysis is based on the information and data which has Word form. The formats are not number. The main objective of qualitative methods is understanding the underlying reasons, opinions and so on. This type of research contains so many methods to collect the data such as case studies, interviews, focus groups and so on. These types of researches become stronger thanks to examining the topic in detail and using the experiences of the people instead of quantitative researches. Researchers have a clear vision about what is expected from a framework for quick revision with fresh information. Everything in this method such the success of research depends on the ability and knowledge of the researchers. Evaluating rigidity might be difficult and cause time consuming too. Creswell (2003) also talked about that the process of qualitative research is largely inductive, with the inquirer generating meaning from the data collected in the field. These types of researches may not be seen as acceptable among the researchers (Sharma, 2018).

Bromley (1986) has set 10 critical success factors for qualitative analysis.

- Clearly state the research issues or questions.
- Collect background information to help understand the relevant context, concepts and theories.
- Suggest several interpretations or answers to the research problems or questions based on this information.
- Use these to direct your search for evidence that might support or contradict these. Change the interpretations or answers if necessary.
- Continue looking for relevant evidence. Eliminate interpretations or answers that are contradicted, leaving, hopefully, one or more that are supported by the evidence.
- Cross examine' the quality and sources of the evidence to ensure accuracy and consistency.
- Carefully check the logic and validity of the arguments leading to your conclusions.
- Select the strongest case in the event of more than one possible conclusion.
- If appropriate, suggest a plan of action in the light of this.
- Prepare your report as an account of your research.

There are so many methods for collecting qualitative data. The first one is participant observation. This method is usually applied in sociology, anthropology and so on. Data are collected via observation. During the observation, sometimes, observer or researcher should be covered. Because the researcher is observing the community, and joins to this community. During the observation, if the community knows that they are watched by a researcher, results may not be true. Covering is one of the most important parts of this type of data collection. Another one is non-participant observation. It is usually applied in the empirical classes. Another type is shadowing which applicable for especially organization studies. In this type of data collection, the researcher move with a participant and this participant continues in his/her daily life. The researcher participates in meetings or appointments with the participants, listen to the calls, even the researcher stays with the participant continuously. The last one is the case study method for collecting qualitative data (Kawulich, 2005).

Table 3.2. Comparisons of Quantitative and Qualitative Analysis (Cropley, 2015).

	Quantitative Analysis	**Qualitative Analysis**
General Framework	· Seek to confirm hypotheses about phenomena · Instruments use more rigid style eliciting and categorizing responses to questions · Use highly structured methods such as questionnaires, surveys, and structured observations · Unstructured or semi-structured response options · Number-based · More generalized · Natural science model · Sample is large and can be generalized to cover the entire population	· Seek to explore phenomena · Instruments use more flexible, iterative style of eliciting and categorizing responses to questions · Use semi-structured methods such as in-depth interviews, focus groups, and participant observation · Fixed response options · More subjective · Less generalize · Human behavior model · Sample is small and non-representative of the entire population
Analytical Objectives	· To quantify variation · To predict casual relationships · To describe characteristics of a population	· To describe variations · To describe and explain relationships · To describe individual experiences · To describe group nırms
Question Format	· Closed ended	· Open-ended
Data Format	· Numerical (obtained by assigning numerical values to responses)	· Textual (obtained from audiotapes, videotapes, and field notes)
Flexibility in Study Design	· Study design is stable from beginning to end · Participant responses do not influence or determine how and which questions researchers ask next · Study design is subject to statistical assumptions and conditions	· Some aspects of the study are flexible (for example, the addition, exclusion or wording of particular nterview questions · Participant responses affect how and which questions researchers ask next · Study design is iterative, that is data collection and research questions are adjusted according to what is learned

3.3. Data Collection Method Applied in the Research

3.3.1. Definition of Case Study

There are so many different definitions for the case studies in literature. Yin (2014) defines the case study methodology as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context". Stake (1995) defines case study method as "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances". This definition tells what the case study focus on instead of how it is studied. Another definition is from Merriam (2009). The case study is "an in depth description and analysis of a bounded system" according to Merriam.

Table 3.3. Comparisons of Qualitative and Quantitative Analysis (Yin, 2003).

Strategy	**Research Question**	**Control of Events**	**Focus on Contemporary Events**
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How Many, How Much	No	Yes
Archive Analysis	Who, What, Where How Many, How Much	No No	Yes/No Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

Case study as in the modern days has started in the 1920s-1950s. At first, there was a thought that the case study method can provide limited validation. Then this method is developed by Glaser *et al.* (1967). The inductive methodology has started to use and in this method, a detailed systematic procedure is used. This interest for inductive methodology has led to the usage of case study methods in some other researches. The methodologic quality of case study has been increased thanks to Yin, by applying experimental logic to the social sciences and combining this with qualitative methods (Yin *et al.*, 2014).

The case study is very simple in theory but in the application phase, there may be so many different barriers. In our days, especially in education, research, health and social sciences, the case study is one of the most appropriate research methods. For searching especially complicated topics like the investigation of human behavior or social interactions, case study methodology is very useful (Harrison *et al.*, 2017).

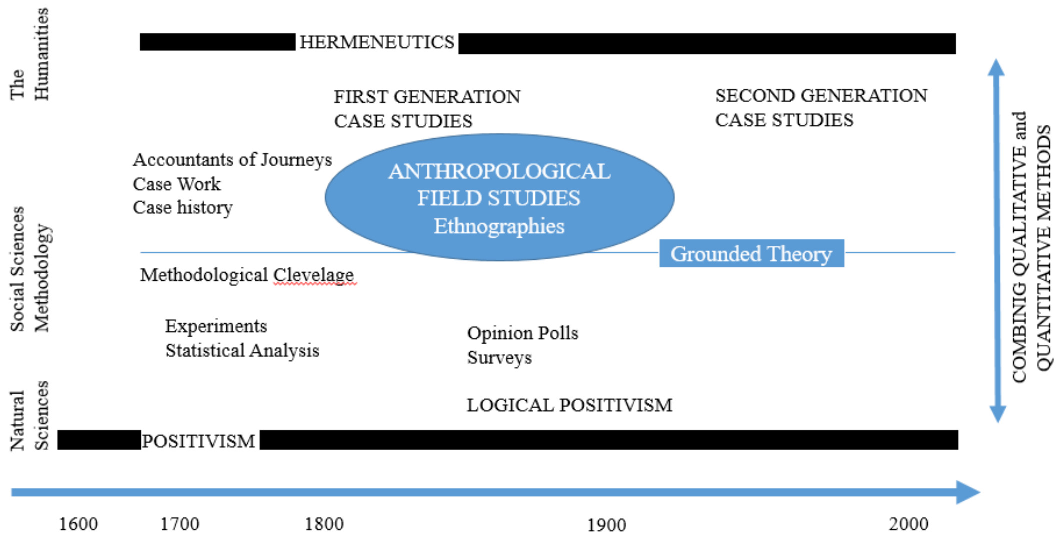

Figure 3.2. The history and evolution of case study research (Jojansson, 2003).

3.3.2. Design of Case Study

The case study method may be criticized because of the lack of robustness. To prevent these critics, the designing phase of this method is very crucial. Researchers may prefer single case design or multiple case designs. If there is no other case to use in the research, the researcher has to prefer a single case method. If the events are very rare, general results cannot be obtained by a single case study. To overcome this, the validity of the process should be controlled by triangulation. In the multiple case study, instead of sampling, by using the replication method real events can be utilized. If cases can be increased by replicating, some other information may be linked to the same theory and previous results can be achieved by this way (Hollweck *et al.*, 2015)

The proper case study should satisfy these conditions:

- Appropriateness to the research question
- Following the appropriate procedure
- The scientific rules should be followed
- The link between the study and theoretical framework

3.3.3. Categories of Case Study

According to Yin (1984), there are 3 main types of case study such as: exploratory, descriptive and explanatory. The exploratory case study is used by the researcher for searching for any phenomenon which is contained in the area of interest of the researcher. For instance, any researcher can ask some general questions like "Has a student use any strategy during the reading" or "How often" Thanks to these questions, the observed event can be examined more and more. This case study may be utilized before fieldwork and small scale data collection. This method may develop a framework of the study as a beginning.

Second is related to the identification studies for identifying the phenomena that occur within the data in the question. The aim of the researcher is to identify the data as in the real. The example of this is a description of the Watergate scandal by two journalists. The hardest part of the descriptive case study is starting with the descriptive theory which supports phenomena or the story. If this fails, there may be problems that occur during the project (Zainal, 2007). Pyecha (1998) made experiments on the special education children in the research. By using the replication method, so much data which were obtained from the different part of USA are compared and hypotheses were formulated. The main objective of using the descriptive method is used for investigating the depth and scope of the case.

In the explanatory case study, data is investigated closely to identify the events. For example, a researcher may ask a question like "Why do the student use a strategy to read". By regarding the data, the researcher may develop a theory and test this theory. In addition to this, explanatory may be used to examine the events in very complex cases. According to Yin (2003), this complex and multivariate cases can be identified by three theory: theory based on information, a problem solving theory and social interaction theory. According to knowledge-driven theory, commercial products are originated from the ideas and inventions of the fundamental researches. Similar concepts are valid for the problem solving theory too. However, according to this theory, products are results of external sources instead of the studies. On the contrary, according to social interaction theory, researches and users are communicating frequently because of the overlapping network of the professionals (Widdowson, 2011).

Table 3.4. Categories of Case Study.

Exploratory	**Descriptive**	**Explanatory**
· Become familiar with basic facts, settings and concerns	· Provide a detailed highly accurate Picture	· Test a theory's predictions or principle
· Create a general mental picture of conditions	· Locate new data that contradict past data	· Elaborate and enrich a theory's explanation
· Formulate and focus questions for future research	· Create a set of categories or classify types	· Extend a theory to new issues or topics
· Generate new ideas, conjectures or hypotheses	· Clarify a sequence of steps or stages	· Support or refuse an explanation or prediction
· Determine the feasibility of conducting research	· Documents as casual process or mechanism	· Link issues or topics with a general principle
· Develop techniques for measuring and locating future data	· Report on the background or context of a situation	· Determine which of a several explanation is best

3.3.4. Advantages of Case Studies

Cronin (2014) claims that case study is a very useful method for both quantitative and qualitative types of research and it is related to understanding and changes of complexities related to interpersonal processes. According to the research of Flyvbjerg (2006), the most important advantage of the case study method is closeness to the situation in the real world and it allows users to test the approaches. Lindvall (2017) claims that the case study provides very detailed analysis related to personal cases. Jacobsen (2002) tells that the case study is very strong in obtaining detailed and related data. So, it has internal validity and because of this, the results of the case study method are very valuable. By analyzing personal cases in detail, unexpected information can be obtained as a result. Thanks to these hypotheses, future researches may be restructured and because of this case studies are very good and efficient methods to develop very wide databases. The case study method is very applicable method for investigating the reasons of interrogations. According to Merriam (1998), if manipulation of variables are not possible during the investigation of current events, the case study method may be the most appropriate method. If there are more than two variables, it can be said that the case study is one of the strongest method. It also provides insight and illuminates meaning that expand the readers' experiences (Merriam, 2009). It is very good resource to obtain ideas about behavior of the people. It gives very good chances for innovation. Theoretical assumptions can be challenged by using case studies method for data collection. Insight that cannot be obtained in other methods can be given. Thease study simplifies the complex concepts. Analytical thinking, communication and developing tolerance to the different approaches is improved thanks to case study methods. It gives ability to people to defend their approaches.

3.3.5. Disadvantages of Case Studies

Flyvbjerg (2006) refers that theory, reliability and validity are polemical and using the case study as a research method is doubtful according to his study. Murphy (2014) claims that results and suggestions of the case study method cannot be approved or rejected because of the nature of the case study. In addition to these, Flyvjerg (2006) mentions about five disadvantages of case study method such as: results cannot be generalized from a case, theoretical information is more valuable than the practical ones, case study method is very useful for generating hypotheses while other methods are more useful for testing hypotheses, and summarizing the case study is more difficult than the others. Stake (1987) also claims that the most important disadvantage of the case study method is the lack of generalizability. Some of the researchers think that the case study is just a story telling because of its nature. According to Yin (2003), the case study method is just a pre-research method. Yin (2009) claims that another important problem of case study is lack of rigor. So it means that results of case study can be affected by suspicious evidence or biases. These result in the lack of rigor. In some case study researches, researchers play an interactive role instead of being acting at a distance or being an observer, and this affects the results of researches. Some expected results can be occurred because of these reasons and this causes questioning of the validity and reliability of the method. There is a requirement for a very long time to analyze the case studies because in the end of the data collection process, there may be very huge databases. Even characteristics and skills of the researcher affect the quality of information that acquired by the case study. For example some participants may be unwilling to share information and the researcher may be shy and this effects directly the quality of data. There is a requirement for a small sample size. It means that if there is a great variety of information, the case study method is very inefficient. Finding an appropriate case study for research topic may be difficult. There is no right answer in the case study and because of this, results cannot be validated (Christie *et al.*, 2000).

3.3.6. Requirements of Case Studies

As it is discussed in the previous part, the case study method is not considered as a scientific research method by some researchers because these researchers claim that bias of surveyor may affect the results of the case study and the case study method have the lack of rigor problem. If the case study can be designed properly, these problems may be resolved. Some criteria are identified to ignore these problems during the use of the case study such as: constructing validity, conformability, ınternal validity/credibility, external validity / transferability, and reliability / dependability.

Construct validity: This criterion provides enough operational precautions for concepts that are examined. So, it means that constructing validity tests compatibility between results after using of precautions and theories of the tests. If many resources are used, a chain of evidence is developed, construct validity can be achieved for case study method. Burgess (1984), Denzin (1978), Jorgensen (1989) and other researchers tell that using of multiple sources and data triangulation is a preferable method for construct validity. Hypothesis and structures which assist to generalize findings can be validated by using data triangulation. Providing systematic process during the meetings can become possible with protocols and interview guide. Subjectivity problems in the case study can be reduced by careful selection by the researchers, structured interview process and so on.

Conformability: If someone except the researcher can confirm that the research is completed as it is identified in the beginning of the process by the author, this means that conformability criteria for the case study are achieved. The fundamental method for achieving conformability is providing some evidence to other researchers. It can be possible by using cassette tapes, videos or notes taken in the interview. Thanks to this evidence, other researchers have a chance to understand the logic of the author (Chaouk *et al.*, 2019).

Internal validity/credibility: During the research some variables may have an impact on the variables. Identification of these causal relationships is defines as internal validity or credibility. However, qualitative methods are interested in creating a phenomenon that productive mechanism or causal power demonstratively instead of investigating the relationship between dependent and independent variables. So, the case study method is trying to find productive mechanisms that assist to identifications of findings that are related to real case experiences (Maxwell, 2004).

Techniques such as cross case analysis, pattern matching, expert peer review and so on, can be used for providing internal validity/ credibility. Also, distinguishing the units, linking the analysis or using pilot case studies may be identified as other techniques for providing internal validity or credibility. If there are related two events, and the third event which results in the other two related events, the relationship between these three events should be identified by the researcher. If the researcher fails to find the relationship between three events, it can be said that internal validity cannot be provided.

External validity/transferability: There is no generalization for the case study research. External validity can be defined as a problem of knowing whether the result of case study is generalizable or not. Positivist researches make generalizations however, in the case study, findings are generalized. This can be achieved by using multiple case study techniques and comparing evidences. There are so many methods for developing analytic generalization to provide replication logic and achieve external validity. Using case study database, cross cluster and cross case study are some of the techniques that can be used for achieving external validity (Tsang, 2014).

Reliability / dependability: Lastly, reliability or dependability is related to ability of the researchers for achieving same or similar result by following same methods. Reliability for the realism research assume that there is only on reality which is tracked repeatedly. On the contrary, different researches may collect some data about same topic by using different techniques within different time intervals. Because of this, there might be some differences between the different data sets. Therefore, to achieve reliability / dependability in case study research demands the enactment of case study procedures to identify a documentation trail. There are some case study methods which specify the techniques for collecting data, proper interview and developing a case study data base. Lastly, thanks to that, a case study database can be developed and other researchers can access to files. By this way, general integration of researches might be increased but creativity of the people might restrict reliability. For "creativity makes conformability path dependent and irreversible".

3.3.7. Development of the Research Framework

In the figure below, the framework is summarized by Ozorhon *et al.* (2013). According to this framework, main components are drivers, barriers, enablers, inputs, benefits and impacts. In shortly, drivers are main reasons for applications, inputs can be defined as resources, tools and strategies, barriers are general term for applications, enablers can be identified as the technique to overcome the barriers, benefits are project level outputs, while impacts are wider outputs. These are amplified in the following sections of the research. In this framework it can be understood that each component are linked with each other. For successful BIM implementation each of them should be identified properly.

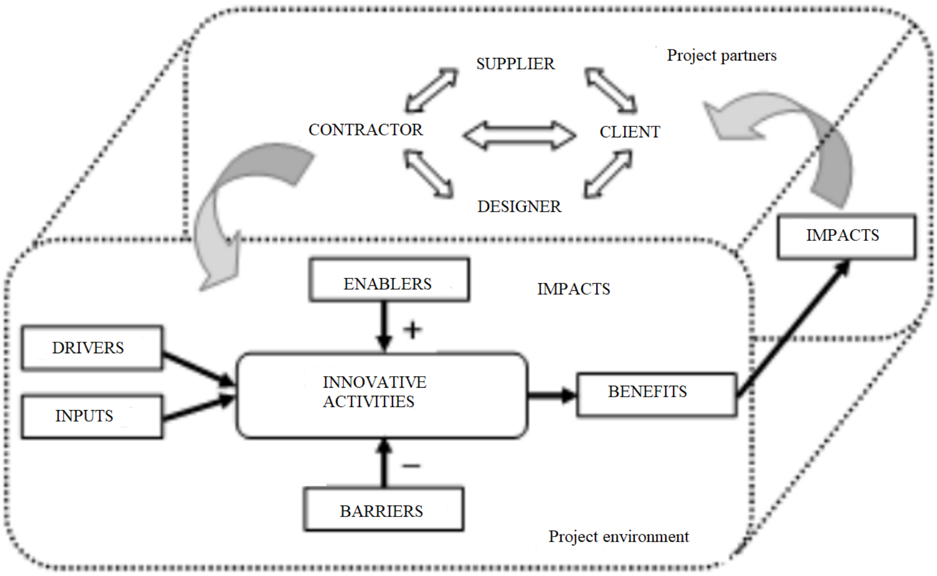

Figure 3.3. The Initial Framework Developed by Ozorhon (2013).

3.3.8. Description of Critical Success Factors

The definitions and details of the CSFs such as driver, enablers, barriers, inputs, benefits and impact can be seen in this section. The relationship between all of these factors can be seen from Figure 3.4.

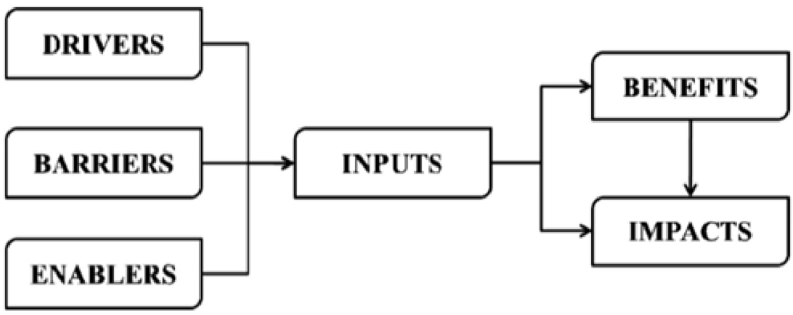

Figure 3.4. The Initial Framework Developed by Ozorhon (2013).

<u>3.3.8.1. Drivers.</u> Some examples of BIM drivers are listed below:

- Government pressure: For providing good examples of BIM implementation public sector publishes guidelines and documents about policies. In the UK, implementing Level 2 for BIM has become compulsory. In addition to the UK, Australian government has made using BIM in public projects compulsory since 2016. If BIM usage is supported by the government, it becomes more common and it is one of the most important drivers for BIM implementation (Geospatial World, 2018).

- Client/competitive pressure: There is a very big and hard competition in the construction industry. Recent developments such as economic depression all over the world, increase the competition in the industry. Only using and implementation of BIM is not enough but also it should be implemented successfully. In addition to these it has been understood that BIM implementation affects the efficiency in the projects in a positive manner and because of this clients expect usage of BIM project from their contractors and they also make contractual push about this (Hussain *et al.*, 2018).
- Improving the capacity to provide whole life value: BIM technology offers to ability of making environmental, energy, and cost analysis to users. Thanks to this, collaboration between stakeholders is very easy. Latham and Egan report tells the inefficiency in the construction industry and after 10 years there are some studies about waste reduction, efficiency improvements (Awad, 2015).
- Designing HSE activities: By using BIM, process and developments can be visualized before it is built. If this visualization is supported by the information from the construction site and HSE directives, it has very big contribution. Thanks to this, construction site may become safer for the workers. To reduce or mitigate the risks about HSE, construction activities may be simulated and tested. Results of these tests and simulation can be applied to real activities in the future (Park *et al.*, 2013).
- Improving communication: BIM offers an additional communication tool for parties. Showing when and how the building is going too constructed to even unqualified workers can improve the processes. Furthermore, globalization in the construction industry, there are so many foreign workers and to make the process clear for all workers in the site, visualization has become more important. Thanks to visualization, BIM promotes cooperation (Bust, 2008).

- Cost savings and monitoring: In 2D drawings, only one view of the building can be visualized. In some researchers proved that enough information cannot be provided in 2D drawings. This causes Requests for Information on the contractor side. RFIs causes delay in the project, also there may be cost overrun and there may be a requirement for a redesign. If all parties in the project implement BIM, the number of RFI can be reduced. This results in cost savings and monitoring. Although there may be so many problems that increase the cost, thanks to BIM implementation these problems can be identified in the earlier stages and can be prevented. BIM can make cost estimation for the changes in the design. In addition to this, BIM may consider some unexpected conditions such as weather, delay in other activities and so on, and calculate the cost regarding these conditions (Rezaei, 2018).
- Time savings: Duration is one of the most important criteria for the success of the project. In the construction process, there may be a requirement for scheduling, re-scheduling, cost and time estimation. If there is a change in design, there is a requirement for meeting with the design team. This process repeats until each party satisfies. Thanks to 5D BIM, project managers, contractors, designers and owners come together very quickly and solve the cost problems. According to research of Azhar *et al.* (2018), time required for creating an estimation of cost can be reduced by almost 80%.
- Accurate Construction Sequencing and Clash Detection: Detailed sequencing of the activities can be developed by the 4D BIM. Time savings can be possible with the efficient and effective scheduling. If projects stay behind the program, this delay effects almost all activities in the site such as procurement, manufacturing and so on. Proper scheduling results in time and money savings. 4D BIM offers ability to schedule oncoming activities and required time for these activities. Savings by 4D BIM decrease the conflicts between the parties. Clashes in the project can be detected by BIM. Azhar *et al.* (2011) also tells that clash detection results in time savings and cost savings also (Azhar, 2008).
- Improving built output quality: BIM using enhances design of the projects and these solution provides better quality and more profitable outlets for the clients (Azhar, 2011).

- Improving building's energy performance: 6D BIM offers an ability to make energy analyzes to users. Bad effects of the projects on the environment can be reduced thanks to BIM. Different scenarios can be simulated and an optimum way for energy efficiency can be chosen by BIM (Gao *et al.*, 2019).

3.3.8.2. Enablers.

- Strategic initiative enablers: During the implementation, BIM should be supported by the top managers. Top managers should be involved actively to do the implementation process. They should provide a valuable resources for this process such as time and human resources. Aims and objectives should be legitimized. Common vision and new responsibilities of employee should be conveyed to related people properly. Strategies for developing new systems should be identified clearly by the top managers. If there are resistance to change in transition process to the BIM, this resistance should be analyzed by the top managers and find appropriate solutions for these problems. They also should prepare work plan for identify strategic benefits, resources, costs and risks. There should be business model which shows required activities that tell the implementation efforts and reasons for investments. Business models make the implementation process easier (Abbasnejad *et al.*, 2016).
- Cultural readiness enablers: Effective communication is very important for the successful implementation of BIM. Expectations may be different for each party in the construction projects because of this, expectation must be identified by related parties. Mid-level managers should announce the importance of BIM. Objectives, activities and updates should be announced to the workers before they become real and changes should be interiorized. Business plans and how BIM is related to their jobs should be conveyed by effective communication. Effective communication can prevent resistance to change. If a communication program which tells what and how should be conveyed can be developed, the transition may be easier. After BIM implementation, results should be shared with the employee. This prevents the mistake which were experienced before. A

person who is powerful in identifying the objectives and managing the transition process should lead (Kjartansdottir *et al.*, 2017).

- Knowledge and learning enablers: Knowledge sharing and effective communication reduce uncertainties and risks. Information technology can make the sharing process easier. Creating a learning environment is very important for successful BIM implementation. Thanks to an employee can develop themselves and recognize their capabilities. If this environment can be offered to workers, they have no fear of failure and they are willing to take risks. BIM may become more efficient thanks to learning by experience (Almeida *et al.*, 2014).
- Network relationships enablers: Training is very important for the successful implication of BIM however it is not enough alone. During the implementation process, companies should investigate good examples and learn their techniques. The company which implements BIM should use consultancy, work with external vendors or develop R&D department (Liu *et al.*, 2017).
- Change management enablers: When there are big changes in an organization, people in this organization are afraid of the unknowns and they cannot recognize the requirement for changes. In some organizations, faults may not be tolerated and employees have to hide the mistakes. However, BIM gives chances for mistakes and provides a very comfortable working environment. Changing agents should be used because they facilitate the BIM implementation and by this way, the culture of the organization is strengthened and fear of the workers is eliminated. Users should be involved in the changing process and awarded. To make the environment safer, education program should be developed. After first implementation help desk should be developed to support the workers (Tanner, 2020).
- Process management enabler: Companies that implement BIM should enhance their BIM performance and process. Maturity assessment tools may be useful to evaluate the performance of BIM usage. Additionally, measurement metrics may be used for comparing. By this way, the company may utilize from the experience of other companies and the best practices (Abdirad, 2017).
- Global standardization may facilitate BIM implementation.

<u>3.3.8.3. Inputs.</u> Input means that all required resources for successful BIM implementation.

- Human Resources: This is the key factor for the successful BIM implementation. To achieve BIM implementation, the organization should appropriately use their human reosurces. The attitude and character of the leader, collaboration and communication between employees, qualification of the employee determine the success of the BIM (Yuan *et al.*, 2019).
- Software and Hardware: During the BIM implementation, choosing the appropriate software and hardware is very important. While software is determining, there should be no interoperability problem determined software and hardware for speaking the same technological language.
- Technological Infrastructure: During the usage of software and hardware, technological infrastructure of the companies should be sufficient.
- Well-Prepared Execution Plan: The execution plan should be prepared appropriately and clearly. If execution plan can be prepared very well, then each party in the project know how the BIM is implemented and their duties, by this way, there will not be any disruption (Lorek, 2018).
- Financial Resources: For BIM implementation, there are some required expenditures such as initial investment, cost of software, hardware and updates, training costs of the employee and some other costs. These costs are high and companies that want to implement BIM successfully should divide too much financial resources and budget for that (Migilinskas *et al.*, 2013).
- External Knowledge Consultancy: In BIM implementation, past experiences and case studies are very important. Some companies that want to implement BIM in their projects successfully may not have experience or knowledge. If a company does not have any experience, they should give external consultancy. Otherwise, they might be fail because of unexpected events during the implementation (Bui, 2018).
- Training and Education: This input is as important as others. Thanks to training and education, even the company's employees do not know about BIM, the company may enhance the knowledge of them.

- BIM Guideline: BIM is a relatively new concept and most of the companies do not know what they should do. Because of this, there is a requirement for a guideline that shows what the companies should do during the preparation and implementation process.

3.3.8.4. Barriers. The main objective of the study is to identify the barriers from the perspective of clients in developing countries. However, there are some barriers in the below to make the concept clear:

- Interoperability: This means the ability to data transfer between different BIM tools. If there is interoperability between different tools, users can transfer data from one tool to another without information loss. Interoperability problems cannot be solved completely because different BIM tools have been developed separately (Pniewski, 2011).
- High cost for Training & Software: There is a requirement for a high initial cost for setting up BIM tools. After BIM tools, the employee should be trained for using these tools. This is an additional cost for companies. Especially for small and medium scale companies, these costs can be seen as a redundant expenditure (Abubakar *et al.*, 2014).
- Unawareness of BIM benefits: Companies are not aware of the benefits of BIM and because of this reason, costs are considered as a redundant. Whereas, if companies understand the benefits of BIM, they are willing to use BIM in their projects (Ahmed *et al.*, 2013).
- Resistance to change: People cannot break the routines easily and they resist to change. Traditional methods in construction have been used for many years and they cannot quit using this traditional method. Because of this, the transition to BIM becomes more difficult (Abubakar *et al.*, 2014).
- Lack of experience and best example: In some countries, the application of BIM has developed a lot, however, the maximum level of BIM implementation cannot be achieved all around the world. Because of this, there is no best use of BIM. Also, implementation of BIM in the AEC industry is the relatively new concept.

Because of this, companies still have not gained experience in this area (Abubakar *et al.*, 2014).

- Lack of guidance: In addition to experience and best example, there is a requirement for complete guidance. Some countries have prepared their own guidance but still there are not best guidance and companies cannot apply the BIM implementation properly. As guidance is published by developed countries, BIM implementation increases (Ali, 2019).
- Lack of qualified personnel: Human is one of the most important resources of the companies for successful BIM implementation. On the other hand, BIM is a very new concept and because of this finding experienced personnel is very difficult (Sawhney *et al.*, 2015).
- Lack of collaboration in the construction industry: The nature of the construction industry is fragmented because there are so many parties which are involved in the construction projects. BIM implementation should be interiorized by each of them for the implementation of BIM to project successfully. However, in our days this cannot be achieved completely (Sawhney *et al.*, 2015).
- Lack of Governmental Support: In some countries, BIM implementation has become compulsory but the number of countries that mandate BIM implementation is very few. Because of this companies are not willing to use BIM tools. As it becomes mandatory, number of BIM implemented projects increases (Chan, 2014).

3.3.8.5. Benefits.

- Better Collaboration and Communication: BIM models allow users to share information, provide collaboration. Cloud provides project management functionality. There are some tools for coordinating the integration and sharing of complex project models. Every party have a chance to add some functions to model and thanks to this, in the end, the model is ready for use (Autodesk, 2018).
- Maintain control: There some features like auto-saving and connections to project history that support users. Thanks to this, the user can prevent information loss or corruption in the files.

- Preventing Time and Money Waste: There is fewer requirement for redesign and duplication of works ıf BIM is used. Model has more information than the drawing sets. BIM tools are faster than the 2D drawing tools and each object is related to the database. Thank this relation, if there are some changes in an object, related objects are updated automatically. These result in time and cost savings (Autodesk, 2018).
- Simulation and visualization: Another advantage of BIM is simulation and visualization. In different seasons, a designer can simulate the sunshine and calculate energy performance of the building. Users can make analysis and develop models very easily (Autodesk, 2018).
- Resolve Conflict: BIM tools can identify conflicts and clashes. By modeling these elements, clashes can be detected in the earlier phases and costs can be reduced. Thanks to the developed model, objects can be assembled perfectly and easily bolted in the site (Autodesk, 2018).
- Sequencing Steps: For a more efficient construction process, the sequencing of resources and teams can be coordinated. Model is completed with the simulation and these models offers a way to facilitate the coordination of activities (Autodesk, 2018).
- Detailing: BIM models provide an efficient environment for information sharing. In traditional models, each detail cannot be seen but BIM gives a chance to monitor every detail. Thanks to automation and customization, users can save time (Fadeyi, 2017).
- Safer Construction Sites: Hazards can be identified thanks to BIM models before they occur. Thanks to this, the construction site is safer. Risks can be mitigated by visualizing the site logistically. Visual risk analysis and security evaluation may be a useful method for providing health and safety (Burger, 2018).
- Better Builds: Reliability of models provides high quality in buildings. Thanks to common BIM tools, designers can work with engineers and they control the technical decisions better. The methods for construction can be tested in the beginning of the project and the best one can be chosen and structural deficiencies can be detected. Better design aesthetics such as lightening with sunlight can be chosen. Capturing reality technology can be utilized during construction.

- Stronger Facility Management and Building Handover: The information in the model is useful for the operation of the structure and after completion it provides a better return on investment. Especially after 7th dimension of BIM, tools are very useful for the whole life cycle of a building. BIM information which are developed during the design and construction phase can be connected to building operations and by this way, contractors can change building handover (Wang *et al.*, 2014).
- Improved Staff Performance: Performance of employees is a very critical factor for success of projects. This process effective decision process, a better procurement process and a better understanding of the scope of the project.
- Project Management Benefits: As it is discussed in the previous parts, RFIs by contractor side results in delays in the projects. By BIM usage, number of RFIs can be reduced, and solutions for RFIs can be found easily (Hughes *et al.*, 2013),
- Improve Energy Savings: Thanks to the 6th dimension of BIM, energy analysis can be made before construction starts. Each alternative can be evaluated and the best option is chosen.

<u>3.3.8.6. Impacts.</u> While the benefits describe the short term gains of the implementer, impacts mean medium-long term gains of BIM for the implementer.

- Better Financial Performance of Company: As a return on investment for project increases, the financial condition of the company also increases after BIM adoption (Walasek *et al.*, 2017).
- Increasing Productivity: Thanks to BIM implementation, processes become more efficient and there is no time consuming. By this way, the company that implements BIM into their processes increase their productivity. For example, the duration of the projects might become shorter (Migilinskas *et al.*, 2013).
- Developing Organizational Memory: In the BIM usage every information can be tracked. Thanks to this, this information becomes available for future using and the company may not make the same mistakes in the previous projects.
- Ease of administration: Information management can become easier with BIM

usage. All information may become accessible too (De Wilde *et al.*, 2019).

3.3.9. Questionnaire for Case Study

In this research, as it is discussed in the previous parts, the case study method is utilized and during the data collection process, the interview is made with different participants. For interview, there is a questionnaire which is conducted to professionals from the industry. According to the framework which is told in the previous section, this questionnaire is developed for the case study participants have evaluated and answered the questions in the form specific to projects. The questionnaire has 3 parts. In the first part, general information about participants, companies and projects. These questions are asked to understand structures of the companies and projects. Some information which is asked in the first part are listed below:

- Participant's profession
- Experience of participants
- Company's expertise area
- BIM experience of the company
- Project's type
- Project's ownership
- Project's construction area
- Budget of projects
- Project's duration
- The total amount of BIM Investment
- Number of Employee Working in Company and in BIM Team

In the second part, evaluation of the barriers which are resulted from the literature review part was expected from the participants by using Likert scale. The barriers are listed in the Table 3.8. Similarly, in the third part of the interview form, participants have evaluated the enablers for BIM applications by utilizing from a Likert Scale too and these enablers are shown in the Table 3.9 too. As it is mentioned in the section 3.3.8, 1 can be considered as lowest important and 5 can be considered as highly important for BIM application in the projects. Participants have evaluated according to this. There are three parts in the both second and third parts of the interview. Because, enablers and barriers are divided according to their relations such as ındustry specific barriers/enablers, company specific barriers/enablers, and project specific barriers/enablers.

An example of the case study form that has been followed during the face to face interviews can be found in the Interview Form.

Table 3.5. Summary of Identified Barriers from the Literature Review.

Barriers **Source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
Low awareness of BIM	+	+				+	+			+	+	+	+			+	+		+	+		+	+				+	+	+				+		+	+	+	+		+	+
Lack of interoperability between BIM Softwares		+		+			+	+	+				+	+					+		+		+	+					+	+				+	+	+			+		
High complexity of BIM							+		+			+		+					+					+									+		+	+	+	+			
Unfavourable economic conditions																												+													
High fragmented nature of industry	+										+		+															+	+										+		
Resistance to change	+					+		+					+		+	+	+	+	+	+							+	+	+						+	+	+		+	+	+
Lack of transparency	+																																								
Unavailability of knowledge		+		+	+				+	+	+	+	+		+		+	+		+			+						+												
Legal uncertainties /restrictions	+	+					+	+	+		+	+	+		+	+		+	+		+		+		+	+	+	+	+						+	+	+				+
Lack of guidance	+	+		+		+	+		+			+	+						+	+	+		+				+								+	+			+	+	
Difficulty in choosing appropriate contractor																																									
Lack of government support	+	+					+			+		+								+							+	+						+							
Unavailability of financial resources																												+													
High Costs	+	+		+	+		+		+	+		+	+	+		+	+		+	+	+	+	+	+		+							+	+	+	+	+	+	+	+	+
Lack of resources	+	+		+	+	+	+		+	+		+	+		+			+	+	+	+		+	+			+	+	+	+			+		+	+	+	+		+	
Unwillingness of people in the company to change	+	+													+		+					+				+							+	+			+		+	+	
Managerial inefficiencies														+																											
Unsupportive organzational culture	+												+						+			+				+							+				+		+		
Unclear project benefits																																			+	+					
Project complexity										+					+			+	+										+											+	
Lack of collaboration		+		+			+	+	+		+		+				+		+						+									+			+				
Conflicting interests of parties																													+												

Table 3.5. Summary of Identified Enablers from the Literature Reviewc (cont.).

Barriers **Source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**
Availability of knowledge	+	+							+				+		+					+	+	+		+	+	+	+		+		+				
Clear advantage and ease of use						+	+					+		+				+										+			+	+		+	
Availability of technological infrastructure	+	+					+	+		+	+	+	+		+	+	+		+		+						+	+							
External incentives and promotions		+	+	+	+		+	+	+	+	+	+	+		+				+		+	+		+	+	+			+					+	
Open Standards for BIM and National Library for BIM					+					+	+		+		+			+								+	+				+	+		+	+
Developed legislative regulations							+		+	+			+	+	+			+	+	+		+									+	+		+	+
Improved technical and technological abilities				+	+		+		+	+	+		+	+				+	+	+	+				+	+		+						+	+
High managerial ability		+				+	+		+			+	+	+	+					+															
High analysis ability and positive attitude of company		+					+					+			+				+					+	+	+									
High qualified human resources							+		+			+			+		+			+	+				+	+								+	
Strong financial resources												+	+		+				+						+										
Efficient training methods																		+	+	+		+				+	+	+	+		+	+		+	+
Positive attitude of managers	+	+					+	+						+	+		+	+	+	+	+	+			+		+		+					+	+
Readiness of organization to change		+	+				+		+		+	+	+	+	+		+	+		+	+	+			+		+					+		+	+
Well-organized Bım maturity plan		+		+	+												+			+							+					+			
Well prepared project BIM execution plan							+			+	+				+			+		+		+												+	+
Demand/ Satisfaction of Client	+							+	+			+	+	+	+		+				+	+		+	+	+	+		+					+	+
High project level collaboration	+	+		+	+				+			+	+		+	+		+		+	+	+			+	+	+	+			+	+		+	
Collaborative working		+																+									+								

3.4. Analysis Method Applied in the Research

3.4.0.1. Likert Scale. In this research, respondents evaluated barriers for BIM application on 1-5 Likert Scale. Likert scale is one of the best techniques for the evaluation of qualitative data.

The Likert scale has developed in 1932 by Rensis Likert. Likert scale is a technique which is a psychometric scale applying in the questionnaires. It can be defined as also some kind of rating system. In the Likert system, respondents asseses a quantitative value to any kind of objective or subjective dimension. If the Likert scale is designed properly, the items in the Likert are both symmetric and in balance. Symmetry means that items include equal numbers of positive or negative positions according to neutral or zero value. Balance means that the distance between each candidate value is the same. Thanks to this, quantitative comparisons can be made. Using five choices is a very common method, but in some researches seven or nine choices can be used too. In a five-level Likert scale, levels in the below can be used:

- Strongly disagree
- Disagree
- Neither agree or disagree
- Agree
- Strongly agree

In the analysis part, each question can be evaluated separately or items can be summed and evaluated with this way. Because of this, the Likert Scale can be named as summative scales also.

In the Likert Scale, "yes" or "no" answer is not accepted, instead of this, participants can identify degrees of opinions. Hence, qualitative data can be transformed into quantitative data and analysis become easier.

Likert scale is a measurement technique that measures positive and negative answers. Sometimes "neither agree nor disagree" is not used. In that case, the even-point scale is utilized. If the participant is not sure, a neutral option is chosen. Because of this, it should be questioned whether it is a neutral option or not. This is the blind side of the Likert Scale.

As it is mentioned, in the last part of the interview, evaluation of the barriers from 1-5 as a Likert Scale is requested. To find the most important barriers from the client's perspective, this part is one of the most important parts of the interview. If a respondent thinks that a related barrier or enabler is less important than the other, 1 is assigned to related barriers; if a respondent thinks that a related barrier or enabler is more important than the other, 5 is assigned. The rating system's definition is shown in the table below.

Table 3.6. Meaning of Ratings in Likert Scale.

Ratings	**Meanings of the Ratings**
1	Insignificant
2	Less significant
3	Moderate significant
4	Significant
5	Very significant

3.4.0.2. Analysis Method. As it is discussed in the previous section, professionals identify the significance of the variables by using the scale from 1 to 5. Because the Likert scale is used in this research, the type of the data is quantitative because of this analysis method should be chosen according to data type. After evaluation of the enablers' and barriers' significance by the professionals according to the Likert Scale, the minimum and maximum values are determined for each variable. In addition to this, the average of these ratings is calculated. These calculations can be made for different discussion topics. For example, minimum, maximum and average ratings are determined with respect to project types, influence level of the barriers and enablers. Additionally, maximum, minimum and average ratings that are assigned by professionals are investigated variable specific. So, for each variable which is determined according to the literature review, minimum, maximum and average ratings are calculated. By looking at these values, it can be determined that which variable is very important for specific project type or which variable is not important for specific project type. In addition to this, it can be understood that which influence level of the barriers or enablers is most effective upon specific project types. This analysis method is important because thanks to this methods, by using the data from Likert Scale, so many inferences can be made about the importance of the barriers and enablers with respect to project types.

4. FINDINGS

In this chapter, firstly, general findings about the profile of the participants, general information about their companies and projects are introduced. After that, minimum, maximum and average ratings which are assigned for enablers and barriers by the professionals are also included in this chapter. These ratings are calculated and demonstrated according to different criteria.

4.1. General Findings about Participants' Profile

4.1.1. Interviewers' Profile

During the selection of the participants, the most important point is selection from the different disciplines. If homogeneity of participants can be achieved, validity of the results can be increased too much. Because of this, selection of the participants is one of the most important part of research.

To collect data, face-to-face interview is made with 31 professionals from 10 companies and 18 projects. The biggest part of the participants are civil engineer. However, as it can be seen from the Figure 4.1, there are some professionals from other disciplines except civil engineering such as architect, electrical engineer, mechanical engineer, survey engineer, and so on.

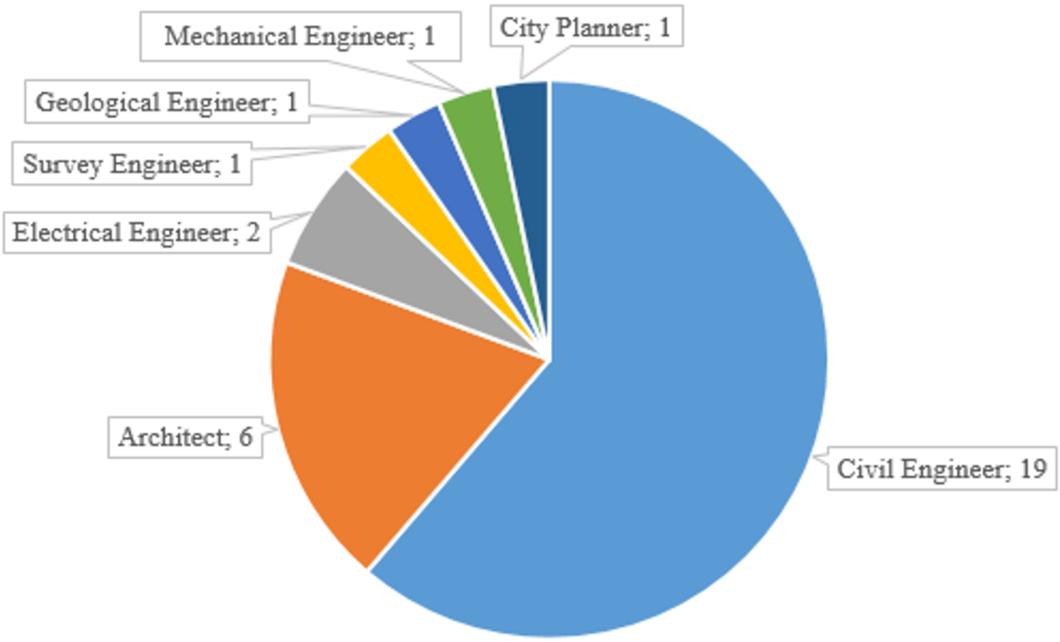

Figure 4.1. Major Disciplines of the Participants.

Positions of the participants can be examined from the Figure 4.2. As it can be seen from the figure, the biggest part of the participants are engineer and project chief. This interview has been conducted to professionals in the public client companies. Because of this, number of BIM expert is only one.

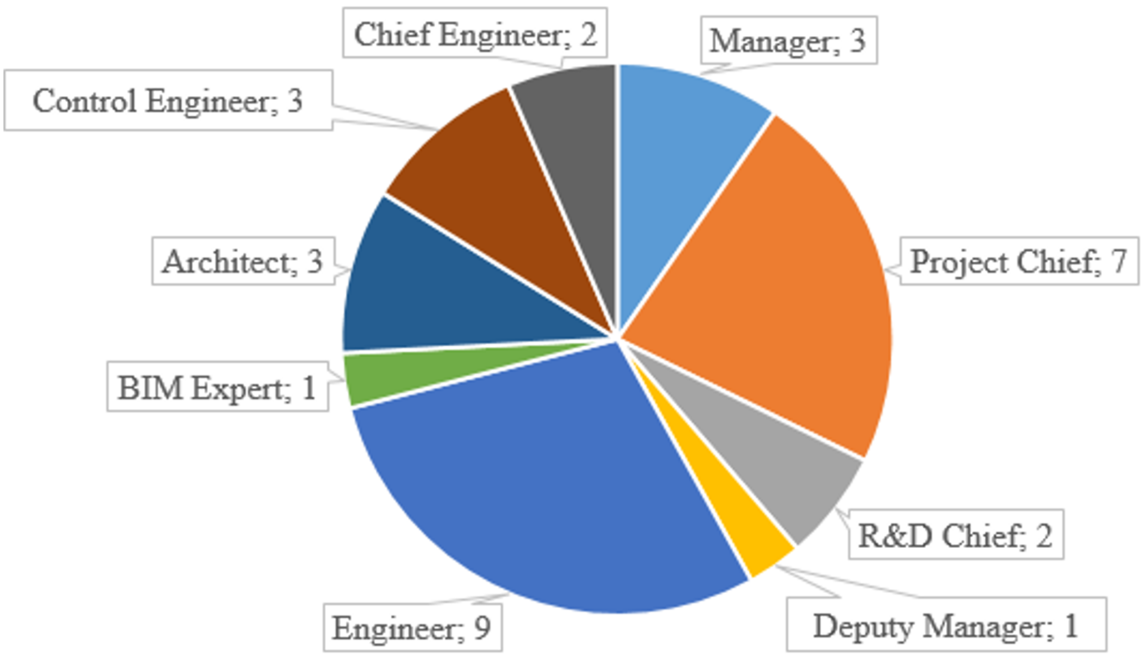

Figure 4.2. Current Positions of the Interviewers.

Experience level of participants can be seen in the Figure 4.3. BIM is very new concept in the construction industry respectively. Because of this, most of participants have experience less than 15 years. Very small number of them have experience more than 21 years. In addition to these, it can be said that, range of experience level of participants is very wide and this enables collecting data from different perspectives.

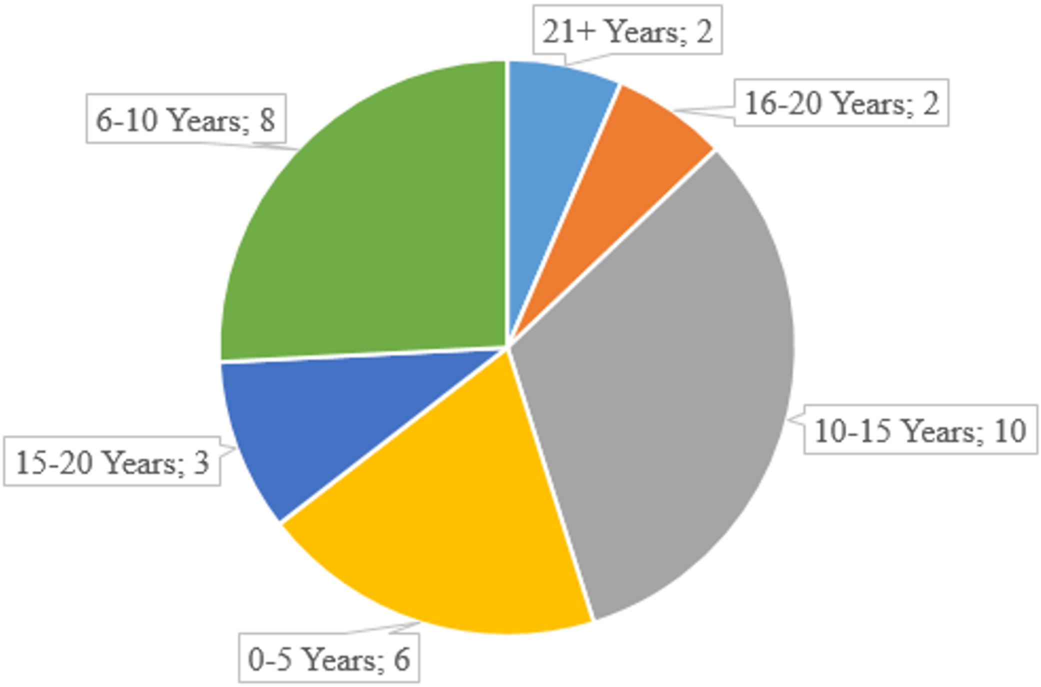

Figure 4.3. Experience Level of the Interviewers.

4.1.2. Companies' Profile

In this research, the interview has been conducted to 11 companies, as it is mentioned before. Each company has different number of employee, field of operation, expertise area and so on. Application area and software which are used by these companies are differentiate from company to another. Different features of the companies can be seen from the following figures.

As field of operations of the companies differentiates, their expertise areas also differentiates. Almost all of the companies which have been conducted in this research have different expertise areas. Some of them are related to road projects, one of them is related to airport and there are also some other countries which are related to other types of projects such as dam, natural gas pipelines, refinery and so on. The variety of the types of projects is also important because each of them have their own features and usage of BIM software may show alternate from a project type to another.

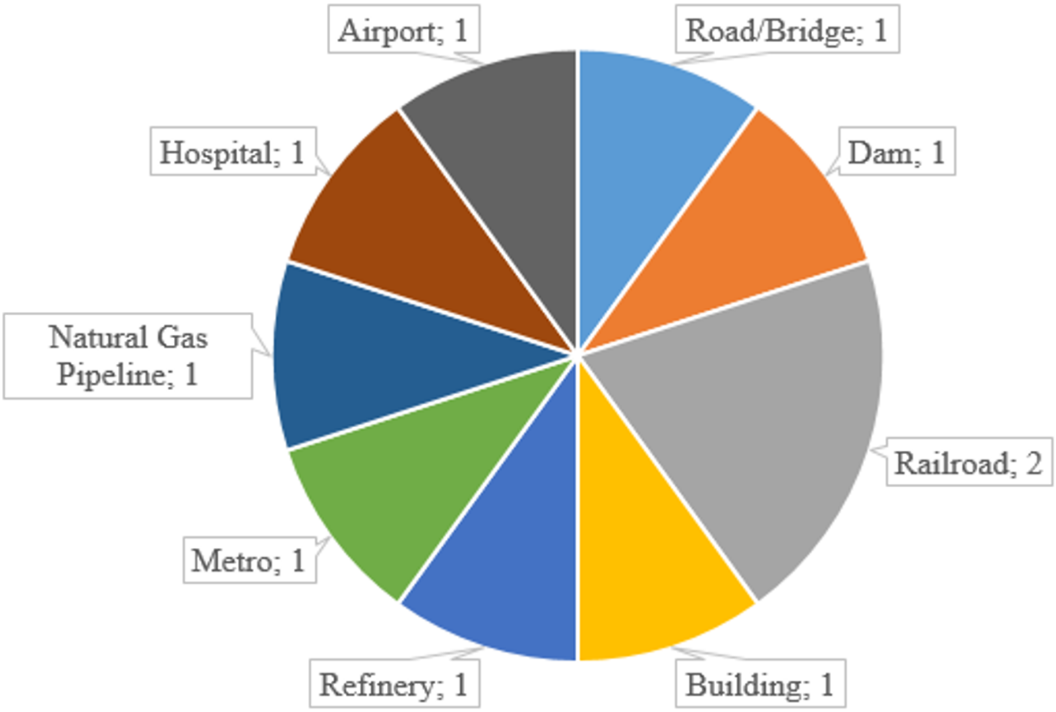

Figure 4.4. Expertise Areas of the Companies.

Another criterion for the companies which are involved to this research is their number of employee. The number of employee is very important indicator for understanding the size of the company. Sizes of the companies have very wide range again, their number of employee changes from 140 employee to 23.000 employee. The distribution of the companies according to their number of employee can be seen in the Figure 4.5.

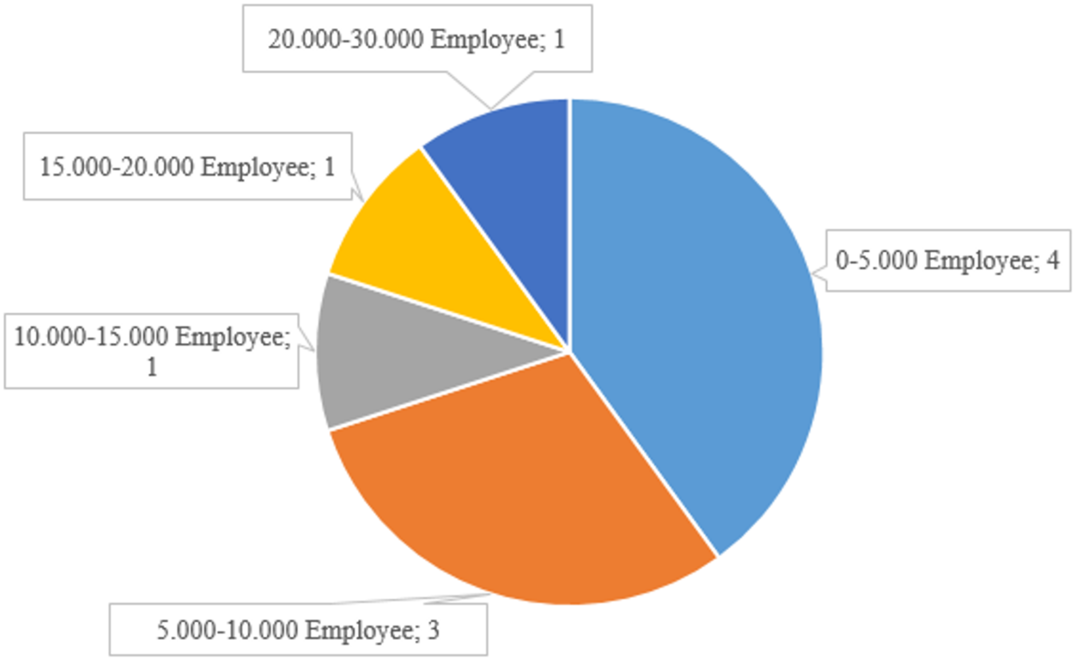

Figure 4.5. Number of Employee of the Companies.

The companies that have been conducted in the research are public clients. Many of them have been established so many years ago. They are very experienced companies in their field of operations and they have completed so many projects for years. The maturity of the BIM application shows variety according to year of the companies. Years of the companies can be examined from the Figure 4.6.

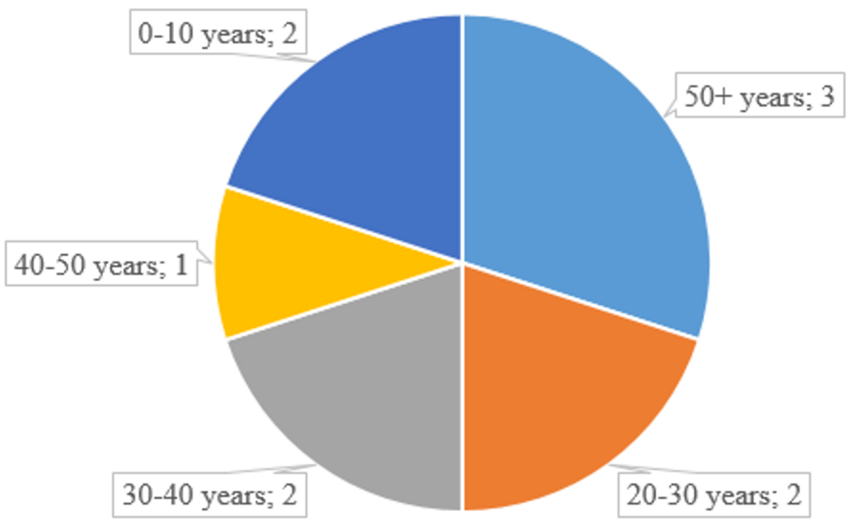

Figure 4.6. Age of the Companies.

The variety of the companies according to number of completed projects can be seen from the Figure 4.7. This is another important criteria for this research because thanks to this statistics, the importance of the experience in the projects for the BIM application can be investigated. The range of the number of completed project by different companies is very wide. Some of them have completed 1-10 projects, some of them 11-50 projects, 50-100 projects, even more than 100 projects.

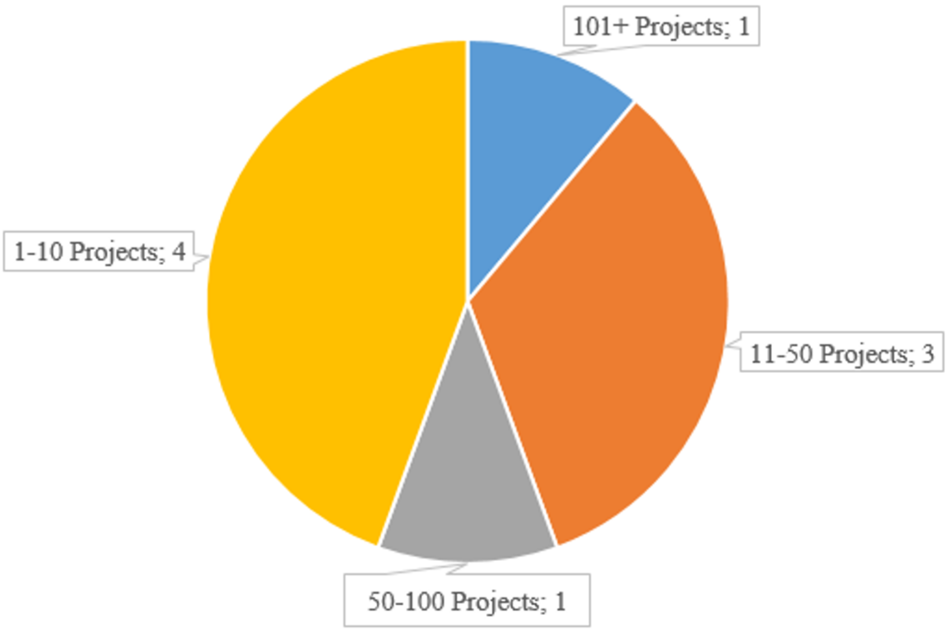

Figure 4.7. Number of Completed Projects by the Companies.

4.1.3. Case Projects' Profile

In this part, there are some information about the case projects which the questions are conducted to professionals about. For this research, 31 professionals have been interviewed for 18 projects. The starting years of the projects can be seen from the Figure 4.8. Some projects are very old, even the starting point of the projects are before the BIM concept. However, these projects are mega structures and their planned durations are very long. Because of this, in the following steps of these projects, BIM has been started to be used.

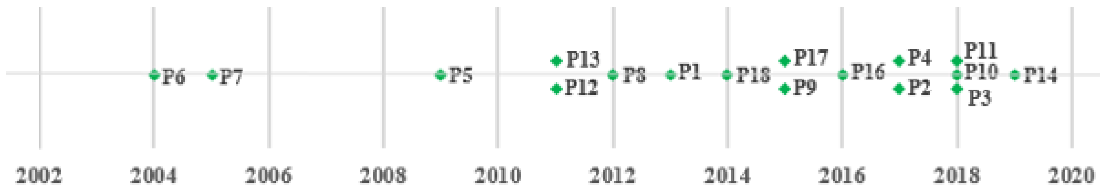

Figure 4.8. Starting Years of the Case Projects.

On the other hand, the distribution of the projects with respect to their types can be seen from the Figure 4.9. There are 3 building projects, 3 metro projects, 2 railway projects, 2 oil refinery projects, 2 dam projects, 2 road projects, 1 airport project, 1 hospital project,1 natural gas pipeline project, 1 bridge project.

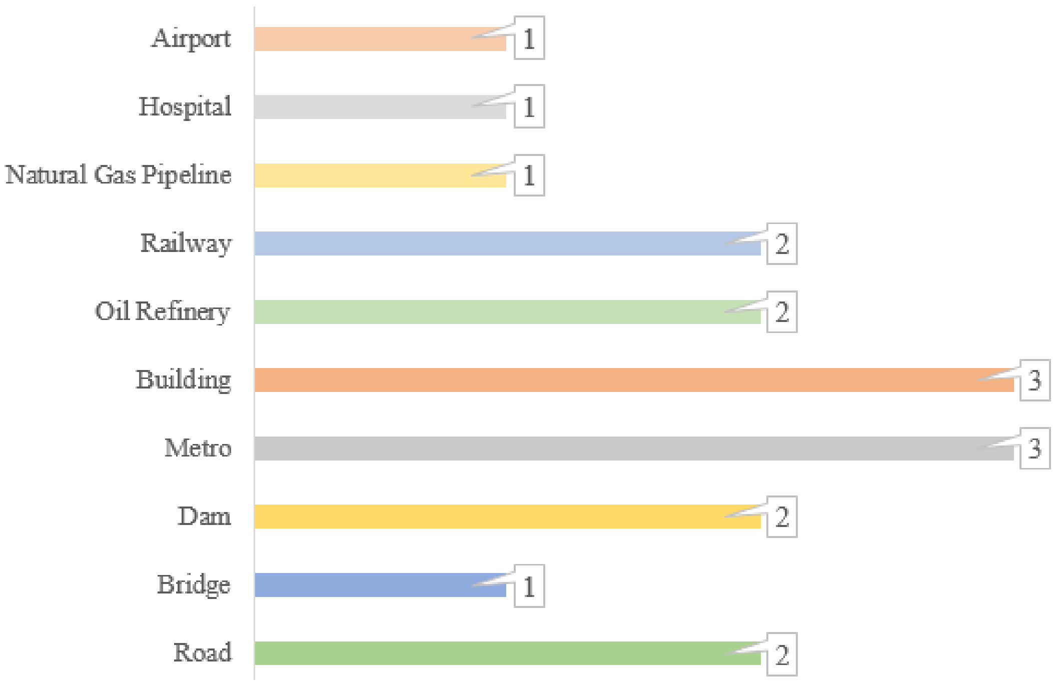

Figure 4.9. Distribution of the Project Types.

Table 4.1.3 and Table 4.2 show more detailed information about the case projects. From these tables, some information such as total construction area, contract type, budget, duration, size of the BIM team can be followed.

As it can be seen from the Table 4.1.3 and Table 4.2, in 11 of these case projects, BIM was enabled while in other 8 of these case projects, BIM was not enabled. Because of this, in 11 case projects, participants answer the questions and assign the significance of the barriers and enablers according to their experience. However the participants from the eight projects in which BIM was not enabled have answered the questions according to their perceptions. The findings are going to be investigated in this research according to these classes. BIM implemented projects are called as Group 1 (G1) while other non-BIM implemented projects are called as Group 2 (G2) in the following sections.

Table 4.1. Detailed Information about Case Projects.

Company Code	**Project Code**	**Project Type**	**Number of Participants**	**Party**	**Construction Area**	**Contract Type**	**Budget**	**Duration**	**Size of BIM Team**	**BIM Function**
C1	P1	Road	1	Client	400 km	BOT	8 Billion	54	25	Coordination, Clash Detection, Scheduling
C1	P2	Road	3	Client	330 km	BOT	4 Billion	36	25	Coordination, Clash Detection, Scheduling, Cost Estimation
C1	P3	Bridge	2	Client	3,5 km	BOT	10.4 Billion	60	20	Coordination, Clash Detection, Scheduling, Cost Estimation, Energy Simulation, Facility Management
C2	P4	Metro	1	Client	76,6 km	Unit price	8 Billion	-	6	Coordination, Clash Detection, Scheduling
C3	P5	Building	2	Client	63.700 m2	Unit price	-	72	-	Coordination, Clash Detection, Scheduling, Cost Estimation
C3	P6	Building	1	Client	18.500 m2	Unit price	-	7	-	Coordination, Clash Detection, Scheduling, Cost Estimation
C4	P7	Oil Refinery	1	Client	340.000 m2	Turnkey	7 Billion	48	3	Coordination, Clash Detection, Scheduling, Cost Estimation
C4	P8	Oil Refinery	1	Client	350.000 m2	Turnkey	-	60	3	Coordination, Clash Detection, Scheduling, Cost Estimation
C5	P9	Natural Gas Pipeline	4	Client	100.000 m2	Unit price	250 Million	12	2	Coordination, Clash Detection, Scheduling

Table 4.1. Detailed Information about Case Projects (cont.).

Company Code	**Project Code**	**Project Type**	**Number of Participants**	**Party**	**Construction Area**	**Contract Type**	**Budget**	**Duration**	**Size of BIM Team**	**BIM Function**
C6	P10	Hospital	2	Client	20.000 m2	BOT	2 Billion	36	3	Coordination, Clash Detection, Scheduling
C7	P11	Airport	2	Client	12 M	Lump Sum	-	24	35	Coordination, Clash Detection, Scheduling, Cost Estimation, Energy Simulation, Facility Management
C8	P12	Dam	1	Client	-	Turnkey	-	12	-	-
C8	P13	Dam	1	Client	-	Turnkey	-	-	-	-
C9	P14	Metro	2	Client	21,6 km	Turnkey	3.1 Billion	48	-	-
C9	P15	Metro	2	Client	20 km	Turnkey	2.34 Billion	60	-	-
C9	P16	Building	1	Client	1.133 m2	Turnkey	-	8	-	-
C10	P17	Railroad	2	Client	87.500 m2	Unit price	-	-	-	-
C10	P18	Railroad	2	Client	533 km	BOT	4.2 Billion	108	-	-

In addition to these, in each project, BIM is using for different purposes by different disciplines. Differences and distribution of the BIM Dimensions which are used in the case projects can be seen from the Figure 4.10. As it can be seen from the figure, while some companies are at the beginning of this process and they are using BIM for coordination, clash detection and scheduling, other some companies have improved themselves and even they are utilizing from BIM to analyze sustainability and manage the facility in their projects.

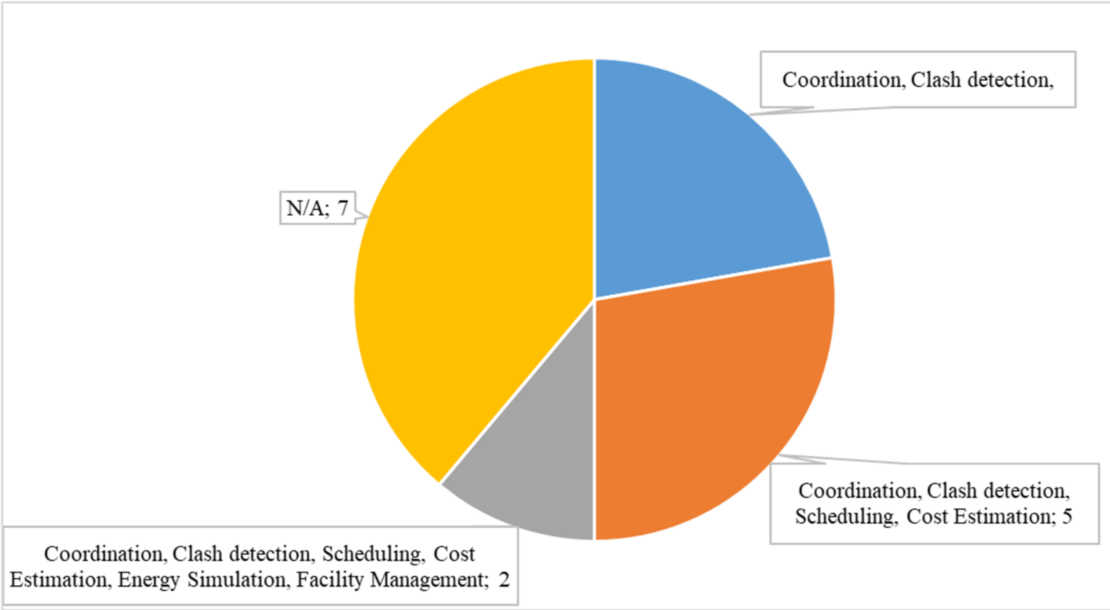

Figure 4.10. Number of Case Study Projects Based on BIM Functions.

4.2. Software Used in the Case Projects

There are 18 projects that have been conducted for this research such as dam, bridge, road, airport, oil refinery and so on. According to requirements, the software that are utilized in the projects differentiates. The software that are used in the case projects can be seen from the Table 4.3. The features of the software can be examined in the previous part of this research. Every discipline uses different software according to their needs. For example, while geology engineers are using Face and Slide, plant engineers are using Smartplant.

Table 4.2. Software that are used in the Case Projects.

Software	Companies	Project	Number of Projects
Revit	C2,C3,C9	P4, P5, P14, P15	4
Smartplant	C4	P7, P8	2
Plaxis	C8,C9,C10	P12, P15, P18	3
BIM360	C2,C7,C9	P4, P7, P15	3
Aconex	C2,C9	P4, P15	2
Naviswork	C2,C4,C9	P4, P15, P8	3
SAP2000	C1,C5,C6,C7,C8,C10	P3, P4, P9, P10, P11, P18	6
Autocad	C1,C4.C5,C6, C7,C8,C10	P1, P2, P3, P8, P9, P10, P11, P13, P17, P18	10
Slide	C1,C8	P2, P12	2
NetCad	C1,C10	P2, P17, P18	3
Microstation	C1,C10	P2, P17, P18	3
Midas	C1	P3	1
Face	C1,C8	P2, P12	2
Geostudio	C8	P12	1
Uncis	C8	P12	1
RS2	C8	P12	1
3D Studio Max	C2	P4	1
Dynamo	C2,C7	P4, P11	2
GIS	C2,C5,C10	P4, P9, P17	3
Primavera	C2,C5,C7	P4, P9, P11	3
Rocscience	C10	P18	1
Bentley	C10	P18	1
MS Project	C5,C7	P9, P11	2
ETAPS	C6,C7	P10, P11	2

Revit is used by three companies in 4 projects. These are building and metro projects. As it is discussed in the part 2.8, Revit provides collaboration between different parties in the projects. Because of this, it increases the efficiencies in the projects. Thanks to its wide range, it can be utilized in different projects. Participant from C9 said that during the construction phase, process could have been performed very well thanks to Revit. Another participant from C9 told that they have used Revit in architectural, mechanical and statically design phases of the P15. Control mechanism was run by the Revit and also conflicts were identified with this tool. If development of using of Revit is examined, it can be said that it is developing and the process can be accelerated thanks to Revit too. In addition to these, collaboration between different parties in this Project can be provided by the Revit.

In refinery projects, smartplant is generally used. Smartplant is used for maintaining the integrity of information through the whole life of the plant. Through this tool, safety can be ensured, projects can be delivered very quickly, and sustainable production can be provided by the owners. A participant from C10 stated that they are using Smartplant for reducing the conflicts and they are planning all phases of the refinery with Smartplant. Another participant from C10 said that they have designed all steps of P8 with Smartplant. In addition to this, participant told that as the Project progresses, Smartplant have been used a lot especially in the engineering part and until the end of the Project, professionals have continued to use by updating.

NetCad is used by two companies. NetCad is the local software which is developed in Turkey. Developing in Turkey can be very efficient for the companies. For example, a participant from C5 said that NetCad has integration with the Turkish and Legistry and Cadastre Information System. In addition to this, NetCad includes all regulations about the constructions thanks to this, conflicts can be eliminated during the construction phases.

Naviswork is also used in 3 projects. Naviswork can be used for 4th dimension and 5th dimension because schedules can be created and cost items can be imported. According to participant from C3, Naviswork can be utilized for providing collaboration thanks to BIM-based procedure. When a part of the structure is revised, other related parts are revised automatically and thanks to this, professionals can earn time a lot and duration of the Project becomes shorter. Thanks to collaboration of Naviswork and Revit, everything can be realized and more accurate information are shared with the engineers in site.

Railway projects are depend on the geography of the area. Because of this, in these projects, so many different projects for analysis of the geography are used such as Rocscience, Midas, and Plaxis. Thanks to this, soil mechanics and tunnel fortification can be analyzed.

4.3. Barriers for the BIM Implementation Process

As it is discussed in the previous parts, barriers make the implementation of BIM difficult or impossible. In this research, some barriers have been identified by reviewing the literature. These barriers have been classified according to their levels such as market level, firm level and project level.

These barriers have been evaluated by a different professionals who is responsible for different types of projects such as building, airport, dam, hospital and so on. Because of this, there is variety in the evaluation of the barriers. This variety explains the reasons why the minimum rating is 1 for every barriers and why the maximum rating is 5 for every barrier. For instance, the high complexity of BIM has very low importance for the professionals who are experienced in BIM using and according to these professionals, the significance of these barriers can be considered as "1", but for another professional significance of "resistance to change" has very low significance. It can be said that resistance has been eliminated in this professional's company.

4.3.1. Market Level Barriers for BIM

The barriers in this class are related to the construction market. So these barriers are not related to companies or projects. To change these barriers, more general decisions should be made. Significance of the market level barriers which are discussed by the professionals in the clients of the projects can be examined from Table 4.4. In this table, there are also average ratings of the values that have been assigned by the professionals from the projects in which BIM was enabled and BIM was not enabled separately. As it is discussed in the previous part, group 1(G1) represents BIM implemented projects while group 2 (G2) typifies non-BIM implemented projects.

There are 12 market level barriers. According to the evaluation of the participants, it can be said that the significance of the different market level barriers is similar. Professionals in the clients have given similar importance to the same barriers with each other.

Table 4.3. Market Level Barriers for BIM Implementation Process.

Market Level						
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V1	Low awareness about BIM	1	5	3.1	3.6	2.6
V2	Lack of interoperability between BIM Softwares	1	5	3.4	4.1	2.4
V3	High complexity of BIM	1	5	2.7	2.7	2.9
V4	Unfavourable economic conditions	1	5	3.8	3.5	4.1
V5	High fragmented nature of industry	1	5	2.8	3.1	2.7
V6	Resistance to change	1	5	3.5	3.7	3.1
V7	Lack of transparency	1	5	2.6	2.5	2.6
V8	Unavailability of Knowledge	1	5	2.8	3.1	2.6
V9	Legal uncertainties/ restrictions	1	5	3.1	3.2	3.1
V10	Lack of guidance	1	5	2.8	3	2.6
V11	Lack of government support	1	5	3.4	3.6	3.1
V12	Difficulty in choosing appropriate contractor	1	5	3.6	3.5	4

Among these market level barriers, “unfavorable economic condition” has been selected as the most significant barrier. After this barrier, “difficulty in choosing appropriate contractor” is in the second whose rating is 3.6 and the third barrier is “resistance to change” which has 3.5 rating. The three least important barriers in market level are “lack of transparency”, “high complexity of BIM”, and “high fragmented nature according to average ratings of all participants”.

If the average ratings of G1 are investigated separately, “lack of interoperability between BIM Software” is the most important barrier according to experience of the participants. “Resistance to change” is the second most significant barrier among the market level barriers and its average is 3.7. In the third place, there are “the lack of governmental support” and “low awareness about BIM” whose average ratings are 3.6. These barriers are four most significant barriers which are met during the implementation of BIM. On the contrary, “lack of transparency”, “high complexity of BIM”, and “lack of guidance” are the least important market level barriers according to the experience of the participants that are using BIM in their projects.

Average ratings of group 2 can be seen from Table 4.4 too. The participants have evaluated the significance of the identified market level barriers according to their perception. “High complexity of BIM” have been evaluated as the most significant market level barriers according to G2. “Difficulty in choosing appropriate contractor” is in second place and its average rating is 4.0. “Resistance to change”, “legal uncertainties/restrictions” and “lack of government support” are sharing third place among the market level because their average ratings are equal and 3.1.

On the contrary, according to the perception of the participants from the projects in which BIM was not enabled, “lack of interoperability between software”, “low awareness of BIM”, “lack of transparency”, “unavailability of knowledge” and “lack of guidance” are the least important barriers.

4.3.2. Organization Level Barriers for BIM

In the interview, participants have evaluated the barriers based on their organizations. These barriers may be overcome if organizations take appropriate precautions. Minimum, maximum and average case study ratings can be seen from Table 4.5. As in the market level barriers table, there are average ratings of assigned values by Group 1 and Group 2 in this table too,

Table 4.4. Organization Level Barriers for BIM Implementation Process.

Market Level							
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V13	Unavailability of financial resources	1	5	3	3.4	2.7
V14	High costs	1	5	3.9	3.7	4.3
V15	Lack of resources	1	5	2.9	2.9	3.3
V16	Unwillingness of people in the company to change	1	5	2.8	2.8	3.1
V17	Managerial inefficiencies	1	5	2.8	2.6	3.1
V18	Unsupportive organizational culture	1	5	3.3	3.5	3

If general results are investigated, it can be seen that average rating of "high costs" is 3.9 and it is the most impactful barrier among the others. "Unsupportive organizational culture" is in the second place and it is considered as very important for the professionals too. In the third place there is "unavailability of financial resources" and its average rating is 3.0. The least important organization level barriers are "unwillingness of people in the company to change" and "managerial inefficiencies" because their average rating is 2.8

If the results of G1 are examined separately, the results are the same as the general results. For example, "high costs", "unavailability of financial resources", and "unsupportive organizational culture" are in the first three places according to participants from the projects in which BIM was not enabled. The ranking for the least important barriers is slightly different from the general ranking. "Managerial inefficiencies" has the least significance according to participants that have implemented BIM in their projects.

If the results of G2 are investigated, it can be seen that there are some differences in terms of the most and the least significant barriers with group 1. According to their perceptions of participants from group 2, the most important barrier that prevents beginning to implement BIM in their projects is "high costs" as in the general results and results of G1. “Lack of resources” is in second place and its average ranking which is assigned by the professionals in group 2 is 3.3. In third place, there are two barriers because their averages are same. These barriers are “unwillingness of people in the company to change” and “managerial inefficiencies” and their average rankings are 3.1. The least ranking belongs to “unavailability” of financial resources.

4.3.3. Project Level Barriers for BIM

Some barriers are related to projects and the significance of these barriers might change in different projects. Minimizing and eliminating these barriers are easier than the others and by taking smaller and project scale precautions, these barriers may be overcome. Maximum, average minimum rating of all projects, average ratings of group 1 projects and group 2 projects can be examined from Table 4.6.

Table 4.5. Project Level Barriers for BIM Implementation Process.

Market Level						
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V19	Unclear project benefits	1	5	2.8	3.2	2.3
V20	Conflicting interest of parties	1	5	2.6	2.9	2.4
V21	Project complexity	1	5	2.7	2.6	3.1
V22	Lack of collaboration	1	5	2.4	2.5	2.6

There are four identified barriers for the project level. If project level barriers are investigated for all participants, “unclear project benefits” have 2.8 average rating. Project complexity is in second place and “conflicting interest of parties” is in third place among the project level barriers. On the contrary, “lack of collaboration” is evaluated as the least important barrier for general results and its average rating is 2.4.

As it is discussed in the previous section group 1(G1) represents the projects in which BIM was enabled. Evaluating the ratings of the barriers which are assigned by group 1 may give an idea about the significance of the project level barriers during the implementation of BIM. According to them, “unclear project benefits” are in the first place among the others and its average rating is 3.2. The average rating of “conflicting interest of parties” is 2.9 and the average of “project complexity” is 2.6. These barriers are in the second and third places respectively. As in the general results, “lack of collaboration” is considered as the least significant barrier according to the experience of the participants who have implemented BIM in their projects.

From Table 4.6, average ratings of non-BIM implemented projects (G2) can be seen. The participants from group 2 have evaluated the barriers according to their perceptions. Their answers give an idea about how much these barriers are important in preventing the BIM implementation. For “project complexity”, 3.1 is the average rating and it is the most significant barrier according to participants from group 2. According to their perception, unlike group 1, “lack of collaboration” is in second place and its average rating is 2.6. While group 1 has evaluated “unclear project benefits” as the most important barrier, according to results of perception of group 2, these barriers are the least important barrier among the others.

4.4. Enablers for the BIM Implementation Process

As it is discussed in the previous parts, enablers can be defined as the accelerating and facilitating factors for BIM implementation. As in the barriers, enablers can also be evaluated in three main classes such as market level enablers, organization level barriers and project level barriers.

These enablers have been identified according to the literature review. Participants have rated these enablers from 1 to 5. If they think that related barrier is very important for successful BIM implementation, they give “5” to this barrier, however, if they think that related enabler is not so much important for the success of BIM implementation, they give “1” to this enabler. These enablers have also been evaluated by some professionals. These professionals are divided into two groups such as group 1 and group 2 as in the barriers. As it is mentioned in the previous section group 1 includes the projects in which BIM was enabled and group 2 includes the projects in which BIM was not enabled.

4.4.0.1. Market Level Enablers for BIM. Market level enablers cannot be affected by the companies' decisions or project decisions. To develop these enablers, there should be bigger decisions and common effort. As effects of the market level enablers increases, companies have more chances to utilize from these enablers. The minimum, maximum and average rating of all participants, average ratings of the answers of the participants from the projects in which BIM was enabled and not enabled can be seen from Table 4.7 separately.

Table 4.6. Market Level Enablers for BIM Implementation Process.

Market Level						
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V1	Availability of knowledge	1	5	4.1	4.3	3.7
V2	Clear advantage and ease of use	2	5	4.2	4.3	4.1
V3	Availability of technological infrastructure	1	5	4	4.1	4
V4	External incentives and promotions	1	5	3.5	3.7	3.3
V5	Open Standards for BIM and National Library for BIM	1	5	3.8	4.1	3.4
V6	Developed legislative regulations	1	5	3.5	3.6	3.3

If the general results are investigated, it can be seen that "clear advantage and ease of use", "availability of knowledge" and "availability of technological infrastructure" are three most important market level enablers. However, among the least important barriers, there are "open standards for BIM and national library for BIM", "external incentives and promotions" and "developed legislative regulations".

If projects that have implemented BIM (group 1) are investigated only, it can be seen that rankings of enablers are similar to the general results. There are "availability of knowledge", "clear advantage and ease of use", "availability of technological infrastructure", "open standards for BIM and National Library for BIM" in the top 4 enablers. The average ratings of "availability of knowledge" and "clear advantage and ease of use" are 4.3 while the average ratings of "availability of technological infrastructure" and "open standards for BIM and National Library for BIM" are 4.1. The least important enabler which has the least impact for accelerating the BIM implementation is "developed legislative regulations" according to the experience of the participants from the projects in which BIM was enabled.

On the other hand, the answers of group 2 may give an idea about the significance of the enablers for starting to implement BIM in the projects because group 2 includes projects in which BIM was not enabled yet. According to them, the top 3 is the same with general results, so, there are "clear advantage and ease of use", "availability of technological infrastructure" and "availability of knowledge" respectively, too. In addition to this, 3 least important enablers are the same as the general results too. The average ranking of "open standards for BIM and National Library for BIM' is 3.4 while average rankings of "external incentives and promotions" and "developed legislative regulations" are 3.3. According to perceptions of the participants from group 2, these enablers have the least impact on starting BIM implementation in their projects.

4.4.0.2. Organization Level Enablers for BIM. Organization level enablers can be improved by the companies or organizations. To improve these enablers and facilitating, organizations can make some decisions as distinct from market level enablers. The minimum, maximum and average ratings which have been assigned by the participants from group 1 and group 2 can be seen from Table 4.8.

Table 4.7. Organization Level Enablers for BIM Implementation Process.

Organization Level						
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V7	Improved technical and technological abilities	2	5	4	4.1	3.9
V8	High managerial ability	2	5	4.1	4.3	3.7
V9	High analysis ability and positive attitude of company	2	5	4.4	4.7	3.7
V10	High qualified human resources	2	5	4	4.3	3.6
V11	Strong financial resources	1	5	3.4	3.7	2.9
V12	Efficient training methods	1	5	4.2	4.3	4.3
V13	Positive attitude of managers	2	5	4.4	4.4	4.4
V14	Readiness of organization to change	2	5	4.2	4.5	4
V15	Well-organized BIM maturity plan	1	5	4	4	4.1

Additionally, if table 4.8 is observed, it can be seen that “high analysis ability and positive attitude of company” and “positive attitude of managers” are sharing first place and their ratings are 4.4 for the general results. While a positive attitude of managers can be defined as the high acceptance level of BIM by the stakeholders, managers and supervisors, high analysis ability includes Cost-Benefit-Risk Analysis, ROI and so on. In addition to this, “efficient training methods” and “readiness of organization to change” have 4.2 average ratings and they are sharing second place. On the contrary, the average of the rankings which are assigned for the “strong financial resources” is very low with respect to others and it is 3.4.

If the average ratings for the group 1 is investigated, it can be obviously seen that “high analysis ability and positive attitude of company” is very important for making BIM implementation more successful and more efficient because its average is 4.7. “Readiness of organization to change” has 4.5 and it is in second place among the organization level enablers according to the experience of the participants from group 1. The third significant enabler is “positive attitude of managers” and its ranking is 4.4. On the contrary, as in the general results, “strong financial resources” is the least significant enabler relatively according to group 2 too.

The rankings of enablers are different in the results of group 2. “Positive attitude of the managers” is in the first place as in the other rankings with 4.4 however second and third places are different than the others. “Efficient training methods” are in the second place and “well-organized BIM maturity plan” is in the third place. If the least important enablers according to the perception of the participants from the projects in which BIM was not enabled are investigated, it can be seen that there are “high managerial ability”, “high qualified human resources” and “strong financial resources”. The average ranking of high managerial ability is 3.7, “high qualified human resources” have 3.6 average rankings and lastly, the average rating of “strong financial resources” is 2.9.

4.4.1. Project Level Enablers for BIM

There are also some enablers that are Project specific. The significance of these may be changed according to Project types. Participants from group 1 have evaluated enablers according to their experiences while participants from group 2 have evaluated by using their perceptions. These Project level enablers can be seen from the Table 4.9.

Table 4.8. Project Level Enablers for BIM Implementation Process.

Project Level						
#	**Barriers**	**Minimum Case Study Rating**	**Maximum Case Study Rating**	**Average Case Study Rating**	**Average Rating of BIM Implemented Projects (G1)**	**Average Rating of non-BIM Implemented Projects (G2)**
V16	Well prepared project BIM execution plan	1	5	4	4.2	3.9
V17	Demand/Satisfaction of Client	2	5	4.1	4.2	3.9
V18	High project level collaboration	2	5	3.9	4.1	3.7
V19	Incentives to employee to use BIM	1	5	3.7	3.8	3.6
V20	Collaborative working	2	5	3.9	4.2	3.6

The demand or satisfaction of the client is the most significant enabler for the successful implementation of BIM in general results of case studies. Another significant enabler is “well-prepared Project BIM execution plan”. Its average ranking is 4 and it is in the second place among the Project level enabler for BIM implementation. Other enablers are “high project level collaboration” and “collaborative working”. “High Project level collaboration” means developed collaboration skills, cross functional co-operation, open communication and information sharing, the willingness of project parties such as project manager, architect, field engineer, subcontractor and so on. “Collaborative working” can be defined as early user involvement, integrated Project delivery, and early contractor involvement. Both of them have the same average ratings and their average rating is 3.9.

If the average ratings for group 1 is investigated, it can be seen that three of them has equal average ratings. These enablers are “well prepared project BIM execution plan”, “demand/satisfaction of client” and “collaborative working”. Their ranking is 4.2. On the contrary, according to participants from group 1 who are working in the projects in which BIM was not enabled, “incentives to the employee to use BIM” is the least important enabler during the BIM implementation.

The average of the ratings which are assigned by the professionals from the projects in which BIM was not enabled can be seen from the Table 4.8 too. According to their perceptions about enablers, “well-prepared project BIM execution plan” and “demand/satisfaction of client” are sharing the first place and their average ratings are 3.9. “High project level collaboration” is in second place among the others whose average rating is 3.7. In the third place, there are two enablers that have equal average ratings and these enablers are “incentives to employee to use BIM” and “collaborative working”. Their average ratings are 3.6. The least important enabler is considered as.

4.5. Ratings of Barriers based on Project Type

Other findings are about the average rating barriers for the projects in terms of market level, organizational level and project level. These average ratings are calculated only for BIM implemented projects. By this way, comparison becomes more consistent. Thanks to these ratings, in which types of BIM-implemented projects market level barriers are important, in which types of projects organizational level barriers are important can be analyzed.

4.5.1. Ratings of Market Level Barriers with respect to Project Types

In the figure below, there are average ratings of the market level barriers with respect to BIM-implemented project types such as building, road, metro, and so on. During the calculation of the average rating, ratings of each participant for each variable are included an average of these ratings are calculated.

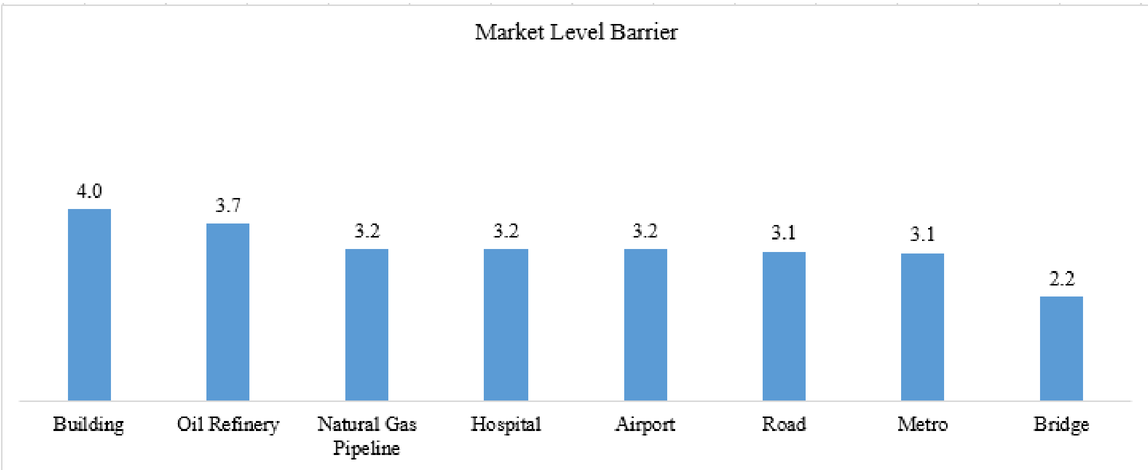

Figure 4.11. Average Ratings of Market Level Barriers with respect to Project types.

Market level barriers affect building projects mostly. The average ratings of all market level barriers which are assigned by the professionals from building projects is 4.0. According to Figure 4.11, the average rating for market level barrier of the bridge projects is the least. Its rating is 2.2 according to the participant from the dam projects.

4.5.2. Ratings of Organization Level Barriers with respect to Project Types

The average ratings of organization level barriers can also be examined specific to the BIM-implemented project. These are also calculated by same method with the average rating of the market level barriers' average rating. The results can be examined from Figure 4.12.

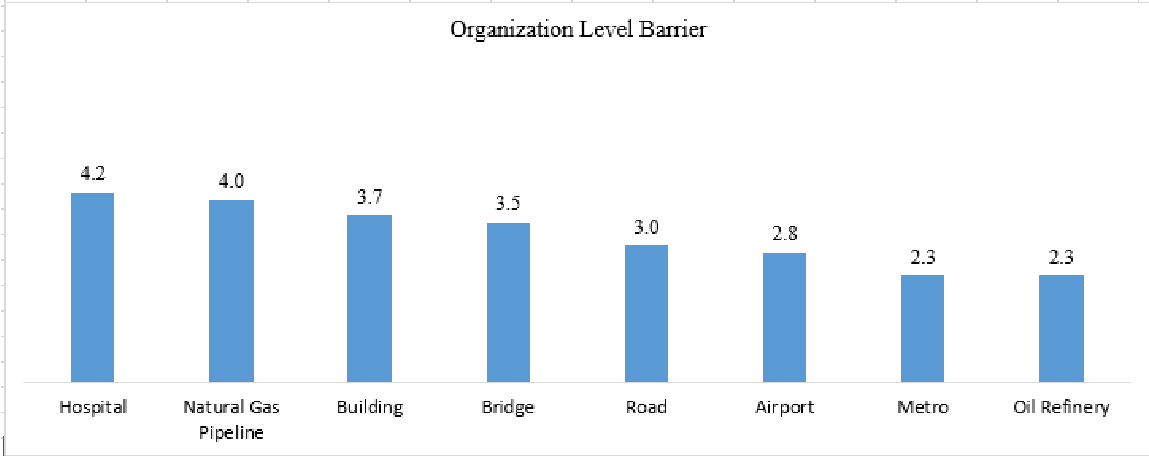

Figure 4.12. Average Ratings of Organization Level Barriers with respect to Project Types No: 1.

As it can be seen from the figure above, the highest rating for this data belongs to the hospital and its rating is calculated as 4.2. It means that organization level barriers are very effective in hospital projects. On the other hand, for the metro and oil refinery projects, the average ratings is 2.3 and it is the least rating among them. It can be said that metro and oil refinery projects are not affected by the organizational level barriers a lot during the implementation of BIM.

4.5.3. Ratings of Project Level Barriers with respect to Project Types

Examining the average ratings of project level barriers with respect to BIM-implemented project types may also give idea. The average ratings of projects which are calculated by using the ratings of all project level barriers based on the projects can be seen from the Figure 4.13.

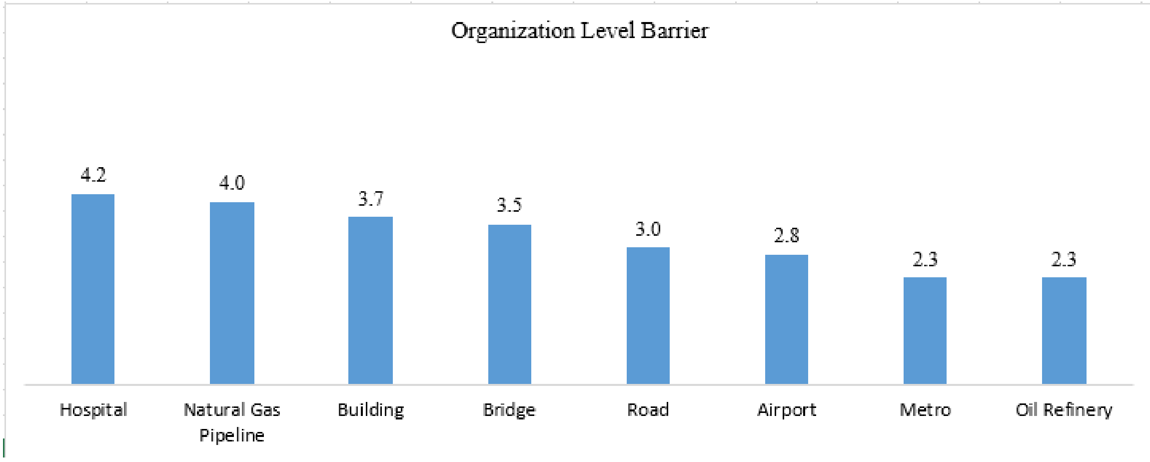

Figure 4.13. Average Ratings of Project Level Barriers with respect to Project Types No: 2.

As it can be seen from the figure above, the average rating of project level barriers for building is so high and it is 4.1. It can be said that in building projects, project level barriers are very effective. On the other hand, bridge projects have 1.3 rating and this is the project that has the least rating.

4.6. Ratings of Enablers based on Project Types

The average ratings of the enablers that are identified by the literature review and conducted to participants can also be calculated with respect to project types. As in the barriers, average ratings of market level enablers, organization level barriers and project level barriers can be calculated. This finding may give an idea about how the market, organization or project level enablers may affect the project types.

4.6.1. Ratings of Market Level Enablers with respect to Project Types

Market level enablers are identified by literature review and the significance of these enablers are conducted to participants. The average of the ratings which are assigned by the participants from BIM-implemented projects are calculated based on the projects types such as the dam, bridge, and road and so on. The average ratings can be seen from Figure 4.14.

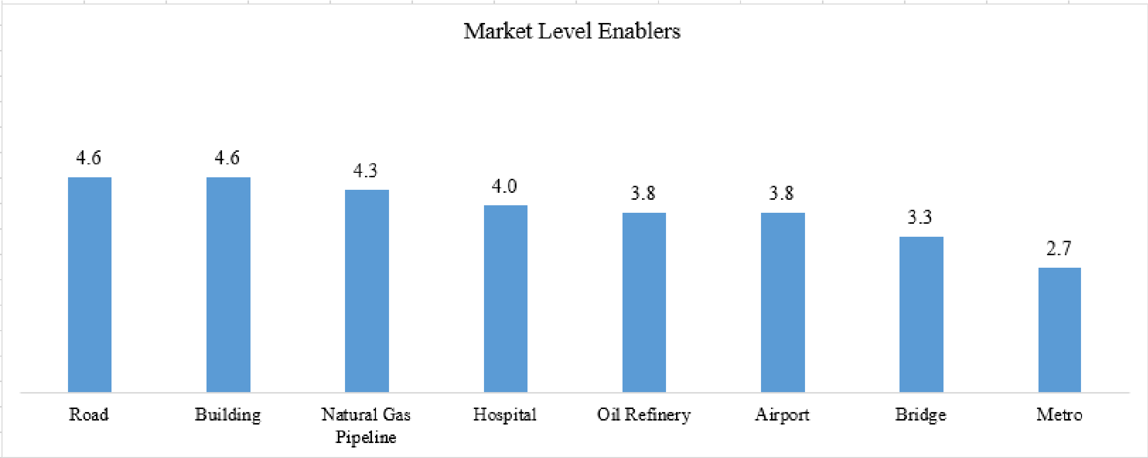

Figure 4.14. Average Ratings of Market Level Enablers with respect to Project Types No: 3.

As it can be seen from the figure above, road projects and building projects have the highest average rating according to market level enablers. After road and building projects, according to market level enablers, there are natural gas pipeline projects and they have 4.3 average ratings. On the other hand, metro projects have the least average rating according to market level enablers. In addition to this, the bridge projects have also very low average ratings and they have 3.3 ratings too.

4.6.2. Ratings of Organization Level Enablers with respect to Project Types

The same calculation with the market level enablers can be made for the organization level enablers and average ratings of organizational level enablers according to different types of BIM-implemented projects can be founded and used for different analyses. The average ratings of organization level enablers can be seen from the Figure 4.15.

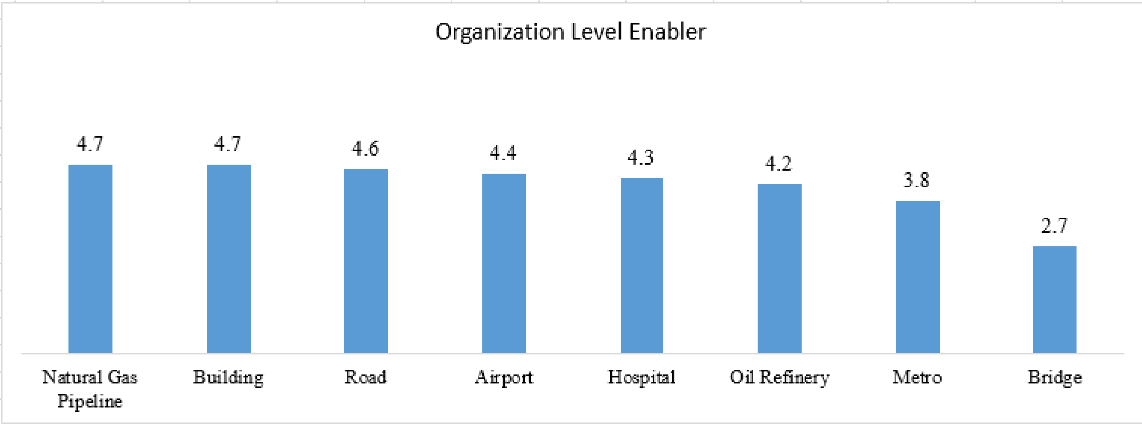

Figure 4.15. Average Ratings of Organization Level Enablers with respect to Project Types No: 4.

The average ratings according to different BIM-implemented project types can be seen from Figure 4.16. Natural gas pipeline and oil refinery projects have 4.7 average ratings for organization level enablers. These types of projects are in the first place in these criteria. The second highest average rating belongs to road projects and its average rating is 4.6. It can be said that for these types of projects, organization level enablers are evaluated as very significant. On the other hand, the average rating of the organization level enablers for bridge projects is 2.7 and it is the lowest rating among the project types. If other projects are examined, it can be seen that average ratings are changed between 3.8 and 4.6.

4.6.3. Ratings of Project Level Enablers with respect to Project Types

The same calculations can be made for the project level enablers for average ratings. The average ratings of project level enablers for different types of projects can be seen from Figure 4.16.

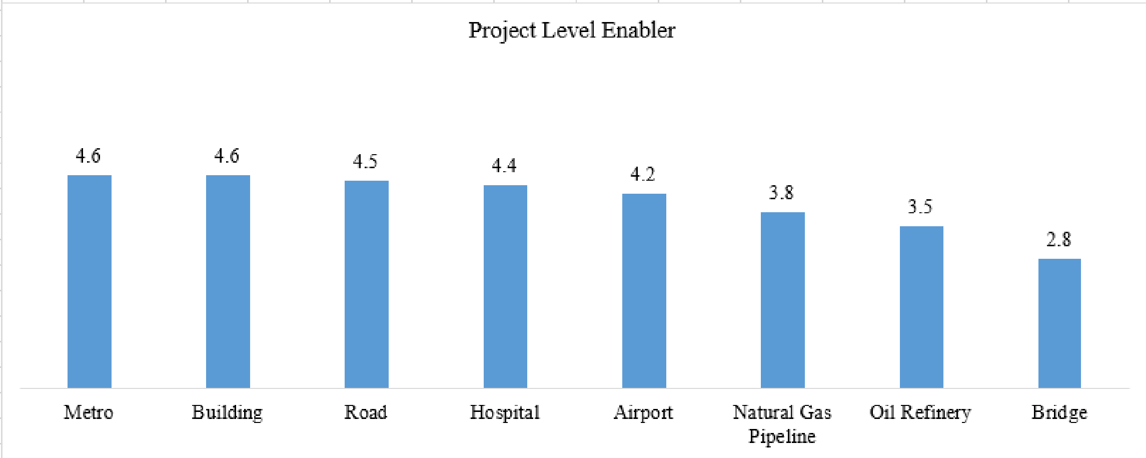

Figure 4.16. Average Ratings of Project Level Enablers with respect to Project Types No: 5.

According to project level enablers, metro and building projects have 4.6 average ratings. These two types of projects are sharing first place according to these criteria. This can be interpreted as the project level enablers are very effective for the metro and building projects. After these projects, road projects have 4.5 average rating. On the contrary, bridge projects have 2.8 average rating. It can be considered that the project level enablers' effects on bridge project is very low.

4.7. Ratings of Barriers and Enablers based on Variables

In Table 4.9, there are minimum, maximum and average ratings of the barriers with respect to different project types. Variable are named with their number which are identified in section 4.2. From these tables, whether a specific variable is important for the specified project types or not. If the difference between the minimum and maximum ratings is low, it can be said that this variable is a common barrier of an enabler for these types of projects. Also in this table, the bridge, airport, hospital and natural gas pipeline projects are not included, because from these types there is only one project which is conducted. Because of this reason, it might not be reliable.

For the lack of transparency, if the minimum and maximum rating in the road project is discussed, it can be seen that the ratings are very close, the minimum is 1 and the maximum is 2. For the two road projects, “lack of guidance” is ranked as 4.

For this study, two dam project is conducted. When the ratings for these two projects are examined, it can be seen that for the “low awareness about BIM”, “lack of interoperability between BIM Software”, “conflicting interest of parties” and “lack of collaboration” are evaluated as “1” for both two dam projects. On the contrary, for “unfavorable economic conditions” and “high costs”, participants from the two dam projects have consensus that the significance of these barriers might be evaluated as “5” so very significant. In addition to these two variables, they have a common view for “difficulty in choosing appropriate contractor” and they give “4” so significant. In this research, there are three metro projects which are evaluated by the five participants. If the ranks of the low awareness about BIM and high fragmented nature of the industry are examined, it can be seen that the rankings are either 3 or 4. So, the difference between the minimum and maximum ratings is very low and there is consensus for these two variables. The significance of these variables is valid for metro projects. On the contrary, the differences between the minimum and maximum value of the high complexity of BIM and resistance to change are high. So, the significance of these variables can be varied from a project to another project.

There are three building projects which are discussed within this research. For these types of projects, especially resistance to change is evaluated as very significant which is resistance to change. Each participants give “5” for this variable. In addition to this, “unfavorable economic conditions”, “high costs” and “managerial inefficiencies” have high rankings. The ranks of these varies between 4 and 5. Another type of project is oil refinery project which is examined within the context of this research. For oil refinery projects, there are two different projects. For the oil refinery projects, there is a consensus for the “lack of transparency” and “lack of government support” and these are evaluated as “5”. So these are very significant barriers to the sector. On the other hand, “unfavorable economic conditions” is evaluated as “2” by the participants, so this barrier is not considered as very significant for the oil refinery projects. In addition to this, the minimum range of “lack of collaboration” is “1” and the maximum range is 2, so minimum and maximum values are very close to each other.

Table 4.9. The Description of Components of Project Management Knowledge Areas and Key References.

Project Type	**Road**			**Dam**			**Metro**			**Building**			**Oil Refinery**			**Railway**		
Barriers	**Minimum Rating**	**Average Rating**	**Maximum Rating**	**Minimum Rating**	**Average Rating**	**Maximum Rating**	**Minimum Rating**	**Average Rating**	**Maximum Rating**	**Minimum Rating**	**Average Rating**	**Maximum Rating**	**Minimum Rating**	**Average Rating**	**Maximum Rating**	**Minimum Rating**	**Average Rating**	**Maximum Rating**
V1	1	3	5	1	1	1	3	3.7	4	3	4	5	4	4	4	1	3	5
V2	3	4	5	1	1	1	2	3.3	5	2	3.3	4	3	3.5	4	4	4	4
V3	4	4	4	1	1	1	1	2.3	4	2	3.3	5	2	3	4	2	3.5	5
V4	2	3	4	5	5	5	2	3	4	4	4.7	5	2	2	2	4	4.5	5
V5	2	3.5	5	1	1	1	3	3.7	4	3	3.3	4	3	4	5	1	3	5
V6	2	3	4	1	1	1	2	3.7	5	5	5	5	3	4	5	4	4	4
V7	1	1.5	2	1	1	1	2	2.3	3	4	4	4	4	4	4	2	3.5	5
V8	1	3	5	1	2.5	4	2	2.7	3	1	3	4	4	4	4	1	3	5
V9	3	3.5	4	2	3.5	5	3	3	3	1	3	4	1	2.5	4	4	4	4
V10	4	4	4	1	2.5	4	2	2.7	3	1	2.7	4	4	4.5	5	2	3	4
V11	1	2.5	4	3	3.5	4	2	3	4	2	3.7	5	5	5	5	3	3.5	4
V12	1	2.5	4	4	4	4	3	3.3	4	4	4.7	5	3	4	5	4	4	4
V13	1	3	5	1	2.5	4	2	3	4	3	3.3	4	1	2	3	2	3	4
V14	3	3.5	4	5	5	5	2	3	4	4	4.7	5	1	2.5	4	4	4.5	5
V15	2	3.5	5	1	2	3	2	3	4	3	3.7	4	1	2	3	4	4	4
V16	1	3	5	1	1.5	2	1	2.3	3	2	3	4	1	2.5	4	4	4.5	5
V17	1	2.5	4	1	2	3	1	2	3	3	4.3	5	1	2	3	3	4	5
V18	1	2.5	4	1	1	1	2	2.7	3	4	4.3	5	2	3	4	4	4.5	5
V19	2	3	4	1	1	1	2	3	4	4	4.7	5	2	2.5	3	2	2.5	3
V20	2	3.5	5	1	1	1	3	3	3	3	3.7	4	2	3	4	2	2.5	3
V21	2	3.5	5	2	3.5	5	1	2	3	3	3.7	4	1	2	3	3	3.5	4
V22	1	3	5	1	1	1	1	2	3	2	3.3	4	1	1.5	2	4	4.5	5

The data for the two railway projects were collected. Participants from these railway projects have consensus on some variables such as resistance to change, legal uncertainties/restrictions, and lack of resources. For these variables, “4” is assigned by the professionals. In addition to this, ratings of unfavorable economic conditions, the unwillingness of people in the company to change and unsupportive organizational culture are so high and these rankings are varied between 4 and 5. It can be said that these variables are very significant barriers to the railway project industry.

The same analysis in the barriers can be applied to enablers. From Table 4.10, these analyses can be seen. From these tables, it can be understood that whether a variable is significant or not. For the same types of projects as in the barriers, enablers are analyzed in this part too.

If the answers for the road projects are examined, it can be obviously seen that for “availability of technological infrastructure”, and “high qualified human resources”, there is a consensus. These variables are assigned as “4” by the professionals. On the contrary, participants have a common view about the “improved technical and technological abilities” and its values vary between 1 and 2.

For the dam projects, there is consensus for the “clear advantage of BIM and ease of use”. In addition to this, the significances of “high managerial ability” and “high project level collaboration” are assigned as “4” by the professionals which are included in this research from the dam projects. On the contrary, the minimum and maximum values of “open standards for BIM and National Library for BIM” varies between 1 and 2. So, this variable is not a significant enabler for the dam projects.

In the metro projects, participants agree that “availability of knowledge” is 4 so it is relatively significant enabler in the metro projects. Also the ranks of the “High analysis ability and positive attitude of company”, and “positive attitude of managers” are between 4 and 5. So participants are at the same point that these enablers are important enablers for metro projects too.

All participants from the building projects consider “availability of technological infrastructure”, “developed legislative regulations”, and “well-organized BIM maturity plan”, as very significant enablers. For example, “efficient training methods”, “well-organized BIM maturity plan” and “well prepared project BIM execution plan” are evaluated as “5” so these are the most significant barriers according to professionals. In addition to this, all participants evaluated “availability of technological infrastructure” as “4”.

For the oil refinery projects, all professionals assigned “4” for “availability of technological infrastructure” and “demand and satisfaction of clients”. Also, they give ranks between “4” and “5” to “developed legislative regulations”, “high analysis ability and positive attitude of the company”, and “readiness of organization to change”.

Another type of project is railway project. “Efficient training methods” is assigned as “5” by professionals it means that it is very important enabler for BIM implementation in the railway projects. There are consensus about the “clear advantage and ease of use”, “external incentives and promotions”, “high analysis ability and positive attitude of company”, “well prepared project BIM execution plan” and “incentives to employee to use BIM” and according to professionals, the maximum and minimum ratings of these are 4 for railway projects.

Table 4.10. The Description of Components of Project Management Knowledge Areas and Key References.

Project Type	Road			Dam			Metro			Building			Oil Refinery			Railway		
Barriers	Minimum Rating	Average Rating	Maximum Rating	Minimum Rating	Average Rating	Maximum Rating	Minimum Rating	Average Rating	Maximum Rating	Minimum Rating	Average Rating	Maximum Rating	Minimum Rating	Average Rating	Maximum Rating	Minimum Rating	Average Rating	Maximum Rating
V1	4	4	4	1	3	5	4	4	4	3	4.3	5	3	3.5	4	4	4.5	5
V2	5	5	5	5	5	5	3	3	3	5	5	5	2	3	4	4	4	4
V3	5	5	5	3	4	5	1	2.7	4	4	4.7	5	4	4	4	4	4	4
V4	5	5	5	1	2.5	4	2	2.7	3	4	4.3	5	3	4	5	4	4	4
V5	4	4.5	5	1	1.5	2	3	3.7	4	4	4.7	5	3	4	5	4	4.5	5
V6	4	4	4	2	2.5	3	2	3	4	3	3.7	4	4	4.5	5	4	4	4
V7	4	4.5	5	3	4	5	2	2.7	3	4	4.3	5	4	4.5	5	4	4.5	5
V8	4	4	4	4	4	4	3	3.3	4	4	4.3	5	3	4	5	3	4	5
V9	4	4.5	5	2	3.5	5	4	4.3	5	3	4	5	4	4.5	5	4	4	4
V10	4	4.5	5	3	4	5	3	3.7	4	2	4	5	3	4	5	4	4	4
V11	4	4.5	5	1	2	3	2	2.7	4	3	4	5	3	4	5	3	3.5	4
V12	4	4.5	5	3	3.5	4	3	4	5	5	5	5	4	4.5	5	5	5	5
V13	4	4.5	5	4	4.5	5	4	4.3	5	4	4.7	5	3	4	5	4	4.5	5
V14	5	5	5	3	3.5	4	3	4.3	5	4	4.7	5	4	4.5	5	3	4	5
V15	5	5	5	3	3.5	4	3	3.7	5	5	5	5	3	3.5	4	4	4.5	5
V16	5	5	5	3	3.5	4	3	4	5	5	5	5	3	3.5	4	4	4	4
V17	4	4.5	5	3	3.5	4	4	4.3	5	4	4.3	5	4	4	4	3	4	5
V18	4	4.5	5	4	4	4	3	3.3	4	4	4.7	5	2	3	4	3	3.5	4
V19	4	4	4	1	2.5	4	3	3.7	4	4	4.7	5	3	3.5	4	4	4	4
V20	4	4.5	5	3	3.5	4	4	4.3	5	3	4	5	3	3.5	4	3	3.5	4

5. DISCUSSION

In the previous chapter, findings of the interviews and case studies are introduced. In this section, these findings are commented and discussed. Also, the results of case studies are compared with the findings from the literature review.

5.1. General Literature Review Results vs. Case Study Findings

In this part of the thesis, case study findings are compared with the literature review results and some details are introduced. While comparing these two statistics, how many times is related barrier or enablers is mentioned in literature and what is the rating of the related barrier according to interviews. This can be used for both barriers and enablers.

5.1.1. Literature Review Results vs. Case Study Rating for Market Level Barriers

From Table 5.1, ranking of the case study results of all participants, results of participants from G1, participant from G2 and literature review results of market level barriers for BIM implementation can be examined.

Unfavorable economic conditions are in the first place according to average ratings of all participants and participants from group 2 in which BIM was not enabled. On the other hand, according to experience of the participants who have enabled BIM in their projects, it is in fifth place among the others. So, it can be said that unfavorable economic conditions are more impactful for the projects in which BIM was not enabled yet. Regarding unfavorable economic conditions, participant from C9 said that they have enabled BIM into two projects and they have enabled successfully. However, because of the economic conditions of our days, they have to postpone other projects and they have no chance to implement BIM to different projects. If the answers of participants from C8 which is one of the companies that enabled BIM in their projects are examined, it can be seen that unfavorable conditions for this company are very big problem and the budget have to be shrunk. On the contrary, in the first place, there are legal uncertainties and restrictions according to literature review while it is in seventh place according to professionals from the industry. Chynoweth *et al.*, (2007) and Udom (2012) claimed that security of data in the model which is developed in the BIM is very important for parties which are included in the projects, because of this, legal and security issues are very important barriers for the BIM implementation.

Table 5.1. Literature Review Results vs. Case Study Rating for Market Level Barriers.

Ranking	**Literature Review Results**	**Case Study Results of G1+G2**	**Case Study Results of G1**	**Case Study Results of G2**
1	Legal uncertainties/ restrictions	Unfavorable economic conditions	Lack of interoperability between BIM Softwares	Unfavourable economic conditions
2	Low awareness about BIM	Difficulty in choosing appropriate contractor	Resistance to change	Difficulty in choosing appropriate contractor
3	Resistance to change	Resistance to change	Low awareness about BIM	Resistance to change
4	Lack of interoperability between BIM Software	Lack of interoperability between BIM Software	Lack of government support	Lack of government support
5	Lack of guidance	Lack of government support	Unfavourable economic conditions	Legal uncertainties/ restrictions
6	Unavailability of knowledge	Low awareness about BIM	Difficulty in choosing appropriate contractor	High complexity of BIM
7	High complexity of BIM	Legal uncertainties/ restrictions	Legal uncertainties/ restrictions	High fragmented nature of industry
8	Difficulty in choosing appropriate contractor	High fragmented nature of industry	High fragmented nature of industry	Low awareness about BIM
9	Lack of government support	Unavailability of knowledge	Unavailability of Knowledge	Unavailability of Knowledge
10	High fragmented nature of industry	Lack of guidance	Lack of guidance	Lack of guidance
11	Unfavorable economic conditions	High complexity of BIM	High complexity of BIM	Lack of transparency
12	Lack of transparency	Lack of transparency	Lack of transparency	Lack of interoperability between BIM Softwares

While participants were evaluating the legal restrictions and uncertainties, some of them from group 1 said that legal issues are not very big problem for the industry, however, licensing sometimes might be very big issue. Because of this, they try to find some solutions. Some of them use cheaper software, some of them buy software for multiple users and by this way, they can buy one license and more than one user can utilize from the software. For example in P1 of C1, there is only 1 license for 20 personnel.

Difficulty in choosing appropriate contractor is also very important barrier for BIM implementation according to all participants and participants from G2 while it is in eighth place in literature review results. If the answers of G1 are investigated separately, it can be obviously said that this barrier is not as important as G2. This means that choosing appropriate contractor is more impactful in the beginning of the BIM implementation and the effects of this barrier decrease during the BIM implementation. BIM is a relatively new concept and because of this, awareness of clients is not enough for the successful implementation and there is a requirement for capable contractors which can apply BIM in the construction site successfully. Third and fourth places are the same in both results, resistance to change is in third place and lack of interoperability between BIM software is fourth. According to the research of Khemlani (2005) employees' resistance is the primary barriers because they are unwilling to learn BIM technology and because of their traditional beliefs, they do not want to use.

Low awareness about BIM in the industry is in sixth place while it is in second place in the literature review results. If the results are investigated separately for group 1 and group 2. For the projects in which BIM was enabled, low awareness about BIM is one of the top three barriers according to the results of G1. So, low awareness about BIM becomes more important for BIM-implemented projects. On the other hand, low awareness about BIM is not evaluated as important as group 1 according to group 2. This might be commented that this barrier is not very impactful for preventing start to BIM implementation. Enshassi (2017) has investigated BIM implementation for the Palestinian construction industry and he found that "lack of awareness of BIM by stakeholders" is the most significant barriers. Although participants from P2 mentioned about the low awareness about BIM and all of them has rated these barriers as "5", these barriers take more importance in the literature review and it is not considered as significant as in the literature for the professionals in the industry. This research investigates the barriers to BIM implementation from the clients' perspective. So, this barrier might be very important for the other parties in the AEC industry but professionals from the industry told that there is no very big problem about the awareness of BIM and clients side of the projects are aware about BIM and its importance.

Lack of transparency is the least significant barrier according to literature reviews, case study ratings of all participants, and case study ratings of group 1. Additionally, according to group 2, its importance is very low. So, this can be told that, it is not an impactful barrier for both during the BIM implementation and preparation process of the BIM implementation.

This research investigates the identified barriers from the clients' perspective. The barriers which affect the BIM implementation from the perspectives of the other parties such as contractors, consultants and so on. For instance, according to Sijtsema *et al.* (2017). Have investigated barriers and facilitators among the medium-sized contractors in Sweden. This research has showed that lack of demands from the clients, unavailability of knowledge, high costs, complexity of BIM software are vey important barriers for the contractors (Sijtsema *et al.*, 2017). Abubakar *et al.* (2014) has investigated CSFs of BIM implementation from the perspective of contractors in the Nigerian Construction Industry. In this research, challenging factors are identified as "social and habitual resistance to change", "legal and contractual constraints". Lack of enabling environment(legislations), unclear advantages of BIM, lack of open standards, lack of demand of client are some other discouraging factor for BIM implementation according to this research (Abubakar *et al.*, 2014). Another research which investigates the barriers for BIM implementation from the contractors' perspective have made by Ahn *et al.* (2008). Lack of legal framework, low awareness are identified as significant barriers in this research (Ahn *et al.*, 2008). Rogers *et al.* (2015) have investigated adoption of BIM technology from the engineering consulting services. According to this research, unfavorable financial conditions, problems related to process changes, legal issues and professional support by both companies and government are identified as very important barriers for BIM adoption (Rogers *et al.*, 2015). In addition to this, Aibinu, *et al.* has investigated barriers to BIM adoption by doing an interview with the consultants. According to these researchers, change aversion, consultants' attitude, incomplete model, unavailability and lack of knowledge are significant barriers (Aibinu, *et al.*, 2014). Chau, *et al.* (2017) has investigated 5D BIM implementation from the perspective of clients, contractors and consultants by using case study methods. According to them, openness to change of the contractors is lower than the clients because contractors do not understand the clear advantages of BIM. Because of these, they continue to do their jobs with traditional methods. This research has also investigated BIM adoption and barriers from the perspective of BIM consultants. According to this research, some consultants think that BIM is time-consuming and BIM software are complex (Chau *et al.*, 2017).

5.1.2. Literature Review Results vs. Case Study Rating for Organization Level Barriers

Six barriers for organization level have been identified by the literature review and these barriers are asked to professionals in clients of the AEC industry. The comparison of case study results of all answers, answers of group 1, group 2 and literature review results can be viewed from Table 5.2.

Table 5.2. Literature Review Results vs. Case Study Rating for Organization Level Barriers

Ranking	Literature Review Results	Case Study Results of G1+G2	Case Study Results of G1	Case Study Results of G2
1	Lack of resources	High costs	High costs	High costs
2	High costs	Unsupportive organizational culture	Unsupportive organizational culture	Lack of resources
3	Unwillingness of people in the company to change	Unavailability of financial resources	Unavailability of financial resources	Unwillingness of people in the company to change
4	Unsupportive organizational culture	Lack of resources	Lack of resources	Managerial inefficiencies
5	Managerial inefficiencies	Unwillingness of people in the company to change	Unwillingness of people in the company to change	Unsupportive organizational culture
6	Unavailability of financial resources	Managerial inefficiencies	Managerial inefficiencies	Unavailability of financial resources

In the first place for the case study results, there are high costs. It is evaluated as the most important barrier according to both group 1 and group 2. So it can be said that high costs for BIM affects both BIM implemented projects and non-BIM implemented projects. As it is mentioned in the previous sections, these costs include investments for software, hardware and updates, investment for BIM specialists and training of other employee, also required time for learning and applying BIM.

Accordingly, this barrier in the second place among the results of the literature review. Elmualim and Gilder (2013) showed that most of their research participants thought that the biggest barrier for BIM implementation is lack of the capital to invest in getting started to use BIM.

Unsupportive organizational culture is the second important barrier in the case study results while it is in fourth place among six literature review results. As in the general results, unsupportive organizational culture is in the second place according to answers of the group 1 which are the projects in which BIM was enabled. However, participants from group 2 evaluated this barrier as one of the least important organization level barriers among others. One of the participants from group 1 said that the top managers accept what they want about BIM, however there is a requirement for too much time to convince them. In the long run, the idea of each top manager is going to change and this barrier is going to be eliminated. Stephenson and Blaza (2001), and Love *et al.* (2001) told that some organizations do not want to change their processes and they want to continue with the same ways. According to them, some companies are also afraid from transition too because they do not accept uncertainty. Giligan and Kunz (2007), mentioned the top managers' mind, according to them, to reduce the resistance for changing, top managers' behavior is very important and this might be very big barrier for BIM implementation.

Unavailability of financial resources is in third place according to results of G1 while it is evaluated as the least important barrier by the participants from G2. The participants from C9 and C10 stated that almost every company has understood that this technology is required for efficiency and additionally they said that their companies try to allocate their financial resources for these developments. So, because of this, it can be said that the companies from group 2 do not have problem about the financial resources. Actually their problems are different. As in the results of group 2, this barrier is in the sixth place in literature review results, so it is considered as the least important barrier in literature too. Ozorhon *et al.* (2010), showed that unavailability of financial resources is second most important barrier among the others according to her research. Actually, these barriers are related to high costs. As costs of BIM increase, the companies have to reserve too much financial resources for BIM. Some participants said that because of the lack of financial resources, they cannot afford to buy license of the software and they cannot full version of these software.

In addition to financial resources, lack of other resources is also important barrier for BIM implementation. According to literature review, it is the most significant organization level barrier, while it is in the fourth place among the case study results of group 1. As it is mentioned in the previous paragraph, unavailability of financial resources are not considered as very important by the group 2, however, the companies in the group 2 have very big problem about the lack of resources. Gerrard *et al.* (2010) said that "lack of BIM knowledge and expertise as the greatest barrier as indicated by the respondents" and he means resources with BIM knowledge and expertise. These resources are well-trained and skilled personnel, training, and ability of professionals to apply BIM to their process. Stewart and Mohammed (2003) claimed that lack of skill and skilled personnel can minimize the resistance and because of this it is very important criteria for BIM implementation. According to professionals from the AEC industry clients, these resources are not as important as the financial resources.

According to case study results, managerial inefficiencies are the least significant barrier. It is not considered as too much important by the literature too.

In some researches, the organization level barriers are conducted to contractors and consultants. These have been investigated from the perspective of these parties. Some interviewees from the contractors claimed that organizational culture sometimes discourages BIM implementation (Sijtsema *et al.*, 2017). Research of Abubakar *et al.* (2014) which have investigated Nigerian construction industry shows that "high costs of training" is the most discouraging barrier among the other organization level barriers for contractors (Abubakar *et al.*, 2014). Another research which investigates the barriers for BIM implementation from the contractors' perspective have made by Ahn *et al.* High costs, negative attitude of the companies and top managers are identified as most discouraging barriers in this research (Ahn *et al.*, 2008). Research of Rogers *et al.* (2015) have showed that among the organization level barriers lack of human resources, incentives from the companies are very important barriers (Rogers *et al.*, 2015). In addition to this, Aibinu *et al.* (2014) has investigated barriers to BIM adoption by doing an interview with the consultants. According to these researchers, learning time, change aversion, consultants' attitude, incomplete model, and cost of implementation are significant barriers (Aibinu *et al.*, 2014). Thurairajah, N. has investigated the barriers of BIM implementation from the cost consultant's point of view. He said that investment costs and required time for learning are very important barrier for BIM implementation (Thurairajah 2013).

5.1.3. Literature Review Results vs. Case Study Rating for Project Level Barriers

As it is mentioned in the previous sections, there are market level and organization level barriers. In addition to these, there are also barriers related to project level. The rankings of results of the case study according to group 1 and group 2 and literature review can be seen from Table 5.3. The interviewee has evaluated project level barriers according to their importance too.

Table 5.3. Literature Review Results vs. Case Study Rating for Project Level Barriers

Ranking	**Literature Review Results**	**Case Study Results of G1+G2**	**Case Study Results of G1**	**Case Study Results of G2**
1	Lack of collaboration	Unclear project benefits	Unclear project benefits	Project complexity
2	Project complexity	Project complexity	Conflicting interest of parties	Lack of collaboration
3	Unclear project benefits	Conflicting interest of parties	Project complexity	Conflicting interest of parties
4	Conflicting interest of parties	Lack of collaboration	Lack of collaboration	Unclear project benefits

Unclear project benefits mean some thoughts such as it is not profitable and its ROI is low. This is considered as important by the professionals from G1 while it is not considered as important barriers according to literature review results and professionals from group 2. So, there are two alternatives for this: this barrier might be more impactful for BIM implementation process instead of the preparation process of BIM implementation or companies from G2 may overcome this barrier. Actually, this is related to mind of the top managers which is discussed in the previous part. Because top managers are the decision makers and if their mind can be changed and they convince that BIM is profitable and decreases the cost of the projects, unclear project benefits is not going to be a barrier for BIM implementation anymore. Kiani *et al.* (2015) made a research for construction industry and he claimed that without telling clear benefits to managers and other decision makers shifting to BIM is almost impossible.

Another project level barrier which is discussed in the context of this research is project complexity. According to participants from G2, project complexity is a very important barrier to this. On the other hand, it is not considered as a very important barrier for group 1. So, it can be said that this barrier is the most impactful barrier for the preparation of BIM implementation process. This is also in second place according to literature review results.

5.1.4. Literature Review Results vs. Case Study Rating for Market Level Enablers

Same discussions in the market level barriers can be made for the market level enablers too. So, some enablers are identified from the literature review and importance of these enabler for accelerating and facilitating BIM implementations is asked to industry professionals. As in the barriers, the significances of the enablers according to professionals are investigated in two categories such as projects in which BIM was enabled and not enabled. The projects in which BIM was enabled are represented as group 1 and the projects in which BIM was enabled are represented as group 2. The ranking of the enablers according to case study results for group 1 and group 2 and the number of frequency in the literature can be seen in Table 5.4. The first place of literature review results means that this enabler is repeated in the literature at most and its frequency is very high according to other.

Table 5.4. Literature Review Results vs. Case Study Rating for Market Level Enablers.

Ranking	Literature Review Results	Case Study Results of G1+G2	Case Study Results of G1	Case Study Results of G2
1	External incentives and promotions	Clear advantage and ease of use	Clear advantage and ease of use	Clear advantage and ease of use
2	Availability of technological infrastructure	Availability of knowledge	Availability of knowledge	Availability of technological infrastructure
3	Availability of knowledge	Availability of technological infrastructure	Availability of technological infrastructure	Availability of knowledge
4	Developed legislative regulations	Open Standards for BIM and National Library for BIM	Open Standards for BIM and National Library for BIM	Open Standards for BIM and National Library for BIM
5	Open Standards for BIM and National Library for BIM	External incentives and promotions	External incentives and promotions	External incentives and promotions
6	Clear advantage and ease of use	Developed legislative regulations	Developed legislative regulations	Developed legislative regulations

Clear advantage and ease of use is considered as very important for both group 1 and group 2 while it is the least important enabler in the literature review results interestingly. This means that it is very impactful for both BIM implementation process and preparation of BIM implementation process. For example, commands in the AutoCAD or in the some other software have not changed for years. Thanks to this, each users can bear these commands in their mind and they have become very practical in time. This enables BIM implementation and makes the implementation process easier. In addition to this, there are some clear advantages of BIM implementation. Pensuapp *et al.* (2005) claimed that the motivation and will of the employee is directly related to mind of them about the technology and there are some variables that affect the perception of them such as “clear advantage of use” and “ease of use”.

Availability of knowledge and availability of technological infrastructure are considered as very important enablers for both group 1, group 2 and literature review. All of the three participants from C9 have assigned “5” for this enabler. Additionally one of the participant from group 2 has pointed to consultancy and she said that by taking consultancy they can achieve and accelerate the BIM implementation process. Almost all participants from group 1 and group 2 have stated that “availability of technological infrastructure” is also very important for successful BIM implementation. In addition to this, Olawumi *et al.* (2018) told that as the knowledge and availability of knowledge increase, BIM implementation can be enhanced into projects. Abbasnejad *et al.* (2016) said that training is very important for the BIM implementation, however, training is not enough on its own and it should be supported with external organizations who are successful and leader in the BIM implementation.

Open standards for BIM and National Library for BIM is in the fourth place according to case study results while it is in the fifth place in the literature review results. So it can be said that it is not considered as too much important by both case study and literature review. The reason for that might be importance of the other enablers. Of course open standards and national library is important according to professionals but advantages of BIM, availability of knowledge and technological infrastructure are more important enablers. Marzia (2013) told in her research that "The adoption of open standard in the AEC industry is very important because participants are not obligated to employ specific property applications".

Interestingly, while external incentives and promotions are in the fourth place according to evaluation of participants from both group 1 and group 2, in the literature it is the most important enabler. One of the interviewee said that before external incentives and promotions, other enablers are more important for them. There are some promotions in some projects however this enabler is not enough to prompt BIM usage on its own.

As in the barriers, these enablers are evaluated from the clients' point of view. Therefore, comparing these results with the literature which shoes the opinion of contractors and consultants may give idea the difference among the point of view of different parties. For instance, Liao *et al.* (2017) has focused on the contractors in the Singapore AEC industry. Some enablers which are related to market level are identified as very important in this research such as high accuracy of model based documentation, data sharing and access on BIM platforms (Liao *et al.*, 2017). Abubakar *et al.* (2014) has investigated CSFs for BIM adoption in Nigerian construction industry from the perspectives of contractors. For market level, BIM software availability and affordability, awareness of technology, government support through legislation and collaborative procurement methods and considered as important (Abubakar *et al.*, 2014). On the other hand, there is also consultancy part. Rogers *et al.* (2015), have focused on the consultants in the Malaysian construction industry. According to this study, financial support and subsidy from government, mandatory BIM use on public projects, intention from government, growing awareness, shared models, adequate advice, market requirement are some of the important market level enablers (Rogers *et al.*, 2014). Aibinu *et al.* (2014) have investigated BIM adoption in Australian construction industry by using experience of consultant. Ease of use, availability of knowledge such as case studies, quality information in models, and integration with current software are some of the important market level enablers.

5.1.5. Literature Review Results vs Case Study Rating for Organization Level Enabler

There are also enablers which are related to organization. These enablers are expected to be evaluated by the participants. The ranking of these enablers according to case study average ratings and frequency in the literature review can be seen from the Table 5.5. Participants from group 1 has evaluated the enablers according to their perception while participants from group 2 has evaluated with respect to their perceptions.

High analysis ability and positive attitude of company is in the first place according to evaluation of participants from group 1 while it is in the seventh among the literature review results. This enabler is not considered as one of the most important enablers by the participants from group 2 because it is in the sixth place among others. This might be commented that this enabler is not very impactful for starting the BIM implementation and instead of this, the companies which are planning to implement BIM into their projects should give importance other enablers instead of this. About high analysis ability, Mom and Hsieh (2012) told that during the assessment of BIM implementation, benefits, cost and risk analysis is very important and this should be a key factor for successful BIM implementation according to them.

Table 5.5. Literature Review Results vs Case Study Rating for Organization Level Enablers.

Ranking	Literature Review Results	Case Study Results of G1+G2	Case Study Results of G1	Case Study Results of G2
1	Readiness of organization to change	High analysis ability and positive attitude of company	High analysis ability and positive attitude of company	Positive attitude of managers
2	Improved technical and technological abilities	Positive attitude of managers	Readiness of organization to change	Efficient training methods
3	Positive attitude of managers	Efficient training methods	Positive attitude of managers	Well-organized BIM maturity plan
4	Efficient training methods	Readiness of organization to change	Efficient training methods	Readiness of organization to change
5	High qualified human resources	High managerial ability	High managerial ability	Improved technical and technological abilities
6	High managerial ability	Improved technical and technological abilities	High qualified human resources	High analysis ability and positive attitude of company
7	High analysis ability and positive attitude of company	High qualified human resources	Improved technical and technological abilities	High managerial ability
8	Well-organized BIM maturity plan	Well-organized BIM maturity plan	Well-organized BIM maturity plan	High qualified human resources
9	Strong financial resources	Strong financial resources	Strong financial resources	Strong financial resources

The most important enabler for the group 2 in which BIM was not enabled is positive attitude of managers according to group 2 perception. So, thanks to this, it can be understood that positive attitude of managers is determinant enabler for starting to BIM implementation. In addition to this, the impact of this enabler cannot be ignored according to evaluations of participants from group 1 and literature too, because it is in the third place for them among others.

Another important enabler for group 2 is efficient training methods. It is in the second place among the others Participants from Group 2 can start BIM implementation easier if effective training methods can be obtained because they stated that BIM is a very new concept and there is a need for a lot of training. Participants said that trainers from the software companies visit them regularly and tell information about how this software can be used. It is the fourth important enabler according to experiences of group 1. Some of the companies from group 1 send their employees to education about the BIM. For example, C4 is going to start expand the using area of BIM in their projects and they provide training for their people. This is also mentioned in the literature by some authors. For example, optimization of BIM performance is possible thanks to training and learning curves of employee according results of research of Azhar (2011). In addition to this, Singh *et al.* (2011) stated that ıf training schedules are developed according to specific requirements, the problems about BIM usage might be minimized.

Readiness of organization to change is another enabler for BIM implementation and it is the most significant enabler according to literature review results. Importance of readiness of organization to change is significant because every personnel should internationalize the BIM for successful implementation. People in the site are the implementer of this technology and they should be ready for this. On the contrary, they are not going to be willing to implement BIM in their works. If the average ratings of the value that have been assigned by group 1 and group 2, it can be said that the impact of this enabler cannot be ignored. A participant from C2 which belongs to group 1 claimed that the employee in their company is ready to transition from traditional methods to BIM implementations. This mind of them has made this transition easier. Because of this, this is one of the most significant enablers.

High managerial ability is not as effective as other enablers. Top managers are not familiar with the BIM because it is very new concept for them. So, this enabler is not too much effective for the projects which are conducted for the case study. Especially according to group 2 participants, there is a requirement for some other enablers instead of this to accelerate the beginning of the BIM implementation.

Another common view for the results of group 1 and literature review is that well-organized BIM maturity plan. It is one of the least significant enablers among the identified enablers. Interestingly, it is considered as important by the participants from group 2 and this enabler is one of the top 3 enablers. As it is discussed in the discussion of the barriers, unavailability of financial resources are not considered as very important barrier and similarly according to literature review again, strong financial resource is the least important enabler for both group 1 and group 2 and literature review results. Although for some companies, high costs causes requirement for huge expenditures, advantages of BIM usage is understood clearly by them and they expend their financial resources for BIM in our days. So, other enablers are more important than the strong financial resources.

If the affecting enablers which are discussed in this research are compared with different parties from the AEC industry such as contractors and consultants, there can be seen some similarities and differences. Abubakar *et al.* (2014) have identified availability of trained professionals, readiness to cultural change as very important enablers for organization level (Abubakar *et al.*, 2014). According to research of Liao *et al.* (2017), leadership from top management, changes in organizational structure, training on new skills are some of the important enablers which belong to organizational level (Liao *et al.*, 2017). Aibinu *et al.* (2014), has investigated the enablers from the perspective of consultant.

According to this research, cost benefit analysis, scenario training are the important enablers for BIM adoption which are organization based with respect to consultant (Aibinu *et al.*, 2014).

5.1.6. Literature Review Results vs Case Study Rating for Project Level Enablers

In the Table 5.1, comparison between the results of case study and literature review can be made by using same method with others. As in the others, Table 5.1 shows the rankings of project level enablers according to average ratings which are assigned by the participants and frequencies of enablers in the literature.

Table 5.6. Literature Review Results vs Case Study Rating for Project Level Enablers.

Ranking	Literature Review Results	Case Study Results of G1+G2	Case Study Results of G1	Case Study Results of G2
1	High project level collaboration	Demand/Satisfaction of Client	Demand/Satisfaction of Client	Demand/Satisfaction of Client
2	Demand/Satisfaction of Client	Well prepared project BIM execution plan	Well prepared project BIM execution plan	Well prepared project BIM execution plan
3	Well prepared project BIM execution plan	High project level collaboration	Collaborative working	High project level collaboration
4	Collaborative working	Collaborative working	High project level collaboration	Collaborative working
5	Incentives to employee to use BIM	Incentives to employee to use BIM	Incentives to employee to use BIM	Incentives to employee to use BIM

The rankings are similar for the project level enablers. So, the enablers which are placed in the first three alignments are same. Interestingly, the results of G1 and G2 are almost same. If the rankings of other enablers and barriers are investigated, it can be said that there are some differences in the rankings of group 1 and group 2. Demand/satisfaction of client is in the first place in the case study results while it is in the second place in the literature review results. C1 make using of BIM compulsory and thanks to this number of BIM implementation has increased. In addition to this, some companies like C3, C9 make some software for BIM compulsory and they only accepted projects which are prepared by using these software. So, they have some kind of procedure to show how this projects should be designed and prepared. According to results of Aladag *et al.* (2016) there are two important enablers and one of them is “demand and contract obligations” too. This research aimed to understand perspectives of clients in the industry and they put an item which identifies the required software for the projects in their agreement. This is binder for the contractor and to meet these requirements they have to use these software.

In the second place for group 1 and group 2, there is well-prepared project BIM execution plan while it is the third important enabler according to literature. Actually, this enabler might be seemed similar to enabler in the organization level which is well-organized BIM maturity plan. However, one of this is related to organization and another is related to project specific. Many of the participants said that this plan should be prepared at the beginning of the projects. By this way, which parties should be involved, how the process continue can be determined easily. Participant from C2 which is one of the companies that have implemented BIM mentioned about the importance of the well-prepared BIM execution plan. In addition to this, he said that if the BIM execution plan may be prepared very well at the beginning of the Project, every steps become easier and efficiency of BIM plan is increased by this way. Additionally, Özorhon *et al.* (2015) claimed that pre-set well-organized BIM execution plan is very useful for fully integration of BIM from the beginning of the project.

Third important enabler in the project level according to case study results of group 2 is high project level collaboration. As it is well known, there are so many parties in the construction projects and good collaboration and communication is very important not only for successful BIM implementation but also for every steps of construction. It can be commented that this enabler should be provided for starting to BIM implementation. For example, according to participants from group 1 if they cannot prepare BIM execution plan very well, they cannot provide collaboration among them and because of this, BIM plan is primary. On the other hand, it is considered as the most important enabler in the literature. Abbasnejad *et al.* (2016) mentioned that knowledge sharing and high project level communication play vital roles for successful BIM implementation because thanks to these, risks and uncertainties can be reduced and also resistance to change can be minimized.

There is a consensus about incentives to employee to use BIM. According to literature review results, case study results of G1 and G2, this enabler is the least important enabler. Of course, this is required and very important for the successful BIM implementation however, other enablers are more important than this. For example, some participants said that of course incentives are good for employee and it is going to increase the will of them but it is not enough on its own. According to participants, prizes, incentives and etc. are very important for implementation of the BIM, however, at first the mind of the people should be changed". Because of this, they cannot evaluate this enabler as important as other enablers.

5.2. Comparisons of Barriers and Enablers Based on Project Types with respect to Average Ratings

At this part, the findings which are introduced in the section 4.5 and 4.6 are discussed. These findings introduce average ratings of market level, organization level and project level barriers and enablers respectively especially based on the BIM-implemented project types. These findings helps us to understand which levels of barriers or enablers are most important for the specific types of projects.

For the road projects, as it can be seen from Figure 4.12 average rating of market level barriers is 3.1 while average rating of organization level is 3.0 as in the Figure 4.13 and average rating of project level is 3.3 as in the Figure 4.14. So by looking these statistics, it can be said that clients which is related to road projects are not affected from the barriers in general however there is a still way to go.

Another project type is bridge projects. Average rating of bridge projects for market level barriers is 2.2. Comparing to other projects, bridge project's rating is one of the smallest ratings. Average rating of organization level for bridge is 3.5 and if this rating is compared with other projects, it can be said that it is not so high. Lastly, the average rating of the project level barriers is 1.3 and it is too low according to other ratings. If the ratings for bridge projects is observed generally, the ratings are very low according to others. This means that the company which is client for the road projects overcomes the barriers with respect to others.

There are also metro projects which are conducted in a context of this research. According to Figure 4.12, average rating for this type of project in market level barriers is 3.1. Average rating of organization level is 2.3 can be seen as in Figure 4.13 and project level barriers' rating is 2.3. So, project level barriers are not very effective for the metro projects. According to other project types, these ratings are not so high. Also, it can be said that project level barriers are not seemed as very significant especially.

If ratings which belong to building projects are investigated from Figure 4.12, Figure 4.13 and Figure 4.14. It can be seen that average rating of market level is 4.0, average rating for organization level is 3.7 and average rating for project level 4.1. So if these ratings are compared with the other average ratings, it can be said that building projects are in the first place that are affected by the market level, it is in the fourth place according to organization level and lastly, building project is a sector that is the most affected project types by the project level and it is in the first place. Although especially project level barriers become prominent, ratings of market level and organization level are too high. According to interviewees' answers, all types of problems prevent successful BIM implementation.

In Figure 4.12, average ratings of market level barriers with respect to different project types can be seen. According to this figure, average of the ratings of the market level barriers for oil refinery projects is 3.7. So it can be said that market level barriers affect the oil refinery projects at most. If average ratings of organization level and project level that belong to oil refinery projects are examined from the Figure 4.13 and Figure 4.14, it can be said that organization level barrier's and project level barrier's average rating are 2.3. There is a very big difference between the average ratings of market level, organization level and project level barriers. By looking these findings for the oil refinery projects, it can be said that market level barriers are the major barriers for them and they have solved barriers in organization level and project level in a vast scale.

Average rating of market level barriers for natural gas pipeline projects is 3.2 according to Figure 4.12. Average rating of organization level barriers is 4.0 and project level barriers' average rating is 2.5. By looking these statistics, it is obviously seen that the major barriers are organization level barriers. According to these types of barriers, natural gas pipeline projects are in the third place. Even, it can be said that, the company in the natural gas pipeline projects has almost handled and overcome the barriers in the project level.

The average rating of market level barriers for hospital projects is 3.0, while rating for the organization level barriers is 4.2 and project level barriers' rating is 2.8. Average ratings of market level barriers and project level barriers are not so high with respect to others and these are in the acceptable level. However, hospital projects are in the first place with respect to organization level barriers. So it can be said that organization level barriers affect hospital projects at most and also hospital projects are affected by the organization level barriers at most.

Lastly, if airport projects' average ratings are investigated, it can be said that the impacts of the all types of barriers are in the acceptable level. For example, according to Figure 4.12, average rating of market level for airport project is 3.2 while the average rating of organization level and average rating of project level barriers are 2.8. The participant from the company which is conducted for the research said that they are trying to eliminate all impact of these barriers in their following projects and by this way, they aim to implement BIM to their projects successfully.

The discussions above are related to average ratings of different types of barriers based on different project types. Same discussions can be made for the different types of enablers with the same way too.

Firstly, for the road projects, average rating of market level enablers is 4.6, average rating of organization level enablers is 4.6 according to Figure 4.16. So, all average ratings of all types of enablers are too high in the road projects. This might be interpreted as although average ratings of barriers for road projects are high, they also have high ratings for the enablers, so they are trying to overcome these barriers thanks to some enablers. If the ratings are investigated with respect to types of enablers such as market level, organization level, and project level, it can be said that road projects are in the first place according to market level enablers. This means that identified market level enablers facilitates their implementation process and make this process easier. Also road projects are in the first place with respect to project level enablers. Actually this ratings are compatible with the opinions of the interviewees, because they said that they are trying to implement BIM into their projects.

Second project type is bridge project. If the statistics of bridge project investigate from the Figure 4.15, Figure 4.16, it can be seen that average rating of market level enablers is 3.3, average rating of organization level enablers is 2.7 and average rating of project level 2.8. Bridge projects are in the last position among the project types according to significance of organization level enablers and project level enablers. So, this shows us identified enablers are not very effective in the BIM application. As in the road projects, actually these ratings are compatible with the opinion of the people. For example, participant from the client of the bridge projects said that they are not very advanced in BIM implications in their projects. He also added that contractors are more advanced in bridge projects.

While investigation of the average ratings of metro projects, especially looseness of average rating of organizational level enablers is glittered. This might be related to looseness of average rating of organization level barriers. Because of the looseness of average rating of organization level barriers, they have not given attendance to organization level enablers and average rating is 3.8. This rating is dropped behind according to other project types. Also, according to market level enablers, metro projects are the second last among others. If the average rating of market level barriers is considered, it is also too low as in the enablers. So, this means that they do not afford to utilize from enablers to eliminate the barriers because the effects of barriers in the market level is not too high. Metro projects' average rating for project level enablers is high and on the contrary average rating of project level barriers is not too high. This might cause implement BIM into their projects successfully despite difference between average ratings of market level barriers-enablers and organization level barriers-enablers.

Another project type is building. There are three cases which are conducted for these research. According to these three cases, average rating of market level enablers is 4.6 and average rating of organization level enablers are 4.7 and lastly, average rating of project level enablers is 4.6. According to other ratings, it can be said that these ratings are too high. As it is mentioned in the discussion about the barriers, building projects are affected too much by the all types of barriers. Participants claim that they can minimize the high effects of the barriers in their projects thanks to high ratings for enablers.

During the investigation of oil refinery projects, there is a fact that especially project level enablers' average rating is very low and it is 3.5. Average rating of the project level barriers for oil refinery projects is 2.3 so it is very low. On the other hand, rating of organization level enablers is 4.2 as it can be seen from the figure 4.16. This might be very big advantage for oil refinery projects because organization level barriers' rating is too low. Thanks to this big difference between ratings for organization level barriers and enablers, BIM implementation can be successful.

According to rating of organization level enablers, ratings of natural gas pipeline is in the first place. Actually during the interview, participant from C5 which is the client of natural gas pipeline projects claimed that their organization is ready to implement BIM into their projects, even they have applied BIM technology in P9. Based on market level enablers' rating, natural gas pipeline projects are again one of the projects that have high average ratings, its rating is 4.3. Despite these high average ratings for market level and organization level enablers, the average rating of project level is not so high with respect to other industries. However, average rating for project level is not so high too, this means that they do not meet with so many difficulties in related project. Thanks to this, they can apply BIM into this and other projects successfully.

As it can be recognized from the discussion part on the average ratings of the barriers, the rating of the hospital project with respect to organization level is too high it is in the first place among the project types. The average rating of organization level enablers is high with respect to other projects. Despite this high rating, because of the organization level barriers for hospital projects, BIM technology cannot be applied successfully by the client. Project level enablers' average rating is also high according to others. The participants claim that the biggest advantage of this hospital project is choosing an appropriate contractor because this contractor is experienced and they can apply BIM successfully.

Airport project's average rating is high by comparison. For example, average rating for market level enablers is 3.8, rating for organization level enablers is 4.4 and lastly rating is 4.2 for project level enablers. On the other hand as it is discussed in the previous part of this section, barriers are not considered as very significant by the interviewee. Participant from the C7 which is the client of airport project said that they are making an effort to implement BIM into their projects successfully. This difference between the significance of barriers and enablers make successful BIM implementation to projects easier.

5.3. Comparisons of Barriers and Enablers Based on Project Types with respect to Min and Max Ratings

In this section, the findings which are interpreted in the section 4.7 are discussed. In section 4.7, the findings show the minimum, average and maximum ratings which are assigned to barriers and enablers separately. These findings are important because by using these ratings, it can be understood that whether related variable is valid for a project or for all projects in the same types such as road, railway, building or so on. For example, if difference between minimum and maximum ratings is high, it can be understood that this variable does not have same effect on the each same types of projects. On the contrary, if difference between minimum and maximum values is small, it can be thought that related variable has same effects on each projects which are same types. In addition to these, project types which have two or more examples in context of this research are examined according to these findings for providing more meaningful inferences.

As it is shown in the previous sections, difference between minimum and maximum values of "low awareness of BIM" is so high and this might be commented as this variable is not very big barriers for all road projects and its significance might be varied from project to another. Also this situation might be valid for the "unavailability of knowledge", "lack of government support", "unavailability of financial resources", and "lack of collaboration" too. On the contrary, for some enablers such as "high complexity of BIM" and "lack of guidance", "4" is assigned by the participants and this means that these two barriers causes' difficulties for road projects and these might be general barriers for the road projects. This analysis can be made for the enablers specific to road projects. All ratings which are assigned by the participants for enablers varies between 4 and 5. So it can be said that significance of the enablers which are discussed by the participants from the road projects might be general and ınclusive for the most of the road projects.

Another project type which is discussed according to these findings is dam projects. There are two different dam projects which are investigated for this research. The minimum and maximum ratings of market level barriers are so similar. Even ratings for the most of the market level barriers are equal. So it can be said that market level barriers have same significance over the different dam projects. For example, while "low awareness of BIM", "lack of interoperability between software", "high fragmented nature of industry" and "resistance to change" are evaluated as "1" for both dam projects, "unfavorable economic conditions" is evaluated as "5", this means that it is very significant and impactful barrier for BIM implementation in the dam projects. Among the organization level barriers, "high cost" are evaluated as very significant barrier and "5" is assigned by the professionals. On the contrary, there is a common view that "unsupportive organizational culture" is not very significant for the dam projects. Because there is consensus for these barriers, these might be considered as valid for most of the dam projects. If project level barriers are investigated, it can be seen that "1" is assigned for "unclear project benefits", "conflicting interest of parties" and "lack of collaboration" by both projects' professionals. These barriers are not very significant upon dam projects. On the other hand, for some barriers, the difference between minimum and maximum ratings is high and for these barriers it can be said that views which is determined by the professionals cannot be generalized and these barriers are not valid for the all dam projects. For example, professional assigned "1" as minimum and another professional assigned "4" as maximum for "unavailability of knowledge" and "lack of guidance". This discussion can be made for the enablers too. Among the market level enablers, "clear advantage and ease of use" is rated as "5" by the professionals. "High analysis ability and positive attitude of company" and "high project level collaboration" are evaluated as "4" by the both projects' professionals.

In addition to these, difference between the minimum and maximum ratings of some enablers is very small. For example, minimum rating of “open standards for BIM and National Library for BIM” is “1”, while maximum is “2”. So, because of the small difference, it can be said that it has small effects on the successful BIM implications on the dam projects. On the contrary, difference between minimum and maximum ratings of some enablers such as “availability of knowledge”, “external incentives and promotions” and “incentives to employee to use BIM” is too high. This means that the effects of these enablers are not same for all dam projects, their effects vary from project to another.

Another project type is metro projects. There is no consensus for the ratings of the barriers among the participants from the companies which are the clients of the metro projects. On the other hand, the difference between the minimum and maximum ratings is not so high too. So this means that the opinions of the participants for the barriers might be appropriate for the general. For example, minimum rating which is assigned for the “low awareness of BIM” and “difficulty in choosing appropriate contractor” is “3” while the maximum rating of these is “4”. In other words, effects of these barriers on the metro projects are not very significant but effects of them cannot be denied. For the enablers there are common views for some enablers. For example, minimum and maximum ratings of “availability of knowledge” are “4”. “4” means that the effects of this enabler is significant for successful BIM implementation and because of the consensus of participants effect of this barriers might be generalized for the most of the metro projects. In addition to this, ratings of “clear advantage and ease of use” is “3”. “3” interprets that this barriers is not very significant but its adverse effects on the BIM implementation cannot be denied. Also, for some enablers, difference between minimum and maximum ratings is very small. Minimum rating of “high analysis ability and positive attitude of company”, “positive attitude of managers”, “demand/satisfaction of the clients” and “collaborative working” are “4” and the maximum ratings for these are “5”. Because the difference are very small, these enablers help to professionals in metro projects for successful BIM implementation generally. On the contrary, the difference between minimum and maximum values of some enabler is high, for example, minimum rating of “availability of technological infrastructure" is "1" while maximum rating is "4" for this enabler. This means that the effects of this enabler upon success of BIM implementation may vary from project to another.

There is a consensus among the participants from the companies which are the clients of the building projects for some enablers such as "resistance to change" and "lack of transparency". For "resistance to change", all professionals assigned "5" and assigned "4" for "lack of transparency". This means that the adverse effects of these barriers are valid for almost all building projects. In addition to this, for some other barriers, there are no common view but difference between maximum and minimum values is very small in some barriers as in the other projects. It might be considered that the adverse effect of these barriers might be similar in other building projects. The minimum rating is "4" for "unfavorable economic conditions", "difficulty in choosing appropriate contractor", "high costs", "unsupportive organizational culture" and "unclear project benefits" while the maximum rating of them is "5". On the contrary, in some barriers, difference between the minimum and maximum values might be high. Especially, "high complexity of BIM", "unavailability of knowledge" and "lack of guidance" might be appropriate example for this because their minimum rating is "1" and maximum rating of them is "4". This can be commented as these barriers' effects are project specific and effects cannot be assumed as same in the all building projects. While enablers are investigated, there is fact that participants have consensus about effects of some enablers such as "clear advantage and ease of use", "developed legislative use", "well-organized BIM maturity plan" and "well prepared project BIM execution plan" and their minimum and maximum ratings are "5". This can be commented as these enablers have positive effects upon successful BIM implementation for most of the building projects. In addition to this, there are some enablers in which minimum and maximum values are so close such as "availability of technological infrastructure", "external incentives and promotions", "open standards for BIM and National Library for BIM", "improved technical and technological abilities", "high managerial abilities", "readiness to change" and "incentives to employee to use BIM". These enablers' minimum rating is "4" and maximum rating is "5". These are also accelerating BIM implementation and make this process faster for most of building projects. On the contrary, difference between minimum and maximum values of some enablers is too high for the building projects. This may be commented as these enablers' effects are not be generalized and effects of them are specific to projects. For example minimum value of "high qualified human resources" is 2, while its maximum value which is assigned by participants is "5". Another example for this is "collaborative working" because its minimum value is "3" and maximum value is "5". These difference are high with respect others.

Some barriers have common view of the participants in the oil refinery projects. For example, significance of "low awareness of BIM", "lack of transparency", "unavailability of knowledge", and "lack of government support". For "lack of government support", participant from oil refinery projects assigned "5" and for the others, they assigned "4". According to scale, these ratings are high and participants claim that these barriers have significant effects on their projects and prevent successful implementation of BIM. Because these enablers have consensus, the results of these can be considered as valid for the general of the oil refinery projects. On the contrary for some barriers, the difference between minimum and maximum ratings are high and this means that the results of the research cannot be generalize for most of the oil refinery projects. For example, minimum values of "legal uncertainties and restrictions" and "high cost" are "1" while maximum values of them are "4". Because of this, these barriers' effects are not same for every oil refinery projects. Same analysis can be made for the enablers' ratings of the oil refinery projects. As it can be seen from finding parts, there are consensus for some enablers. For example, for "availability of technological infrastructure" and "demand and satisfaction of clients", participants from the oil refinery projects assigned "4" as minimum and maximum ratings. In addition to these, as in the other projects, some enablers' have small differences between minimum and maximum values. For example, "4" is assigned as minimum value for "developed legislative regulations", "improved technical and technological abilities", "high analysis ability and positive attitude of company", "efficient training methods" and "readiness of organization to change" while "5" is assigned for these enablers a maximum value. Effects of these enablers are also generalized for other oil refinery projects and it can also be said that these are effective enablers for implementing BIM technology into their projects successfully. Actually difference between the minimum and maximum values of other enablers are not so high. There are no outliers in the ratings of the enablers according to clients of the oil refinery projects.

Last project type for this discussion section is railways. During the observation of the results of case study of railway projects, there are so many barriers that have high difference between minimum and maximum values. For “low awareness of BIM”, “high fragmented nature of industry”, “unavailability of knowledge”, “1” is assigned as minimum value while “5” is assigned for these barriers. The means that this barriers might be very preventive for some railway projects while for some projects, these may not be very big problems. Of course, there are some barriers that have very small differences between the minimum and maximum values even for some of them there are common views by the participants. For example, participants thought that the effects of some barriers is “4” and all of them gave only “4” to these barriers such as “lack of interoperability between BIM Software”, “resistance to change”, “legal uncertainties”, “difficulty in choosing appropriate contractor” and “lack of resources”. In addition to this, for some barriers, participants assigned minimum “4” and maximum “5”. “Unfavorable economic conditions”, “high costs”, “unwillingness of people in the company to change”, “unsupportive organization culture” and “lack of collaboration” can be shown as example for these enablers. For the railway projects none of the barriers is evaluated as insignificant. If enablers’ ratings are examined, it can be understood that each enablers are evaluated as significant by the participants. Almost all ratings which are assigned for enablers in the railway projects vary between “4” and “5”. So, because of this, it can be said that these enablers which are identified by the literature review are supportive for most of the railway projects. The ratings can be seen from the figure 4.9 in detail.

5.3.1. Discussion Based on BIM Functions Used in Projects

In addition to previous section, in this section, dimensions of BIM which are used in the case study projects are discussed and dimensions are compared. The projects which are conducted in the context of this research use 4D, 5D and 7D in their projects mostly. Four companies use 4D BIM, five of them use 5D BIM and two of them utilize from 7D BIM.

In oil refinery projects, they are using 5D BIM. By utilizing from the 5D BIM, they can schedule their construction and activities. In addition to this, by using 5D, they can also make cost estimation.

Lack of guidance is not very big barriers for the companies that are using 4D and 5D BIM technology. However, the professionals from the companies which use 7D BIM in the projects evaluated this barriers as very significant. The major reason for this might be 7D BIM is relatively new technology and guidance which include 7D is very difficult.

If the ratings of barriers which are assigned by the professional from project which use 7D BIM are investigated, it can be seen that “5” is assigned only for “lack of interoperability between BIM software”. In addition to this, none of the enablers are evaluated as less significant. The professional from this project said that by utilizing all enablers, they are trying to apply 7D BIM into their projects appropriately. So, by looking this example, it can be said that utilizing from almost all enablers as maximum as possible and minimizing the effects of barriers is very key for the successful 7D BIM implementation.

Lack of transparency is not evaluated as significant by the participants from companies that use 4D and 7D but it is very big barriers for successful BIM implementation according to companies that use 5D BIM in their projects. Lack of government support is assigned as “5” by 5D BIM users so it can be said that it is very important barriers and this prevents successful BIM implementation. However, 4D and 7D BIM users did not consider as very important. This can be commented as during the transition from 4D to another dimensions, government support is required. Independently from the used BIM Dimension, “high project level collaboration” is very significant enabler for success of BIM implementation because the ratings which are assigned by these professionals vary between 4 and 5.

6. CONCLUSION

As the main objective of this thesis, barriers for the implementation of BIM from the perspective of public construction projects' clients in Turkey have been investigated and identified. Enablers have also been included and identified although the major point of this research is identifying the barriers. The reason is that, of course identifying the barriers is very important but finding the enablers which can be used for eliminating the adverse effects of these barriers is also important.

As it is mentioned in the introduction part, one of the objectives of this research is identifying the barriers and enablers by reviewing the literature. Secondly, methods have been investigated for developing comprehensive framework which show what the barriers are and how they can overcome.

Additionally another objective of this research is evaluating the barriers and enablers with professionals in public construction clients for real case projects in Turkey. To achieve this objective, interviews were made with the professionals from Turkish public clients and their opinions about the significance of the identified barriers and enablers were asked too. According to their views, some findings have been obtained and discussions have been made. Participants have been divided into two groups: group 1 represents the projects in which BIM was enabled and group 2 represents the projects in which BIM was not enabled. Group 1 has answered the questions according to their experience and group 2 has evaluated the enablers according to their perceptions. So this research paper investigates also significance of barriers and enablers for during BIM implementation and for preparation process to start to implement BIM separately.

6.1. Conclusion Based on Research Findings

Differently from the other researches, this research is built upon a framework and especially, enablers and barriers components of this framework is investigated. Findings which are the results of the interview which were made with the interviewees from the public clients in of different types of construction projects in Turkey. Some of the interviewees are working in the projects in which BIM was enabled and some others are working in the projects in which BIM was not enabled. These are also investigated separately. General findings are shared in Chapter 4. In chapter 5, these findings are evaluated with respect to influence level and different project types.

In this research, different project types in which BIM is implemented and in which BIM is not implemented are investigated and participants from the Turkish public construction clients are conducted. Even, there are more than one participants from some projects. They have a consensus about some barriers and enablers, and their common view is used for this research. Thank to these, this research might be used to compare barriers and enablers with respect to different project types, sizes and some other features of the project. It can be said that this study fills an important gap by identifying barriers and enablers for the BIM implementation from the Turkish public client's perspective.

During the comparison between case study results and literature review's results, there is a fact that from some aspects, they are similar but from some aspects they are quite inappropriate with each other. For example, while a barrier might be the most important barrier according to the case study, it might be the least important in the literature review. On the contrary, the significance of some of the barriers or enablers is the same in both case study and literature.

The major barriers for the market level are identified as "lack of interoperability", "resistance to change" and "low awareness about BIM" according to results of group 1 while first three barriers are "unfavorable economic conditions", "difficulty in choosing appropriate contractor" and "resistance to change" according to the perception of participants from group 2.

Three most significant organization level barriers in projects that belong to group 1 are "high cost", "unsupportive organizational culture" and "unavailability of financial resources". However, the first three organization level barriers according to group 2 are “high costs”, “lack of resources” and “unwillingness of people in the company to change” in turn.

If project level barriers are examined by utilizing from the experience of group 1, it can be seen that first three barriers are “unclear project benefits”, “conflicting interests of parties” and “project complexity” while “project complexity”, “lack of collaboration”, “conflicting interests of parties” are in the first three places in the results of group 2.

The top three market level enablers according to their significance which has been assigned by the participants are “clear advantage and ease of use”, “availability of knowledge” and “availability of technological infrastructure”. Top three enablers are similar in the results of group 2 too. There are “clear advantage and ease of use”, “availability of knowledge” and “availability of technological infrastructure” respectively.

In organization level enablers, according to case study results of group 1, “high analysis ability and positive attitude of company toward BIM”, “readiness of organization to change” and “positive attitude of managers” are three most important enablers while according to the perception of participants from group 2, three most important organization level enablers are “positive attitude of managers”, “efficient training methods” and “well-organized BIM maturity plan”.

Lastly, for project level enablers, the top 2 enablers are the same in the results of group 1 and group. These enablers are “demand/satisfaction of clients” and “well prepared project BIM execution plan”.

In the discussion part, there is a comparison of barriers and enablers between clients, contractors and consultants. According to the results of this research, there are so many different barriers. However, according to literature that discussed the barriers and enablers from the perspective of the contractor and clients, barriers are related to time and costs mostly. These are related to the organization level. In addition to this, some of the researches have told that lack of awareness about BIM, interoperability problems between BIM software are important barriers for BIM implementation which are related to the market.

Lastly, this research has been conducted to public construction clients in Turkey. These results are appropriate for only public clients. However, the market level barriers are valid for both public and private clients such as lack of interoperability between BIM software, high complexity of BIM, unavailability of knowledge, lack of guidance and the lack of government. These barriers are going to be challenging for private clients in the the Turkish construction industry. However, the organization level conditions for private clients are different from the conditions of the public clients and it can be said that private clients might be more advantageous than the public clients in Turkey. Especially, economic conditions and financial resources may be less challenging for them. Of course, high costs are going to be very important barriers for them too but they can minimize the effects of high costs easier thanks to better organizational conditions. There are some barriers such as project complexity, conflicting interest of parties in the project level. It can be thought that these barriers are going to be valid for the Turkish construction private clients too. These might be also valid for the enablers. For example, market level enablers such as availability of technologic infrastructure, external incentives and promotions, open standards for BIM are going to be very important for private clients in Turkish construction industry too. On the contrary, private clients in Turkey have advantages in terms of organization level enablers. As it is discussed in the previous parts, of course, enablers are important for public clients and these make BIM implementation easier for them. However, private clients might utilize from the organization level more. For instance, Turkish private clients may have better technological abilities, higher qualified human resources and stronger financial resources. For instance, there are some hospital and building projects that are constructing by the private clients. In these hospital projects, BIM usage is more common because the employee in these clients have better knowledge about BIM. In addition to this, private clients make BIM implementation obligatory in these projects.

6.2. Recommendations

If developments of the other countries are examined, it can be seen that Turkey is at the beginning stages of the BIM implementation and there is a very long way to go for achieving complete implementation of BIM in the projects. This research includes 31 professionals from different Turkish public construction clients whose disciplines are different from each other. Even, from some projects, there are more than one participant that come together and they have consensus about the effects of barriers and enablers to the implementation of BIM. From this perspective, this research might be useful for showing the barriers and enablers. Additionally, the transitions and changes should be started from the clients because they are decision makers. This research investigates from the clients' perspective and this research might be used for identifying barriers and giving a start for the changes.

This research investigates the barriers and enablers in three influence levels such as market level, organization level and project level. Because of this, investigating the recommendation in these influence levels might be useful too.

6.2.1. Market Level Recommendations

Actually, market level barriers and enablers are more inclusive than the other influence level. Because of this, changing and enhancing the conditions of the market is very important and difficult as well. If market level barriers' effects can be minimized and the effects of market level enablers can be increased, the appropriate environment for BIM implementation might be offered to clients in the Turkish AEC industry.

As it can be recognized from the finding and discussion parts there are 12 identified market level barriers. According to the experience of participants from group 1, lack of interoperability between BIM software is a very big problem for them and this makes them slower. During the selection process of appropriate BIM software, this barrier should be considered. The most important barrier for group 2 is discussed as "unfavorable economic conditions". So, this means that the biggest barrier for the companies that are planning to start to implement BIM in their projects is economic problems. Also, BIM is still very immature in Turkey and because of this, none of the parties are very expert in the BIM usage. This causes difficulties in finding experienced and appropriate contractors, even clients are willing to implement BIM to projects. Especially for group 2, this is a very big problem because to start to implement BIM, they have very big concerns about contractor selection. Because of this, contractor should also develop themselves too. To train the contractors about BIM, efficient methods should be implemented.

If case study ratings for group 1 and group 2 are investigated separately, it can be seen that ratings of the enablers in the market level are similar. Telling the clear advantages and ease of use of BIM may accelerate the implementation of BIM in the projects which belong to both group 1 and group 2. Other important enablers are "availability of knowledge" and "availability of technological infrastructure". BIM is related to technological developments so much and because of this, improving technological infrastructure makes BIM implementation efficient for both BIM implementation process and pre-BIM process. Also, some other methods for increasing know-how such as receiving consultancy is going to be useful.

If these barriers are eliminated and these enablers are improved, the Turkish AEC market may become more developed. This increases the efficiency in the market inevitably.

Table 6.1. Recommendations for market level barriers.

RECOMMENDATIONS FOR MARKET LEVEL		
Challenges	**Enablers and Solutions in Practice**	**Proposed Strategy**
Lack of interoperability between BIM Software	Availability of technological infrastructure	During the selection process of tools choosing compatible BIM tools with each other
Unfavorable Economic Conditions	Strong financial resources	For eliminating the effects of enfavorable conditions, making consistent estimation and allocating enough financial resources
High complexity and immaturity of BIM	Improved technical and technological abilities	Efficient training methods and clarifying the use of BIM, providing easy integration, using communication technology, providing lifecycle information management, increasing organizational learning capacity
Low awareness about BIM, lack of knowledge	Availability of knowledge, internal&external knowledge	Academic partnership between industry and academia, utilizing from the academic researches about BIM
Difficulty in choosing appropriate contractor	High managerial ability, high analysis ability, clarifying the abilities of the chosen contractor	Increasing the awareness of contractors about BIM
Legal uncertainties/ restrictions	Developed legislative regulations	Improving legal aspects, identifying data protection procedure, clarifying responsibilities and roles
Lack of government support	External incentives and promotions	Preparing stimulus package, giving some incentive and priveleges to companies which enable BIM
Lack of guidance	Open Standards for BIM and National Library for BIM	Developing common standards, make these standards and libraries more clear

6.2.2. Organization Level Recommendation

In addition to developments in the market level for successful BIM implementation, it is not enough on its own. Organizations that are active in the AEC industry should improve themselves and their conditions. Even sometimes, companies' performance might be more important than the market. The findings which are interpreted in this research might be very useful for Turkish clients to identify their barriers and enablers.

According to the findings, the most important barrier is high cost for both group 1 and group 2. This means that both initial investment and operating costs such as updating, software and so on are high. Actually, companies may not affect the costs but they can divide more financial resources for these investments. This is hardly related to the culture of organization and "unsupportive organizational culture" is the second most important barrier for group 1 which includes the project in which BIM was enabled. Because of the high updating costs, the organization should support BIM implementation. Actually, for an organization, all of these barriers are related to each other. As it is mentioned in the market level recommendation part, if the advantages of BIM can be told, awareness of top managers and organizations about BIM increases, they might be convinced to divide more resources and budget for BIM investments. Participants from group 2 who have evaluated the barriers according to their perception told that lack of other resources such as qualified personnel, training methods are very big problems for them. The companies that are planning to implement BIM into their project should arrange their human resources and methods according to these requirements.

If the results of group 1 and group 2 is investigated separately, it can be seen that the rankings of organization level enablers are quite different from each other. The most important enabler is high analysis ability and positive attitude of the company for group 1. Actually, this means that, if a company that implementing BIM analyzes the costs and benefits of BIM properly, it can be seen that BIM becomes very efficient for them and their mind about BIM can be changed positively. This is very important and impactful enabler. Another important enablers for group 1 are readiness of organization to change and positive attitude of managers. Attitude of managers are related to attitude of company. Because readiness of organization to change is very important, the companies should tell the BIM clearly for increasing the efficiency. For the companies which have not implemented BIM yet in their projects, positive attitude of managers, efficient training methods and well-organized BIM maturity plan are very important. Because of this, these types of companies should focus on training their employee by using efficient methods and preparing BIM plan very well. If plan is good and appropriate the results for them is going to be well too. These can be seen from the Table 6.2.

Table 6.2. Recommendations for organization level barriers.

RECOMMENDATIONS FOR ORGANIZATION LEVEL		
Challenges	**Enablers and Solutions in Practice**	**Proposed Strategy**
High costs	Strong financial resources	Decreasing cost is very difficult because of this, to overcome this challenge, enough financial resources may be allocated
Unsupportive organizational culture	Readiness of organization to change	Telling the clear advantages of BIM and telling that the BIM usage make easier the activities in the projects for every parties, making cost -benefit-risk analysis
Unavailability of financial resources, Lack of resources	Improved technical and technological abilities, technological improvements in organization enhancing the scope of BIM, strong financial resources	Training human resources, preparing courses and raising awareness about BIM in colleges, internal and external staff trainings
Unwillingness of people in the company to change	Efficient training methods, telling clear advantages and the ease of BIM usage	Telling that BIM usage make the acrivities easier and telling the other advantages of BIM

6.2.3. Project Level Recommendation

Actually identified barriers of project level are not considered as very important. However, starting a switch to BIM from the smallest unit is very important. This means that, if effective usage of BIM is expected, minimizing the effects of barriers in the project level is easier and the outcomes might be achieved in shorter time in contrast with market level and organization level. Related enablers and proposed strategies are shown in Table 6.1.

Table 6.3. Recommendations for project level barriers.

RECOMMENDATIONS FOR PROJECT LEVEL		
Challenges	**Enablers and Solutions in Practice**	**Proposed Strategy**
Unclear project benefits	Clear advantage and ease of use	To clarify the benefits, giving trainings to staff
Conflicting interest of parties	Making the roles and expectation of parties clear from the beginning	Increasing the communication between the parties, providing the clarify the expectations of each parties from the beginning, telling that the BIM usage decreases these conflicts
Project complexity	Well prepared project BIM execution plan	Providing efficient communication among the parties, using cross functional cooperation, make information sharing easier
Lack of collaboration	High project level collaboration	Early user involvement, using IPD, early contractor involvement

The companies that have already implemented BIM in their projects have evaluated “unclear project benefits” as the most important barrier according to their experiences. So the companies like that should focus on clarifying the advantages of BIM in project level. Another important barrier for group 1 is conflicting interests of parties and because of this, expectations of different parties should be clarified. Participants from group 2 that have not implemented BIM yet told that “project complexity” is a very big barrier. To make simpler the projects they might divide projects into sections and by this way, they might handle with this barrier. Another project level barrier for group 2 is lack of collaboration and to overcome this barrier, they may find some ways and solutions for providing effective communication.

The demand and satisfaction of the client is the most determinant enabler for both companies and projects. Because of this, clients should determine the regulations about BIM and identify these into contracts. By this way, both clients and contractors may become more profitable. The second important enabler for both groups is well-prepared project BIM execution plan. As it is mentioned in the organization level, preparing a plan and adapting this plan make BIM implementation efficient. In addition to this, a possible problem might be foreseen by this way.

6.3. Future Research

If researches about BIM implications are investigated in detail, it can be seen that the CSFs are investigated from all perspective. However, there are so many parties which are involved in construction projects and CSFs can be varied according to parties. This research investigates the barriers for the successful BIM implementation from the perspective of clients. In the future, ıf some studies investigates the barriers from the other parties’ perspectives, it is going to be useful. On the other hand, CSFs have been usually investigated in general. For example, the number of researches that investigate barriers, enablers, drivers, inputs, benefits separately are not so many. If these types of researches are prepared in the future, the methods for successful BIM implementation can be found easier. This research might be seen as similar with the other researches, however, barriers and enablers are investigated from the perspective of the Turkish AEC industry's clients more specific. For further studies, the framework which is utilized in this research may give an idea.

In our days, in practice, so many companies are using the fourth or fifth dimensions of BIM. Some companies have started to switch to sixth or seventh even eighth dimension BIM. However, as it is discussed in the discussion part, the companies that are using sixth, seventh, eighth dimension of BIM have troubles finding resources about the latest dimensions of BIM. These dimensions of BIM are related to energy efficiency and facility management. If the number of researches that approach the latest dimension of BIM, companies may become aware about the different using area of BIM. It might be useful for industry and the efficiency of companies might increase. As the importance of energy efficiency increases, the number of these types of research should be increased. By this way, 6D BIM and the importance of awareness of energy conservation can be understood by so many professionals in the industry. In addition to these, the interview which is provided data for this research is conducted to professionals who are working on the on-going projects. Turkey is very good and advanced in the AEC industry and as it is mentioned in the application area of BIM, as technology is improved, new application areas appear. For example, one of them is laser scanning. Making research in this area might be very useful for industry and direct professionals about different applications. This research investigates the barriers from the clients as it is mentioned in the previous parts. Actually, clients are very important in the decisions and as it is discussed in the discussion part, the demand of clients are very determinant in the BIM usage, for example, which software should use, in which stage of the projects, software should use are specified in the contracts. There are lack of studies about BIM usage in the contract management area. Additionally, the importance of understanding the advantages of BIM is told in the findings and discussion parts. Actually, if these advantages could be shown to stakeholders, clients and so on, these parties might be convinced easily and they might become willing to implement BIM in their projects and even they make BIM usage in projects obligatory. Because of this, some researches that focusing only upon showing the clear advantages of BIM should be made and it might be a very good research area.

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APPENDIX A: INTERVIEW FORM

BOĞAZİÇİ UNIVERSITY
INSTITUTE OF GRADUATE STUDIES IN SCIENCE AND ENGINEERING
CIVIL ENGINEERING DEPARTMENT
CONSTRUCTION MANAGEMENT MASTER THESIS QUESTIONNAIRE

	Thesis	:
	Student	:
	Professor	:
	General Information (Respondent)	
1	Name/Surname	:
2	Age	:
3	Your Profession in construction industry	:
4	Your position in your company	:
5	How many years have you been working in industry?	:
6	How many years have you been working in this company?	:
	General Information (Company)	
7	Company Name	:
8	Field of operation	:
9	Company's expertise areas	:
10	Annual turnover of your company(in M$)	:
11	Total number of years that your company has been operating	:
12	Total number of projects	:
13	Year that your company adopted BIM	:
14	Establishment year of your company	:
15	Which project did you choose for benchmarking first?	:
16	Number of finalized projects of your company?	:
17	How many of them did you apply BIM?	:
	General Information (Project)	
18	Project name	:
19	Project type	:
20	Project ownership	:
21	Total construction area	:
22	Contract type	:
23	Delivery type	:
24	Contractual budget of the project	:
25	Duration of the project	:
26	Total amount of time savings	:
27	Total amount of BIM investment	:
28	Is there a BIM team/Number of people	:
29	Software	: Revit/ 3D Studio Max/ ArchiCAD/ Dynamo/ GIS
30	Why did you choose to adopt BIM to this Project?	:
31	In which parts of the Project, BIM is utilized?	:
32	Do you feel that BIM facilitates activity?	
33	Can you tell the development of BIM usage from the beginning of the Project?	:

Figure A.1. Interview Form 1.

Please indicate the importance level of the relevant enablers in your project (1-Lowest-5 Highest)

Market Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Availability of knowledge	Internal&External Knowledge, company know-how, consultancy, increased research and development in the industry and academia, academic partnership and research teams					
Clear advantage and ease of use	Tangible benefits of BIM, easy application of BIM					
Availability of technological infrastructure	Technological developments enhancing the scope of BIM, availability of databases, data richness, easy integration and communication, Standard platforms for integration & clear communication among staff, use of communication tech					
External incentives and promotions	Governmental support and pressure					
Open Standards for BIM and National Library for BIM	Common standards and protocols					
Developed legislative regulations	Legal aspects, data protection, shared risk and liability, roles&responsibilities					

Organization Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Improved technical and technological abilities	Developments of BIM Tools, communication between BIM Tools (Interoperability), Developed BIM Tools, their usability, appropriate software, technological improvements in organization enhancing the scope of BIM					
High managerial ability	Developing knowledge management system, lifecycle information management, organizational learning capability, experience					
High analysis ability and positive attitude of company	Cost-benefit-risk analysis, ROI, risk aversion					
High qualified human resources	Qualified staff&leader, trained human resources					
Strong financial resources	Investment ability of company to BIM					
Efficient training methods	Internal and external staff trainings					
Positive attitude of managers	Acceptance by Stakeholders, top management, supportive supervisors					
Readiness of organization to change	Supportive culture, cultural change management, commitment					
Well-organized Bım maturity plan	Advanced project monitoring, strategic vision and plan, previous experience					

Project Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Well prepared project BIM execution plan	Standardization of BIM process, business process reengineering					
Demand/Satisfaction of Client	Contractual obligation					
High project level collaboration	Developped collaboration skills, cross functional cooperation, open communication and information sharing, willingness of project parties (Project manager, architect, field engineer, subcontractor)					
Incentives to employee to use BIM	Rewards and Recognition					
Collaborative working	Early user involvement, integrated project delivery, early contractor involving					

Figure A.2. Interview Form 2.

Please indicate the importance level of the relevant enablers in your project (1-Lowest-5 Highest)

Market Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Availability of knowledge	Internal&External Knowledge, company know-how, consultancy, increased research and development in the industry and academia, academic partnership and research teams					
Clear advantage and ease of use	Tangible benefits of BIM, easy application of BIM					
Availability of technological infrastructure	Technological developments enhancing the scope of BIM, availability of databases, data richness, easy integration and communication, Standard platforms for integration & clear communication among staff, use of communication tech					
External incentives and promotions	Governmental support and pressure					
Open Standards for BIM and National Library for BIM	Common standards and protocols					
Developed legislative regulations	Legal aspects, data protection, shared risk and liability, roles&responsibilities					

Organization Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Improved technical and technological abilities	Developments of BIM Tools, communication between BIM Tools (Interoperability), Developed BIM Tools, their usability, appropriate software, technological improvements in organization enhancing the scope of BIM					
High managerial ability	Developing knowledge management system, lifecycle information management, organizational learning capability, experience					
High analysis ability and positive attitude of company	Cost-benefit-risk analysis, ROI, risk aversion					
High qualified human resources	Qualified staff&leader, trained human resources					
Strong financial resources	Investment ability of company to BIM					
Efficient training methods	Internal and external staff trainings					
Positive attitude of managers	Acceptance by Stakeholders, top management, supportive supervisors					
Readiness of organization to change	Supportive culture, cultural change management, commitment					
Well-organized Bim maturity plan	Advanced project monitoring, strategic vision and plan, previous experience					

Project Level						
Enablers	**Description**	**1**	**2**	**3**	**4**	**5**
Well prepared project BIM execution plan	Standardization of BIM process, business process reengineering					
Demand/Satisfaction of Client	Contractual obligation					
High project level collaboration	Developped collaboration skills, cross functional cooperation, open communication and information sharing, willingness of project parties (Project manager, architect, field engineer, subcontractor)					
Incentives to employee to use BIM	Rewards and Recognition					
Collaborative working	Early user involvement, integrated project delivery, early contractor involving					

Figure A.3. Interview Form 3.