An Ontological Study on the State of the Turkish Construction Industry and its Implementation of Building Information Modeling (BIM)

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ABSTRACT

Due to the inconvenience of old and traditional ways of work in the Architecture, Engineering and Construction (AEC) industry, Building Information Modeling (BIM) was introduced and is considered as one of the most beneficial and successful developments in the industry since it provides accurate virtual models for digital construction as well as it is best known for reducing mistakes and errors by improving the coordination between various design areas.

BIM technology is progressively being implemented in many countries, however there is contrast in the usage and awareness among these countries in which some of them appear to utilize and be aware of such technology more than others. In the case of a country like Turkey, it falls behind other countries like Finland and Canada when it comes to advanced implementation of BIM in construction. For this reason, an ontological study on the state of the Turkish construction industry and its BIM implementation is carried out to investigate the work processes in the industry and to see how frequently BIM is implemented. A quantitative research methodology is adopted in this study to acquire statistical information about the work processes in the Turkish construction industry and its BIM implementation. At the end of this study, BIM implementation in Turkey is found to be limited as it is rarely used by the Turkish construction industry. Moreover, an ontological framework for BIM implementation in Turkey is created which can be used to aid Turkish construction companies in adopting and implementing BIM in a more effective way.

Keywords: BIM, Ontological framework, Turkey, Turkish construction industry.

ÖZ

Mimarlık, Mühendislik ve İnşaat (AEC) endüstrisindeki eski ve geleneksel çalışma biçimlerinin sıkıntısı nedeniyle, Bina Bilgi Modellemesi (BIM) tanıtıldı ve doğru sağladığı için sektördeki en faydalı ve başarılı gelişmelerden biri olarak kabul ediliyor. dijital yapı için sanal modeller ve çeşitli tasarım alanları arasındaki koordinasyonu geliştirerek hataları ve hataları azaltmak için en iyi bilinir.

BIM teknolojisi birçok ülkede aşamalı olarak uygulanmaktadır, ancak bu ülkeler arasında, bazılarının bu teknolojiyi diğerlerinden daha fazla kullandığı ve farkında olduğu görünen ülkeler arasında kullanım ve farkındalık konusunda bir tezat vardır. Türkiye gibi bir ülke söz konusu olduğunda, BIM'in inşaatta ileri düzeyde uygulanması söz konusu olduğunda Finlandiya ve Kanada gibi diğer ülkelerin gerisinde kalmaktadır. Bu nedenle, sektördeki iş süreçlerini araştırmak ve BIM'in ne sıklıkta uygulandığını görmek için Türk inşaat sektörünün durumu ve BIM uygulaması üzerine ontolojik bir çalışma yürütülmektedir. Bu çalışmada, Türk inşaat sektöründeki iş süreçleri ve BIM uygulaması hakkında istatistiksel bilgi elde etmek için nicel bir araştırma metodolojisi benimsenmiştir. Bu çalışmanın sonunda, Türkiye'deki BIM uygulamasının Türk inşaat endüstrisi tarafından nadiren kullanıldığı için sınırlı olduğu görülmüştür. Ayrıca, Türkiye'de BIM uygulaması için, Türk inşaat şirketlerinin BIM'i daha etkin bir şekilde benimsemelerine ve uygulamalarına yardımcı olmak için kullanılabilecek ontolojik bir çerçeve oluşturulmuştur.

Anahtar Kelimeler: BIM, Ontolojik çerçeve, Türkiye, Türk inşaat sektörü.

DEDICATION

I dedicate this thesis to my family who has supported me from the very beginning throughout the making of this study.

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LIST OF ABBREVIATIONS

AEC	Architecture, Engineering and Construction
AGC	Associated General Contractors of America
AIA	American Institute of Architects
BDS	Building Description Systems
BIM	Building Information Modeling
BPM	Building Product Model
CAD	Computer Aided Design
GBM	Generic Building Model
GLIDE	Graphical Language for Interactive Design
HVAC	Heating, Ventilation and Air Conditioning
IPD	Integrated Project Delivery
ROI	Return On Investment
MEP	Mechanical, Electrical and Plumbing
NBIMS	National Building Information Modeling Standard
NIBS	National Institute of Building Sciences
UAE	United Arab Emirates

Chapter 1

INTRODUCTION

1.1 Introduction to the Research

In the past before BIM was introduced, the Architecture, Engineering and Construction (AEC) industry relied on traditional approaches that were used to progress in whatever work was presented. However, these traditional practices had their flaws and limitations in the industry which made them inconvenient in some occasions. For instance, the nature of the AEC industry is that it is separated and disintegrated as it is branched into several fields, areas, groups and stakeholders. (Latham, 1994). For that reason communications are considered important. But since traditional means of communications are usually paper-based according to Arnorsson (2012), any mistakes or clashes that would be included in paper documents will create delays and other kinds of obstructions like over-costs and possible claims between teams of the construction project. (Saad, Baba, & Amoudi, 2015). Another example of how inconvenient traditional procedures can be is that it can be difficult to comprehend the features and properties of a construction project as well as it is tough to obtain the needed information due to the overabundance of construction documents which could contain 2D drawings, specifications and requirements, and bill of quantity papers. (Büchmann-Slorup & Andersson, 2010).

The concept of BIM emerged in the late 1970s from Professor Charles Eastman at the Georgia Tech School of Architecture. (Reddy, 2011; Latiffi et al., 2013). In the mid-2000s, it was begun to be used by the AEC industry in construction projects. (Latiffi et al., 2013; Azhar et al., 2008). With the introduction of BIM and its rapid evolution in the AEC industry, it is considered as one of the most advantageous and successful developments in the industry since it offers precise virtual models for digital construction. (Tam & Le, 2019). It also has useful features like detecting clashes, analyzing concept designs, and the inclusion of a database that can contain all kinds of information such as architecture and construction designs, bill of quantities and cost estimates into one 3D model. (Czmoch & Pękala, 2014). Furthermore, one of the most beneficial uses of BIM is minimizing mistakes and errors by having the capability to enhance the coordination between various design specialties. It also has the ability to provide expected costs, quality, and on-time delivery based on the client's demands. (Sinopoli, 2010).

Seeing Turkey implement BIM in their construction projects like the Istanbul Grand Airport is a good thing for the Turkish construction industry since they were able to reduce costs that would have been incurred had they not implemented BIM in that project. (Koseoglu, Sakin, & Arayici, 2018). However, even though the Turkish construction industry is making billions of dollars' worth of construction, it is still falling behind compared to other countries that excel in implementing BIM like Finland and Canada as there are few Turkish construction companies that use BIM nowadays. For this reason, an ontological study on BIM implementation in Turkey is conducted to investigate the Turkish construction industry and its current normal work processes and to see if BIM is widely implemented or not.

Before talking about the ontological study of this thesis, the term "ontology" needs to be known first. There are many definitions for ontology. According to McQueen &

McQueen (2010), Ontology is “the branch of metaphysics which studies ‘being’. It considers what types of things there are in the world and what ‘parts’ or ‘substances’ the world can be divided into” (p. 151). Another definition for ontology according to Smith (2012) is “the science of ‘what is’, of the kinds and structures of objects, properties, events, processes and relations in every area of reality” (p. 47). Ontological analysis is used to explain the knowledge structure and without it, there cannot be a vocabulary for knowledge representation. (Aliyu et al., 2015). In summary, ontology focuses on the nature of existence and structure of reality.

There are two ontological positions or assumptions in social sciences which are objectivism and constructionism/subjectivism. Objectivism according to Bryman (2016) is “an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors” (p. 29). An example of objectivism is the following: If there is a red car on the road and some people saw the car, they would know that the color of the car is indeed red. Hence the “color” of the car is objective, which is a fact that cannot be changed whatsoever. For constructionism or subjectivism, Bryman (2016) defined it as “an ontological position that asserts that social phenomena and their meanings are continually being accomplished by social actors” (p. 29). An example of constructionism or subjectivism is the following: If there is car of a certain model on the road and some people saw the car, some of them would think that the car visually looks good while others would think that it looks bad. Hence the “look” of the car is subjective, which is dependent on what people may perceive it.

In research studies, a quantitative research is considered as an objective one since it involves accurate measurement and analysis of target concepts where questionnaire surveys are usually used and the data is interpreted in the form of numbers and statistics. While a qualitative research is considered as a subjective one since it involves individuals' interpretations of events and occurrences where interviews, observations and case studies are usually included and the data is interpreted in the form of words, pictures or objects. (Neuman, 2000).

In this thesis, the ontological study is an objective one where a quantitative approach is involved for the purpose of investigating the Turkish construction industry and its BIM usage. Furthermore, a framework is eventually provided to help the industry in adopting the BIM technology.

1.2 Scope, Aim and Objectives

It is important to see how the development of BIM influences the Turkish construction industry since its usage is becoming more common globally nowadays. It is also important to give insight about the state of the construction industry in Turkey and how its work processes affect BIM adoption overall. It must be noted that the study is limited to include only primary data collected from industry professionals working in Turkish construction firms and organizations in which some of them use BIM while others do not.

Since this thesis is an ontological study, its aim is to investigate and check the Turkish construction industry and its work processes as well as to see if BIM is widely implemented in the industry or not. Also, this study aims to help the Turkish construction industry in implementing BIM.

The objectives needed to reach the goal are as follows:

- To find out information about the BIM technology and get a general understanding of its impacts.
- To design a questionnaire survey that can be used to investigate the work processes of the Turkish construction industry as well as its BIM usage.
- To produce an ontological framework that can aid the Turkish construction industry in adopting BIM in a better way.

1.3 Research Methodology

The research methodology for this study is briefly explained in several steps:

- Carry out a literature review that covers general information about BIM as well as its impacts that are mentioned in various case studies.
- Make a questionnaire survey that is distributed to professionals in Turkish construction companies where they are asked to provide information BIM implementation and the work processes used in the industry.
- Conduct descriptive analysis on the survey results and discuss the overall outcome of the survey.
- Generate an ontological framework for BIM implementation in Turkey which is based on several factors that can affect the adoption process.

1.4 Achievements

What is achieved in this study is the identification of the work processes used in the Turkish construction industry and how it is affected based on various factors. This study also identifies how often BIM is implemented in Turkey, what benefits are gained and what challenges are encountered from using such technology. Another achievement in this study is the production of an ontological framework which can be used to assist Turkish construction firms and organizations in adopting and utilizing BIM to its fullest extent.

1.5 Thesis Outline

This thesis is divided into six chapters including the introduction. Chapter 2 is the literature review which covers general information about BIM. Chapter 3 talks about the impacts of BIM implementation mentioned in different case studies. Chapter 4 covers the research methodology and its results in which it mentions the method used for data collection and how data is analyzed as well as the results and the overall outcome of the research methodology. Chapter 5 includes an ontological framework for BIM implementation in Turkey that can help in adopting the technology. Chapter 6 is the conclusion which concludes the thesis as well as it includes recommendations for future researches and studies.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

For the purpose of enhancing the efficiency of construction projects, the construction industry is increasing the utilization of technological solutions. One of these solutions is BIM which is one of the technological approaches that establishes a whole new working environment in the industry. (Hamdi & Leite, 2013). It is also considered as one of the most favorable developments in the AEC industry. (Eastman et al., 2008). BIM is known as a process that includes the application and preservation of an essential digital rendition of all building data for different stages of a project lifecycle in the form of a data repository. (Gu & London, 2010). It is also known as a group of technologies and solutions that improve cooperation and efficiency between organizations as well as enhance design, construction and maintenance applications in the construction industry. (Miettinen & Paavola, 2014). From 2D designs to 3D models, BIM has evolved to create representations that are modeled around a database of a project's physical and practical features. (Uddin & Khanzode, 2013).

By reading this chapter, readers will learn that BIM has many names and various definitions in literature. They will also learn that BIM brought a lot of benefits and advantages to the AEC industry as it is not just a technology with multiple dimensions, but is also a process that aids the collaboration between stakeholders and helps in project delivery. The readers will acquire knowledge of the different kinds of specialists that operate in BIM tasks and the several programs and software used in various fields in the AEC industry. Furthermore, the top enablers and barriers of BIM implementation identified from different authors will be listed as well. All of these data and information about BIM which are obtained and gathered from different literature are great for familiarizing the readers about the existence of such technology in general.

2.2 Status of BIM Usage and Awareness

BIM is progressively being implemented in many countries, however there is contrast in the usage and awareness between these countries in which some of them appear to utilize and be aware of such technology more than others. In a study made by Shaikh, Raju, & Malim (2016) about the global status of BIM, they showed the differences among different countries regarding the awareness and adoption of BIM. The countries included are developed countries, India, and Middle Eastern countries. Figure 2.1 shows the rates of awareness and usage of BIM in developed countries.

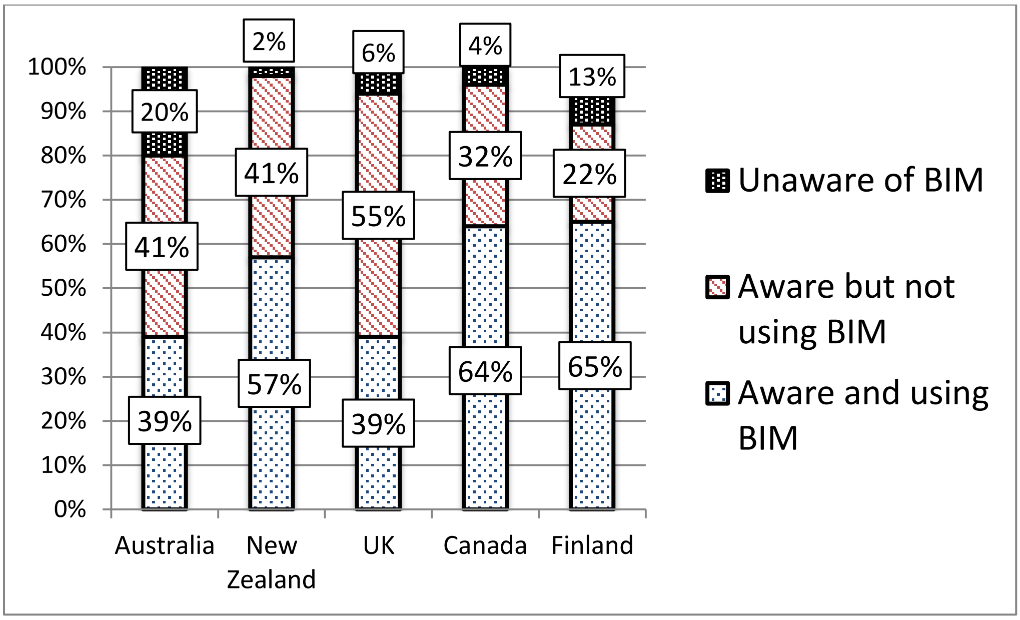

Figure 2.1: BIM Awareness and Usage in Developed Countries

Finland and Canada are the countries with the highest rates of awareness and usage of BIM technology with percentages of 65% and 64% respectively. The country that has most of its people being aware of BIM but not use it is the UK with a percentage of 55%. New Zealand, Canada and the UK have the lowest rates of unawareness for BIM technology with percentages of 2%, 4% and 6% respectively. Overall, these developed countries are very advanced when it comes to implementing BIM in the construction industry regardless of the differences in the rate of awareness and usage among them.

For a country like India, which is trying to adopt and utilize BIM in the construction industry, 41% of its people are aware of BIM but do not use it while those who are aware and are trying to use BIM account for 27% as seen in Figure 2.2. 22% of people in India are aware of BIM as well as use it while only 8% are unaware of the technology.

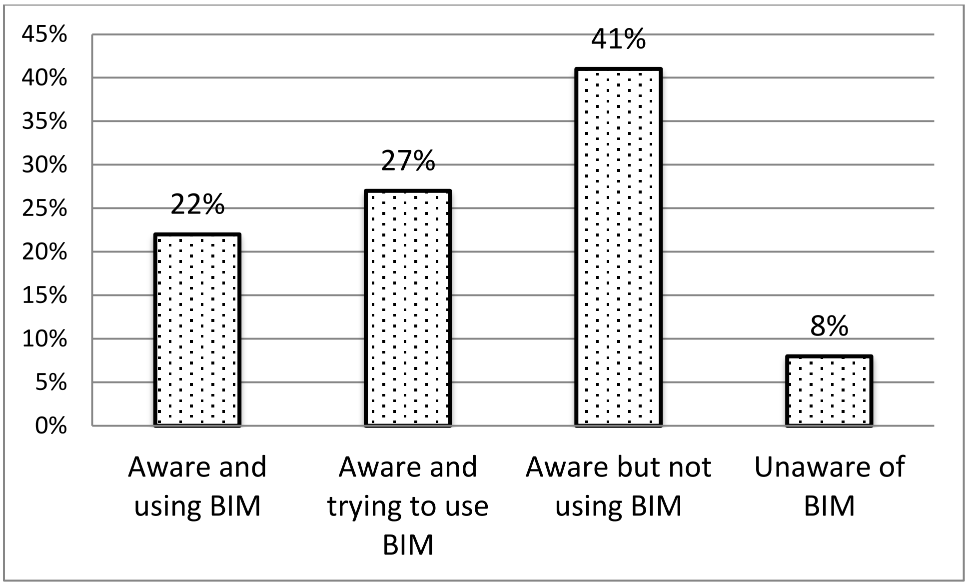

Figure 2.2: BIM Awareness and Usage in India

In the Middle East, there are countries that implement or are trying to implement BIM while others are too far behind when it comes to using the technology. Majority of people that use BIM in the Middle East reside in the UAE with a percentage of 77% while a country like Jordan has the lowest rate of BIM usage with only 7% of people operate in BIM procedures as displayed in Figure 2.3. Other countries like Saudi Arabia (41%) and Qatar (35%) have a fair amount of people that utilize BIM. The possible reason behind UAE having the highest rate of BIM usage among Middle Eastern countries goes back to Dubai Municipality in UAE mandating the use of BIM since 2013 as a strategy to address the declining productivity in the construction industry, thus increasing BIM usage overall.

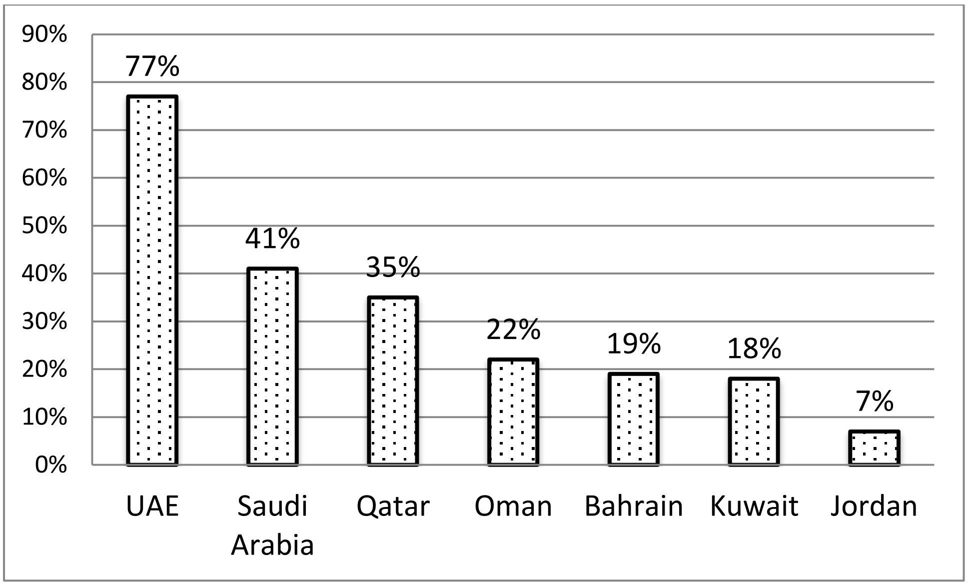

Figure 2.3: Rate of BIM Usage in Middle Eastern Countries

2.3 Definition of BIM

According to the National Building Information Modeling Standard (NBIMS) committee which is a part of the National Institute of Building Sciences (NIBS), BIM is defined as the usage of advanced digital technologies to create a computable rendition of all physical and functional attributes of a facility with its life cycle interconnected data. BIM is considered as a repository of information that is utilized and preserved by owners of facilities throughout its life cycle. (NBIMS, 2010).

Another BIM definition was interpreted by the Associated General Contractors of America (AGC). It defined BIM as the expansion and utilization of computer software models for the purpose of simulating a facility’s construction and operation. The models used provide insightful and parametric digital depictions of facilities which are object-oriented and abundant with data. These models can aid in decision making and enhance the facility delivery process. (AGC, 2005).

The American Institute of Architects (AIA) defined BIM as a digital three-dimensional model connected to a database of project data. It is known as one of the most important technologies to aid the Integrated Project Delivery (IPD) since it has the ability to incorporate many things such as design, fabrication data, erection commands, and project management logistics in one database. It also offers a stage for collaboration during the design and construction of a project. (AIA, 2007).

Latiffi, Brahim, & Fathi (2014) showed that BIM possessed different names back when it had limited applications. In the 1970s, it was called Building Description Systems (BDS) then later called Graphical Language for Interactive Design (GLIDE). In the 1980s, it was labeled as Building Product Model (BPM). In the 1990s, it was named Generic Building Model (GBM). After that in the 2000s and beyond, it got the name "Building Information Modeling" (BIM) which was defined as a constructed model that illustrates building elements which can be utilized as a device to manage data, plans, tasks and operations that are required for all phases of a construction project. Figure 2.4 shows the evolution of BIM definition.

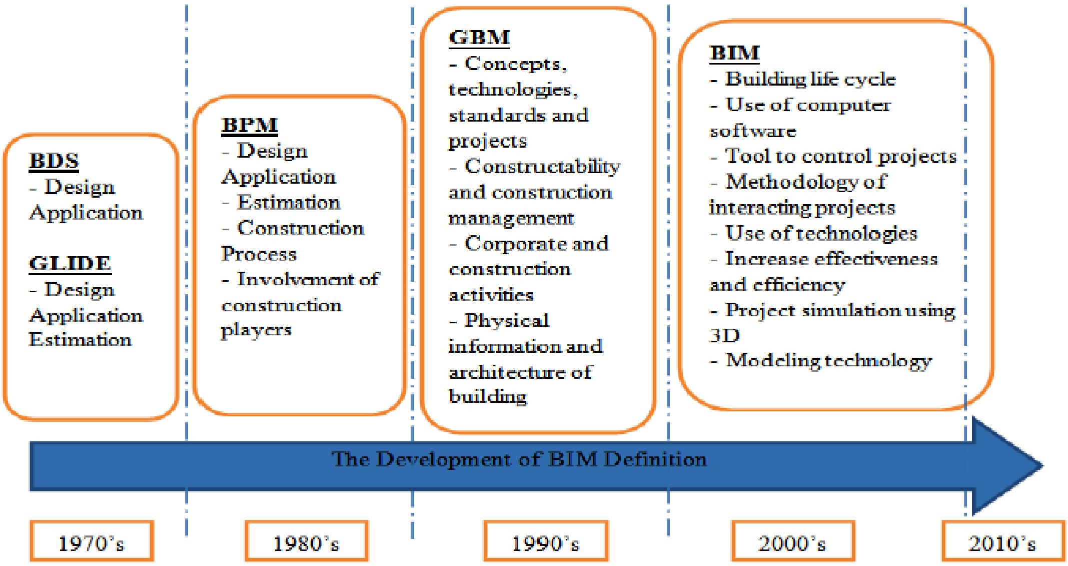

Figure 2.4: Evolution of BIM Definition

2.4 Concept of BIM

The concept of BIM focuses on the idea that in order to resolve issues, and replicate and examine the possible effects of these issues on construction, buildings and structures are constructed through virtual means before being constructed physically. The core of BIM is considered as a reliable building information model. (Smith, 2007).

Virtual means of construction indicate that there are options to exercise building of structures, try out new ideas and make alterations in a project before it is brought to the real world. Since virtual errors can be discovered early in a project, they normally do not possess any significant risk as they can be avoided in the real construction of a project. The majority of a project's relevant features and characteristics can be communicated between stakeholders before the orders for commencing construction are finalized when a project is designed and built virtually. (Kymmel, 2008). Figure

2.5 shows a visual depiction of BIM concept which is taken from a research made by Azhar, Khalfan, & Maqsood (2015).

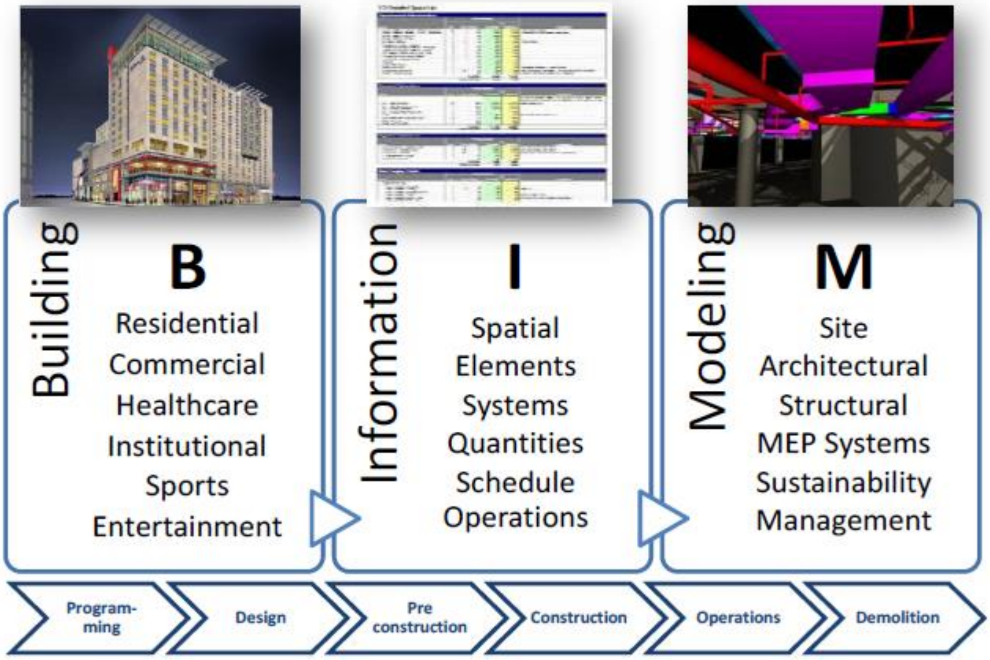

Figure 2.5: Visual Depiction of BIM Concept

BIM offers 2D and 3D models along with data other than dimensions that comprises of parameters, cost data, scope data and schedules. It has the ability to generate an object-oriented database that contains smart objects such as doors, windows and walls which have quantitative and qualitative data about the project. A smart object generated by BIM includes information such as its size, cost, manufacturer, schedule, etc. unlike 2D CAD where it generates objects with just a group of lines. When there is a change or a modification applied to an object in a BIM model, the other objects connected to the modified one would be automatically updated and adjusted instantly. (Elvin, 2007).

Eastman et al. (2008) defined the concept of parametric objects used in BIM compared to the conventional 2D objects as follows:

- Objects contain information and rules linked to them along with their geometric definitions.
- Geometries and dimensions of objects are incorporated in a way that is consistent and can be viewed in 3D from any perspective.
- Geometries and dimensions of objects can be altered automatically by the integration of parametric rules connected to the objects.
- There are distinct levels to how objects can be defined as BIM includes the definitions of the parts and pieces linked to the objects.
- The parametric rules of objects have the ability to recognize when a certain adjustment does not comply with an object’s practicality regarding size, manufacturability, etc.
- Objects can receive and send groups of characteristics and features to other applications and models.

Communication and collaboration are what BIM is based on as the early participation of all project stakeholders is necessary in order to use BIM successfully. This makes the IPD an important part of BIM as opposed to conventional project delivery methods which have very little involvement in BIM-based projects. For the purpose of creating optimized design plans that have adequate qualities and properties, IPD gathers crucial construction management, trades, fabrications, suppliers and product manufacturer experience together with design experts and the owner early in a project. (Gudgel, 2008). A comparison between traditional process and BIM process is shown in Figure 2.6 extracted from Azhar et al. (2015).

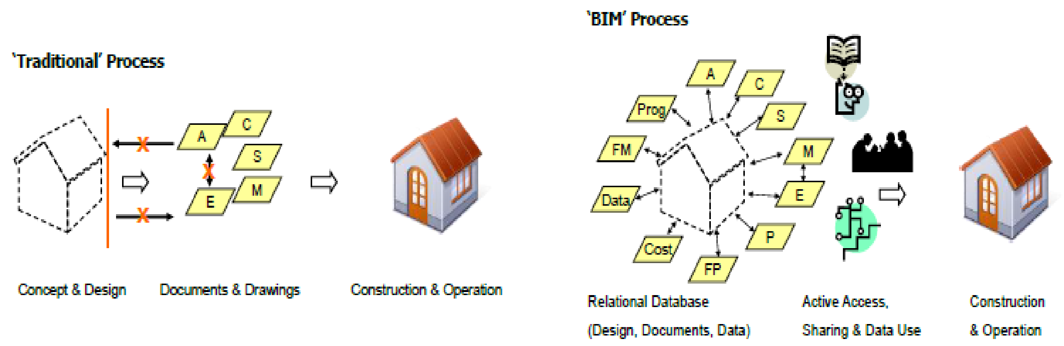

Figure 2.6: Comparison between Traditional Process and BIM Process

BIM is considered as a technology and a process altogether. The technology part aids project stakeholders to imagine what is to be constructed in a simulated environment in order to pinpoint any problem related to design, construction or operation. The process part allows solid cooperation and promotes unification of the roles of all stakeholders on a project. (Azhar et al., 2015).

2.5 Dimensions of BIM

2.5.1 3D BIM

3D includes the three dimensions of XYZ. BIM has the ability to represent design plans in 3D to visually examine the model as it grants better space area examination, and enhanced conveying and comprehension of design ideas between project stakeholders. (Ashcraft, 2008). 3D visualization of spaces compared to 2D plans offers an efficient way to interpret the space. (Uddin & Khanzode, 2013).

All significant systems in a project can be immediately and automatically inspected for clashes and incompatibilities with the creation of 3D space in BIM. (Azhar, 2011). On many projects, BIM utilization can be as basic as the accessibility of a 3D model made by one or more of the specialty contractors or suppliers. (Haron, Marshall-Ponting, & Aouad, 2009).

2.5.2 4D BIM

4D BIM-based models are created by combining the 3D elements with the arrangement of tasks and activities of a project schedule, making time be known as the fourth dimension. To construct a 4D BIM-based model, the development of a BIM-based 3D model and a project schedule should come first; then the 3D elements are combined with the tasks in the project schedule by using a schedule simulator; after that the developed 4D model will present the construction progression by displaying the 3D elements in activities over the duration of the project. (Wang et al., 2014). This allows a visual examination of activities in construction schedules. (Sigalov & König, 2017). Moreover, this enhances the communication and production of design and construction knowledge. (Koo & Fischer, 2000).

BIM applications for the construction management should be established on 4D models if there is a need to represent and examine the continuously altered variables that exist as the construction progresses. (Ding, Zhou, & Akinci, 2014). This would assist project members in managing their project through a better comprehension of the construction schedule. (Kang, Anderson, & Clayton, 2007). 4D BIM-based schedules are considered as advanced tools for sequencing, managing, and conveying planned work to various project participants because 4D schedules provide easier understanding of different demands and necessities throughout the project's life cycle. (Ghaffarianhoseini et al., 2017).

2.5.3 5D BIM

5D BIM models are applied for the appraisal process. (Forgues et al., 2012). They involve 3D model objects that contain description information and other characteristics which can be immediately utilized for estimating the price of construction work. (Stanley & Thurnell, 2014). 5D BIM models are primarily employed for cost approximation of projects and for allowing different branches of knowledge to imagine the progression of construction tasks and related costs over time. (Lu, Won, & Cheng, 2016). They also update both the schedule and the financial plan instantly when any design alteration happens. (Allison, 2010). In summary, the fifth dimension is cost for 5D BIM.

There are three ways of using 5D BIM for cost estimation and appraisal: The first way is to examine the amounts of work to be done from the 3D model and organize those amounts for approximation purposes. The second way is to add costing information and determine the cost and expenses. The third way is to obtain costing information from databases. (Boon & Prigg, 2012).

When 5D BIM is utilized in the design phase of a construction project, it assists in improving the observation of construction drawings in order to mitigate construction reworks that can happen due to alterations in design which can waste time and money. For the construction phase, The predominant applications of 5D BIM in construction management comprise of site layout simulation and optimization, virtual construction, visualization, progress management and cost management. (Xu, 2017).

2.5.4 6D, 7D and 8D BIM

BIM is considered to have multi-dimensional features and attributes (nD BIM) as it can include modeling of facility management (6D), sustainability (7D) and safety (8D). (Harrison & Thurnell, 2015).

For 6D modeling, the first step towards recognizing the possibilities of 6D BIM is to develop an understanding of facility management application areas for BIM-enabled procedures. (Nicał & Wodyński, 2016). BIM can manage information of facilities over their entire life cycle. It has the ability to make comparisons of facility demands and data with its as-planned information. (CRC, 2007). It can also ease the access of real-time data of facilities while examining their performance to see if it is optimum and cost efficient. Moreover, it can generate and upload digital assets to help in facility management tasks such as work order management and repair management. (Becerik-Gerber et al., 2011).

For 7D modeling, BIM can incorporate energy inspection into the building models for precise standard assessment based on appropriate geometrical thermal models and building code essentials. (Dummenahally, 2016). It can also decrease rework and construction waste by connecting new ways to visualization and inspection within sustainable design to improve integration of data during the construction process. Furthermore, through communication between stakeholders, BIM can produce new structures that are designed for performance. (Dowsett & Harty, 2013).

For 8D modeling, BIM is used for supporting “prevention through design” which promotes safety on construction sites. It includes a tool that has the ability to generate danger descriptions for objects and elements that would be gauged based on three severity levels which are critical, moderate and low. It can present recommendations to safe design for the purpose of altering elements with high danger. Also, it suggests on-site risk control for dangers that are too difficult to manage through design alterations. (Kamardeen, 2010).

2.6 Software of BIM

For different construction projects, there are different BIM software that can be used in various fields and categories. Table 2.1 lists examples of BIM software utilized in their respective fields provided by Gonzalez (2010).

Table 2.1: Examples of BIM Software Utilized in their Respective Fields

Field	**BIM Software**
Architecture	• Autodesk Revit Architecture. • Graphisoft ArchiCAD. • Nemetschek Allplan Architecture. • Nemetschek Vectorworks Architect. • Bentley Architecture.
Structure	• Autodesk Revit Structure. • Bentley Structural Modeler. • Tekla Structures. • CypeCAD. • Graytec Advance Design. • Nemetschek Scia.
Mechanical, electrical and plumbing (MEP)	• Autodesk Revit MEP. • Bentley Hevacomp Mechanical Designer. • Gehry Technologies - Digital Project MEP Systems Routing.
Construction, including simulation, estimating and construction analysis	• Autodesk Navisworks. • Solibri Model Checker. • Vico Office Suite. • Bentley ConstrucSim. • Tekla BIMSight. • Synchro Professional.
Facility management	• Bentley Facilities. • Vintocon ArchiFM. • Onuma System. • EcoDomus.

Table 2.1 (cont.)

Sustainability	• Autodesk Ecotect Analysis. • Autodesk Green Building Studio. • Graphisoft EcoDesigner. • IES Solutions Virtual Environment VE-Pro. • Bentley Tas Simulator.

2.7 Specialists of BIM

For the types of BIM specialists that can be hired or recruited for BIM implementation, Barison & Santos (2010) did a summary that talk about different types of BIM specialists and their duties. They have defined 8 different categories of BIM specialists which are as follows:

- BIM modeler/operator: There are multiple focus areas that can fit into the category of a BIM modeler. These areas include roles such as 3D modeler, cost modeler, sequencing modeler and detailing modeler. A 3D modeler focuses on producing geometric BIM models. A cost modeler focuses on incorporating data about building operations and needed materials. A sequencing modeler focuses on generating and arranging a set of sequences regarding the building operations and needed materials. A detailing modeler focuses on tasks related to developing designs for MEP or HVAC. (Panushev & Pollalis, 2006).
- BIM analyst: A BIM analyst focuses on conducting examinations and simulations on a BIM model such as carrying out analysis for structural performance or for energy consumption. (GSA, 2009).

- BIM application/software developer: A BIM software developer focuses on aiding BIM integration by developing the proper software to use. (GSA, 2009).
- Modeling specialist: A modeling specialist focuses on making interoperability or information exchange between different BIM applications much easier by being in charge of identifying what is needed for compatibility with IFC formats. (Weise, Liebich, & Wix, 2009).
- BIM facilitator: A BIM facilitator focuses on helping less skilled BIM workers in obtaining data and information from BIM models. (Kymmel, 2008).
- BIM consultant: There are multiple focus areas that can fit into the category of a BIM consultant. These areas include roles such as strategic consultant, functional consultant and operational consultant. A strategic consultant focuses on creating medium or long-term strategies that derive from a direction that leads to a company's success. A functional consultant focuses on producing programs that include duties and activities regarding the strategies that were made. An operational consultant focuses on generating BIM implementation ideas and schemes as well as planning their execution. (Barison & Santos, 2010).
- BIM researcher: A BIM researcher focuses on educating BIM, establishing research on BIM and cooperating with other researchers. (Barison & Santos, 2010).
- BIM manager/coordinator: A BIM manager focuses on managing the implementation of BIM as he/she reviews and assesses the objectives of using it by creating BIM implementation plans that are suitable and compatible

with the needs of customers and clients, the expertise of the project team, and the availability of materials, supplies and assets. (Kymmel, 2008). BIM managers are considered crucial for advising and leading project teams in decision making. (Post, 2009).

2.8 Benefits of BIM Implementation

BIM provides many benefits and advantages for the AEC industry. Table 2.2 lists the BIM benefits for each stage of a construction project which are presented by Eastman et al. (2008).

Table 2.2: Benefits of BIM Implementation for Each Stage of a Construction Project

Project Stage	**Benefits of BIM Implementation**
Pre-construction stage	• Provides advantages to owners in terms of concept, feasibility and design. • Allows better attentive assessment of schematic models which increases building performance and quality.
Design stage	• More precise design visualizations at early stages. • Automated corrections on a low level when designs are altered. • Production of flawless and uniform 2D drawings at any phase of the design. • Cooperation of several design fields at early stages. • Offers simple examinations against the design objectives. • Estimation of cost at the design stage. • Enhancement of energy efficiency and sustainability.
Construction stage	• Synchronization of design and construction preparations. • The ability to detect errors and clashes before construction. • Fast response to design or site issues. • Utilization of design model as a foundation for manufactured elements. • Provides superior execution and lean construction approaches.

Table 2.2 (cont.)

Post-construction stage	• Offers better management and operation of facilities. • Utilization of an accurate database incorporated with facility operation and management systems.

There are a variety of studies that also identified the key benefits and advantages that BIM can provide. Table 2.3 lists the key benefits of BIM implementation given from 8 different authors.

Table 2.3: Key Benefits of BIM Implementation from 8 Different Authors

Author	**Key Benefits of BIM Implementation**
Qian (2012)	Project level benefits: • Enhanced information control. • Reduced errors and mistakes. • Enhanced communications. Company level benefits: • Better public impression for a company. • Reduced flaws and inaccuracies. • Strategic competitive superiority.
Yan & Demian (2008)	• Less consumption of time. • Less consumption of human resources. • Less consumption of costs. • Enhanced quality and sustainability.
Migilinskas et al. (2013)	• The ability to visualize and apply structural analysis using a single 3D model. • Elimination of delays by utilizing information concerning overlooked design solutions and potential issues that occur early in a project. • Reduction of time consumption occurring from modifications and corrections.

Table 2.3 (cont.)

Ghaffarianhoseini et al. (2017)	• It provides more comprehension and interoperability capabilities. • It offers precise quantities for building materials and elements included within a design. • It decreases documentation mistakes and errors. • It reduces staff turnover. • It mitigates construction costs and contractual claims. • It presents an adequate visualization of working areas and provides simplified understanding of different necessities throughout the project life-cycle. • It provides all stakeholders the chance to carry out project tasks at an optimal level by making use of a unified shared model.
Bryde, Broquetas, & Volm (2013)	• Cost decrease or control. • Time decrease or control. • Better communication. • Better coordination.
Ashcraft (2008)	• Cost reduction in designs especially when they are altered frequently. • The ability to let all groups working to share the same model. • Decrease in clashes by incorporating all key systems into a model. • The ability to contain or connect to information needed to create bills of materials, estimations of sizes and areas, cost of materials, and other related estimating information. • Less errors and mistakes by avoiding the manual handling of material take-offs. • The ability to assess and optimize the construction progression by incorporating 4D capabilities to replicate the construction procedure.
ASHRAE (2009)	• It encourages cooperation between team members in the early stages of a project through the effective use of consistent and comprehensive information. • It eases collaboration by incorporating numerous disciplines within a common model which makes it more frequent to perform design optimization. • It has the potential to minimize costs of design and production through efficient time utilization and superior visualization. • It allows for a better way to achieve sustainability and climate conservation goals for a construction project by initially focusing on lowering energy.

Table 2.3 (cont.)

Azhar et al. (2008)	• Data is shared with ease and can be reused. • It enables new and better solutions by examining building plans and performing simulations. • Environmental behavior is more expected and lifecycle costs are comprehended better. • Project proposals are perceived in a superior way through precise visualization.

2.9 Enablers of BIM Implementation

Enablers and driving factors for BIM implementation must be present to counter the barriers that prevent its usage. Lindblad (2013) claimed that the project owner is the best actor to drive the adoption of BIM as he/she can influence the work activities of other members in the project team as well as make requests regarding how consultants and contractors should operate. And according to Kiviniemi (2013), public clients are the ones who should handle the adoption of BIM since they usually have a long term position in regards to certain projects and since they have a high frequency in engaging in multiple construction projects. Table 2.4 lists the top enablers of BIM implementation given by 8 different authors.

Table 2.4: Top Enablers of BIM Implementation from 8 Different Authors

Author	**Top Enablers of BIM Implementation**
Building Cost Information Service (BCIS) (2011)	• Offering teachings and education on the utilization of BIM. • Assisting the development of information sharing standards. • Influencing the BIM input/output necessities. • Explaining the levels of operating BIM.

Table 2.4 (cont.)

Gu & London (2010)	• Describing the scope, aim, duties, connections and project stages. • Developing roadmaps for work activities. • Finding out about the technical needs for BIM. • Assessing the expertise, knowledge and abilities of project participants.
Kiani et al. (2015)	• Establishing BIM in a university's educational program. • Instructing construction personnel. • Encouraging clients on the significance of BIM-based procedures. • Issuing legislation on using BIM.
Nanajkar (2014)	• Initiating an authorized BIM training. • Assessing the BIM implementation scheme. • Altering vocabulary and perception. • Creating an on-going training initiative.
Newton & Chileshe (2012)	• Considering the size and cost of the project. • Considering mitigating risks on the project. • Considering the quality and precision needed for the project. • Considering that BIM could be sought by the client.
Zahrizan et al. (2014)	• Aid and enforcement of the government to implement BIM. • Creation of a BIM training plan. • Senior management's leadership. • Coming up with a major strategy for training BIM.
Tsai, Mom, & Hsieh (2014)	• Considering top management's assistance. • Considering the functionality of BIM which involves its inclusiveness with certain demands. • Considering the design validation or design clashes between occupations or fields. • Considering the long term suppliers of BIM.
Zikic (2009)	• Encouragement of upper management to implement BIM. • Cooperation, communication, data gathering and analysis. • Building an agreement on using BIM while considering owner demands. • Being adaptable to changes that come from implementing BIM.

2.10 Barriers of BIM Implementation

As beneficial as BIM can be for construction projects, its implementation or adoption often comes with various barriers and obstacles. According to Lindblad (2013), BIM barriers can be linked to issues related to BIM product, BIM process and individual usage of BIM. While Gu & London (2010) categorized BIM barriers into work practice and process related issues, technical issues, and other issues related to training support and responsibilities. Table 2.5 lists the top barriers of BIM implementation given by 8 different authors.

Table 2.5: Top Barriers of BIM Implementation from 8 Different Authors

Author	**Top Barriers of BIM Implementation**
Zahrizan et al. (2014)	• Absence of knowledge about BIM. • Lack of BIM requests or enforcement from clients. • Unwillingness of clients, contractors or consultants to use BIM. • Considering BIM being unnecessary.
Nanajkar (2014)	• Expensive software needs to be obtained to use BIM. • A lot of time is needed to learn BIM application and modification according to company's standards. • Obligation of BIM users to work on a single 3D model rather than multiple 2D files. • A lot of communication and collaboration are needed to use BIM.
Newton & Chileshe (2012)	• Difficulty to comprehend BIM. • Expenses of education & training. • Cost of Start-up. • Altering how companies do business.
Kiani et al. (2015)	• Absence of legal support from authority. • Absence of professional BIM software operators. • High cost of BIM software. • Advantages of BIM implementation being unclear.

Table 2.5 (cont.)

Gu & London (2010)	• Lack of reliability on the inclusiveness and precision of 3D BIM models. • Problems in interoperability which is the ability to exchange information across different software. • Alterations in distributing roles and responsibilities. • Shortage of training and awareness on BIM applications.
Yan & Demian (2008)	• BIM being a waste of time and human resources. • Training cost. • BIM being inappropriate for projects. • Refusal to change since current technology is sufficient.
Ku & Taiebat (2011)	• Existence of a learning curve and unavailability of experienced staff. • Insufficient company investment. • Hesitance of architects, engineers and subcontractors to use BIM. • Shortage of cooperative work procedures and modeling standards.
Lindblad (2013)	• BIM being a bad match with the user’s demands. • Alteration of work processes. • Lack of interest and need to use BIM. • Legal issues regarding model possession and contractual liabilities.

Chapter 3

IMPACTS OF BIM IMPLEMENTATION IN DIFFERENT CASE STUDIES

3.1 Introduction

It is known that BIM implementation costs will remain high, skilled BIM users will remain to be rare and the full potential of BIM for visualization and developments will continue to fall behind if BIM is not adopted at a greater scale. Furthermore, in order to have a great capability in gaining the advantages that BIM has to offer and to achieve an adequate investment returns, a company has to thoroughly take part in implementing BIM. (McGraw Hill Construction, 2014).

BIM is rapidly receiving attention as it is found out that that it provides instant alterations to work approaches and processes after several years of development and demonstrations in the marketplace. Many companies in the construction industry have positive impressions on the results that BIM offers to their business operations as half of those who use BIM said that it brought a positive impact on their companies and only one in ten users experienced a negative impact. (McGraw Hill Construction, 2008).

In this chapter, readers will acquire knowledge of the impacts that BIM provides in general by discussing various case studies in different researches where BIM was implemented in them.

3.2 Impacts of BIM Implementation in Different Case Studies

Hergunsel (2011) conducted a case study in which he showed the outcome of implementing BIM for a research facility called "MIT Koch". For visualization, BIM aided the project team to cooperatively visualize the requirements and necessities of the project before construction. For 3D coordination, BIM decreased the time it takes to organize MEP tasks and reduced the amount of requests for information (RFI) in which additional costs were avoided. For prefabrication, there have been time and labor savings in the field with better quality materials being used. For construction planning, delays in construction schedule and additional costs incurred in construction have been avoided. Furthermore, the BIM model of the facility left a good impression to the project owner as well as it brought the possibility of helping the owner with maintenance and refurbishment of the facility.

Qian (2012) proposed a formula which is used to determine the return on investment (ROI) of BIM implementation for a normal construction consultancy project management department called "department X". According to a decision from the department, they made 30% of the projects in the first year of BIM adoption be carried out by implementing BIM in them. This resulted in an addition to the number of personnel needed as there are already 2D CAD drafters who work together with the new personnel to meet project and contractual demands. The adoption of BIM in the department was efficient as it reduced the amount inadequate and redundant tasks and raised productivity and net revenue. The ROI cash flow of BIM implementation for department X is represented in Table 3.1.

Table 3.1: ROI Cash Flow of BIM Implementation for Department X

	Year 0 (Initial Stage)	Year 1	Year 2	Year 3	Year 4
Staff Employment Allocation					
No. of Architects/Revit Arch.	2	4	4	4	4
No. of M&E Engineers	2	3	3	3	3
No. of Structural Engineers	2	3	3	3	3
No. of Quantity Surveyors	3	3	2	2	2
No. of Project Managers	1	1	1	1	1
No. of 2D CAD Drafters	8	8	6	4	2
Subtotal	18	22	19	17	15
Input Variables					
Percentage of Projects with BIM	0	0.3	0.6	0.9	1
Workstations					
Workstations (Normal/Old)	18	15	8	2	0
Workstations (3D BIM Capable)	0	7	11	15	15
Income/Inflow - ($1,000)					
Income*****	2,000	2,060	2,122	2,185	2,251
Costs/Outflow - ($1,000)**					
Architecture Staff	81.6	168	168	168	168
M&E Engineering Staff	67.2	100.8	100.8	100.8	100.8
Structural Engineering Staff	67.2	100.8	100.8	100.8	100.8
Quantity Surveying Staff	90	90	60	60	60
Project Management Staff	54	54	54	54	54
Drafting Staff	192	192	144	96	48
Newly Procured BIM Workstations*	0	168	96	96	0
Maintenance (Normal Workstation)****	18	15	8	2	0
Maintenance (BIM Workstation)***	0	14	22	30	30
Fixed Overheads	300	298	294	287	280
Savings from Productivity Gain	0	-44	-91	-133	-144
Total Operating Costs	870	1156.6	956.6	861.6	697.6
Total Cash Flow					
Net Revenue/Losses	1,130	903	1,165	1,324	1,553
Change from Base Year	0	-227	35	194	423

Migilinskas et al. (2013) made a research where they discussed 4 case studies in Lithuania in which they applied BIM in each one of them. The first case study was about "Vilnius Municipality" where the new Vilnius Municipal Center would have new engineering systems installed in it. The main goal for one of the contractors was to make sure that the new Vilnius Municipal Center would meet all the essential specifications in terms of quality, durability and cost-effective operation of the structure. The result of applying BIM saved about 20% of time which could have been wasted in view drawing with AutoCAD and redrawing with adjusting errors when modifications take place. BIM also resulted in facilitating discussions with subcontractors and suppliers by utilizing the 3D model for approximation of the bill of quantities for the majority of work packages. Moreover, BIM enhanced the procurement process of manufactured components and items.

The second case study was about “MG Valda Victoria office building”. Practical and technological solutions were requested by the contractors’ experts in order to enhance the properties of the structure and save money on the customer’s behalf. The result of applying BIM helped in eliminating delays by the use of early data concerning the forgotten design solutions and potential issues that may arise. Approximately 10% of the construction site manager and project manager’s time have been saved which could have been wasted in them trying to find issues in the project. Furthermore, BIM helped in facilitating planning and managing construction procedures as well as delivery of materials to the construction site. (Migilinskas et al., 2013).

The third case study was about “PET plastic raw material plant in Klaipėda”. The construction management team’s initial duty in this case study was to point out and assess risks followed by making a plan and predicting the proper measures to manage it. After that, the construction management team began preparing the project structure and schedule along with the construction arrangements. The result of applying BIM aided in reducing time consumption for modifications and adjustments in the design stage. It also decreased errors caused by manual arrangements of materials and products demanded at strict points in time with the help of the work packages quantities created from the BIM model. Additionally, the economic advantage of the BIM system and the savings obtained by chosen solutions and precise bill of quantities were 10 times greater than the additional management costs incurred by the use of BIM methodology. (Migilinskas et al., 2013).

The fourth case study was about an office building in Vilnius where the primary objective was to establish a productive cooperation between various project members, disciplines and software. The result of applying BIM saved approximately 0.5% of the project value in the design phase by the help of interoperability checks between different design fields. It also prevented overpayment for suppliers by the use of precise bills of quantities. In addition, it encouraged the construction management team and the subcontractors and suppliers to collaborate together to find better solutions without unneeded disagreements. (Migilinskas et al., 2013).

Bryde et al. (2013) conducted a research in which they gathered 35 case studies of various finished construction projects that applied BIM to check the benefits of BIM implementation that resulted from those construction projects. These benefits were based on 9 success criteria which are: Coordination, scope, time, cost, quality, organization, communication, risk, and software issues. The benefits in each success criterion were divided into positive and negative benefits. An example of a positive benefit is when there is improvement in coordination, reduction in cost, etc. An example of a negative benefit is when there are difficulties in coordination, problems in saving costs, etc. To point out the positive and negative benefits in the case studies, content analysis was used. The results of the analysis showed that "cost reduction or control" was the most frequented positive benefit which occurred in 29 total occasions and in 60% of the total projects followed by "time reduction or control" and "communication improvement" which occurred in 17 and 15 total occasions respectively. The most frequented negative benefit was "software issues" which occurred in 9 total occasions and in 20% of the total projects followed by "coordination improvement" which occurred in 7 total occasions. Table 3.2 displays the success criteria ranking of BIM implementation where positive and negative benefits for each success criterion are counted based on their occurrences in the case studies.

Table 3.2: Success Criteria Ranking of BIM Implementation

	Positive benefit			Negative benefit		
Success criterion	Total instances	Total number of projects	% of total projects	Total instances	Total number of projects	% of total projects
Cost reduction or control	29	21	60.00%	3	2	5.71%
Time reduction or control	17	12	34.29%	4	3	8.57%
Communication improvement	15	13	37.14%	0	0	0.00%
Coordination improvement	14	12	34.29%	7	3	8.57%
Quality increase or control	13	12	34.29%	0	0	0.00%
Negative risk reduction	8	6	17.14%	2	1	2.86%
Scope clarification	3	3	8.57%	0	0	0.00%
Organization improvement	2	2	5.71%	2	2	5.71%
Software issues	0	0	0.00%	9	7	20.00%

Lu et al. (2014) carried out a study where they did a cost/benefit analysis for BIM implementation in building projects through the use of time-effort distribution curves. The research included two case studies about two public housing projects in Hong Kong. One of the two projects had BIM implemented in it while the other did not. Data from the two projects was collected and used to determine the costs and benefits of BIM implementation. After analyzing the data, it was revealed that BIM implementation raised the amount of effort and input needed at the design phase by 45.93%. However, BIM implementation at the construction phase reduced the costs by 8.61%. Overall, implementing BIM in the sample BIM project resulted in 6.92% cost savings compared to the other sample project where BIM was not implemented.

Arayici, Egbu, & Coates (2012) made a research that focuses on displaying how BIM adoption for an architectural firm assists in alleviating major issues in management and communication in remote construction projects. A case study was included in the research which involved BIM adoption and implementation for a company called "John McCall's Architects" in the UK. The case study revealed that major issues in management and communication like bad quality of construction operations, inaccessibility of materials and components, and inefficient planning and arranging can be alleviated to a great extent by adopting BIM at the design phase.

In a way to show the benefits of BIM implementation, Azhar (2011) gathered 4 case study reports from a general contracting company located in Atlanta, Georgia. These case studies display the cost and time savings resulted from BIM being implemented in the planning, design, pre-construction, and construction stages in different projects. The first case study was about "Aquarium Hilton Garden Inn" where BIM was used for design coordination, conflict detection and work arrangement. The cost of implementing BIM was $90,000 which was 0.2% of the project's budget. The net cost savings were over $200,000 attributed to conflicts being eliminated by the use of BIM. For the time savings, 1,143 hours were saved due to the use of BIM in the project. Overall, the project gained some very good advantages through the implementation of BIM which surpassed the expectations of the owner and other team members in the project.

The second case study was about "Savannah State University" where BIM was used for planning and options/value analysis which is used for choosing the most economical and feasible structure layout. The cost of implementing BIM was $5,000. In this project, three design choices were prepared using BIM each with their own features, characteristics and cost scenarios. To let the owner decide the best choice that fits his demands, multiple 3D viewing sessions were organized which enhanced communications and trust between stakeholders and helped in facilitating quick decision making early in the procedure. The whole procedure took 2 weeks and approximately $1,995,000 cost savings were acquired by the owner at the pre-design phase by choosing the most economical design choice. (Azhar, 2011).

The third case study was about “The Mansion on Peachtree” where BIM was used for planning and construction reporting. The cost of implementing BIM was $1,440. In this project, the major obstacles were problems involving taking care of the schedule and ensuring quality with unfinished and uncoordinated design, and reducing risk and rework. In the planning phase, BIM was used to examine contract documents to get rid of incompatibilities and locate missing components. After that, shop drawings were produced via model extractions which were then assessed with the design team to solve any issues. By using BIM viewer software, the project designers were able to provide the owner with two finishing choices to the building which helped the owner in deciding the better choice in terms of appearance and cost. BIM also helped in visualizing 3D elevations inside the structure in order to display interior features as it facilitated in resolving clash detection before construction could start. Furthermore, BIM aided in arranging construction activities and allocating resources by the use of 4D scheduling model. All of these benefits resulted in saving $15,000 in costs and in finishing the project on time and within budget. (Azhar, 2011).

The fourth case study was about “Emory Psychology Building” where BIM was used for sustainability analysis. In this project, the BIM model was prepared early at the design stage to help in deciding the best positioning for the structure and in assessing different cover options for the structure. BIM also aided in conducting analyses that involved positioning the facility based on the sun's location to further facilitate design adjustments. The results of the analyses reduced cost and time consumption which could have been wasted on redesigns later in the project life cycle. (Azhar, 2011).

In the same research, Azhar (2011) gathered cost data of 10 projects to conduct BIM ROI analysis. The ROI of implementing BIM in these projects held adequate results as the net BIM savings exceeded the BIM cost significantly. Table 3.3 lists the BIM ROI for different projects in Atlanta, Georgia.

Table 3.3: BIM ROI for Different Projects in Atlanta, Georgia

Year	Cost ($M)	Project	BIM scope	BIM cost ($)	Direct BIM savings ($)	Net BIM savings ($)	BIM ROI (%)
2005	30	Ashley Overlook	P/PC/CD	5,000	(135,000)	(130,000)	2600
2006	54	Progressive Data Center	F/CD/FM	120,000	(395,000)	(232,000)	140
2006	47	Raleigh Marriott	P/PC/VA	4,288	(500,000)	(495,712)	11560
2006	16	GSU Library	P/PC/CD	10,000	(74,120)	(64,120)	640
2006	88	Mansion on Peachtree	P/CD	1,440	(15,000)	(6,850)	940
2007	47	Aquarium Hilton	F/D/PC/CD	90,000	(800,000)	(710,000)	780
2007	58	1515 Wynkoop	P/D/VA	3,800	(200,000)	(196,200)	5160
2007	82	HP Data Center	F/D/CD	20,000	(67,500)	(47,500)	240
2007	14	Savannah State	F/D/PC/VA/CD	5,000	(2,000,000)	(1,995,000)	39900
2007	32	NAU Sciences Lab	P/CD	1,000	(330,000)	(329,000)	32900
Total all types				260,528	4,516,620	4,256,092	1633%
Totals without planning/VA phase				247,440	1,816,620	1,569,180	634%

Source: Holder Construction Company, Atlanta, GA.

Note: CD = construction documentation; D = design; F = feasibility analysis; FM = facilities management; GSU = Georgia State University; NAU = Northern Arizona University; P = planning; PC = preconstruction services; ROI = return on investment; VA = value analysis.

In order to find out about the cost savings and ROI of BIM implementation, Giel, Issa, & Olbina (2009) conducted two case studies with each involving two sets of similar projects. The first case study involved two projects with similar features. One of the projects had BIM implemented in it while the other did not. To determine the

ROI of BIM implementation in the two projects, the cost savings were calculated based on the quantifiable cost advantages caused by the reduced amount of change orders and schedule overruns. It should be known that the ROI on the project without BIM assistance was estimated based on cost savings in change orders and schedule overruns, unlike the BIM-assisted project where only cost savings in schedule overruns were used to estimate the ROI due to the lack of change orders. The ROI of the BIM-assisted project and the one without BIM assistance were 16.2% and 36.7% respectively. The second case study was conducted in the same way as the first one except the two projects were larger in size and scale compared to the projects in the first case study. There were also one BIM-assisted project and one without BIM assistance. The ROI for the BIM-assisted project was also estimated based on cost savings only from schedule overruns while the other project included cost savings from change orders and schedule overruns. The ROI of the BIM-assisted project and the one without BIM assistance were 299.9%% and 1653.9% respectively. Since the ROI was higher in larger projects, it was indicated that the sizes and scales of projects should be seriously considered when investing in BIM services. Although, that did not change the fact that implementing BIM holds great benefits regardless of a project’s size or scale.

Shin, Lee, & Kim (2018) did a study that shows the benefit-cost ratios of implementing BIM in 7 projects in a railway construction site located in South Korea. In these 7 projects, 12 errors were spotted which could have been averted if BIM was used before the beginning of construction. Before determining the benefit-cost ratios of BIM implementation, the total cost of BIM implementation was calculated which tuned out to be $116,348. Since the BIM cost estimation was based on the speculation that BIM implementation was thorough during the whole construction process, which was not the real case, a 10% of allowance was added to the total cost of BIM implementation for the sake of computing any amounts that may raise the cost in BIM adoption. This made the total cost of BIM implementation to become $127,983. For the total costs needed to fix the 12 errors through normal means, which could have been avoided if BIM was implemented in the first place, It was found out that $168,984 were incurred with the occurrence of one-month delay, $171,481 were incurred with the occurrence of two-months delay, and $173,978 were incurred with the occurrence of three-months delay. Finally, the benefit-cost ratios were calculated which are the following: 1.32 with one-month delay, 1.34 with two-months delay, 1.36 with three-months delay. These results indicate that implementing BIM offers benefits and cost savings that significantly exceed its costs.

Chapter 4

RESEARCH METHODOLOGY & RESULTS

4.1 Introduction

In this chapter, the research methodology for this study will be displayed along with its results. According to Collis & Hussey (2013), a research methodology is defined as “an approach to the process of the research, encompassing a body of methods” (p. 55). These methods are for data collection and analysis which are considered as the most crucial components in any research study as data and information are collected in a methodical way and then analyzed in order to come out with results for a research. (Bryman & Bell, 2007). Furthermore, it is known that the assessment of data is directly responsible for the authenticity and credibility of the research.

The method used for data collection in this study is a questionnaire survey which is distributed to employees working in the Turkish construction industry. The questionnaire survey covers general questions about the respondents’ work processes and their BIM usage in the industry. The survey is directed to both BIM users and non-BIM users. The method used for data analysis is descriptive analysis in which the results of the questionnaire survey are displayed using pie charts, bar charts and tables. The overall outcome of the survey is discussed for each of the following factors which are: Technology, construction management, construction performance, information management, facility management, sustainability, and BIM usage, benefits and challenges.

4.2 Research Methodology

4.2.1 Questionnaire Survey

The questionnaire survey is chosen as a method for data collection to get information about the current use of information technology and how it affects work in the Turkish construction industry. There are 20 questions in the survey which are close-ended questions about the respondents' work processes and their BIM usage in the industry. The first 13 questions are directed to all respondents while the rest of the questions are for the ones that work in firms or organizations that have experience in using BIM.

The sample selected for the questionnaire survey is based on professionals in the architecture and construction fields that work in both big and small establishments throughout Turkey. The survey is distributed online to these professionals and they were informed that all their personal information will remain confidential. The survey was sent to 184 individuals but the ones that responded and completed the survey were 97 respondents. The number of respondents is enough since it is more than half of the full sample in which the survey has been sent to. Furthermore, since the individuals included in the sample are from different establishments in the Turkish construction industry, the sample is considered to be adequate to represent the survey results for this study. It took a month and a half to finish collecting data.

4.2.2 Descriptive Analysis

After finishing collecting data from the respondents, descriptive analysis is used to show the results of the questionnaire survey in pie charts, bar charts and tables. The overall outcome of the survey is then discussed to lay the foundations for the ontological framework created to aid the Turkish construction industry in adopting BIM in a broader way.

4.3 Results of the Questionnaire Survey

4.3.1 Results of Questions Directed to All Respondents

Question 1: What is your profession in the company you are working in?

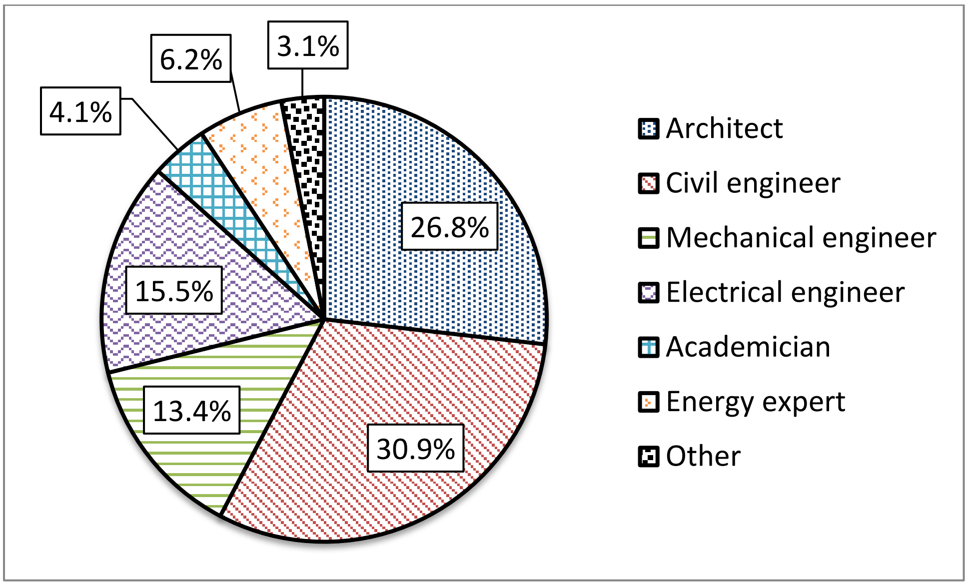

Figure 4.1: Professions of the Respondents

As shown in Figure 4.1, there is a variety in the professions but most of the respondents in the Turkish construction industry who participated in the survey are civil engineers and architects with percentages of 30.9% and 26.8% respectively.

Question 2: Which of the following software/programs do you use for architectural design? (You can choose more than one answer).

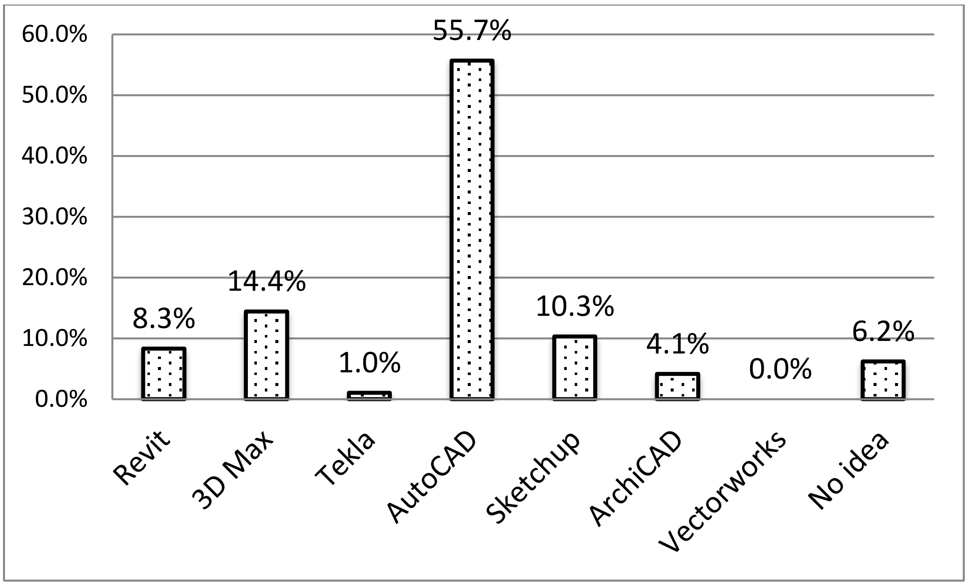

Figure 4.2: Software/Programs Used in Architectural Design

The results in Figure 4.2 show that most construction companies in Turkey rely on traditional 2D designs as more than half of the respondents use AutoCAD for 2D architectural design in the Turkish construction industry with a percentage of 55.7%, followed up by other programs like 3D Max (14.4%) and Sketchup (10.3%) which are used to visualize 2D designs in 3D. BIM software such as Revit (8.3%), ArchiCAD (4.1%) and others are rarely used in architectural design.

Question 3: Which of the following software/programs do you use for structural design? (You can choose more than one answer).

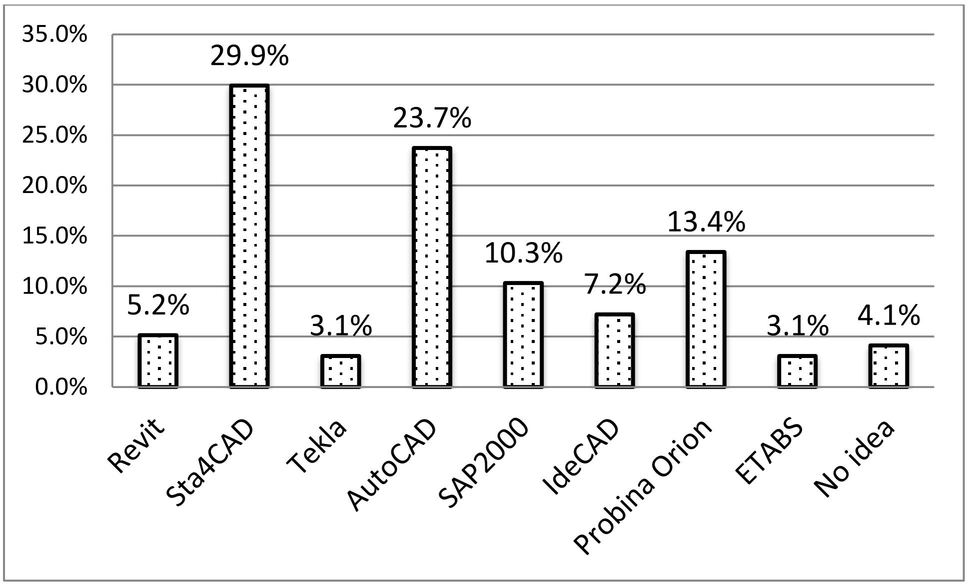

Figure 4.3: Software/Programs Used in Structural Design

In Figure 4.3, it shows that the most used software for structural design is Sta4CAD with a percentage of 29.9%, followed by AutoCAD (23.7%) and Probina Orion (13.4%). The least used software are BIM software like Revit (5.2%) and Tekla (3.1%) along with another program like ETABS (3.1%). The results show that local programs like Sta4CAD, Probina Orion and IdeCAD are commonly used in traditional structural design along with AutoCAD, while BIM-based structural design is very rare in the Turkish construction industry.

Question 4: Which of the following software/programs do you use for MEP design? (You can choose more than one answer).

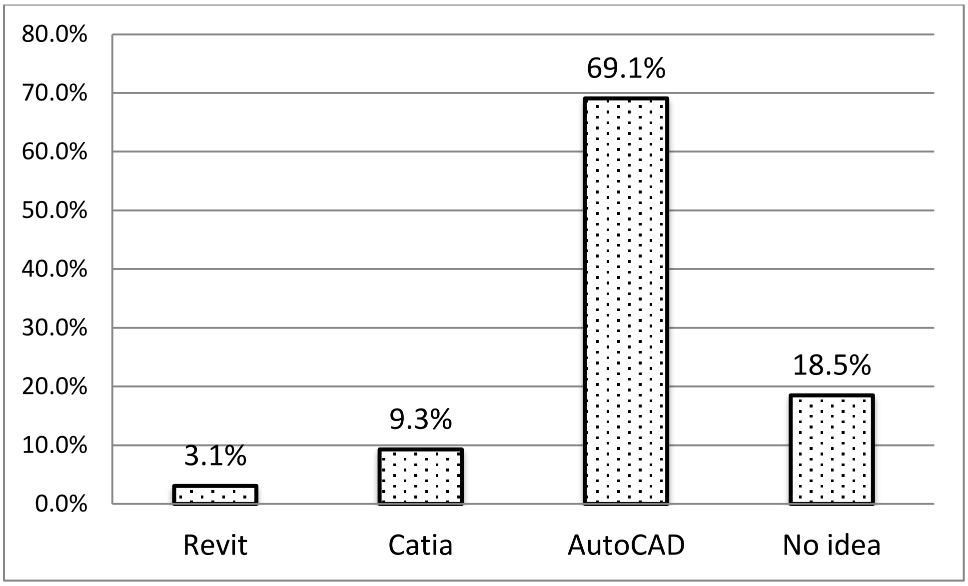

Figure 4.4: Software/Programs Used in MEP Design

For MEP design in the Turkish construction industry, AutoCAD is the most commonly used program with a percentage of 69.1% as displayed in Figure 4.4. Catia (9.3%) which is a 3D design program that can be incorporated into the BIM system is not used very often. Moreover, BIM software like Revit (3.1%) appears to be rarely used by Turkish construction firms for MEP design.

Question 5: How likely a project's duration and budget turn out to be as expected or as planned during the execution stage?

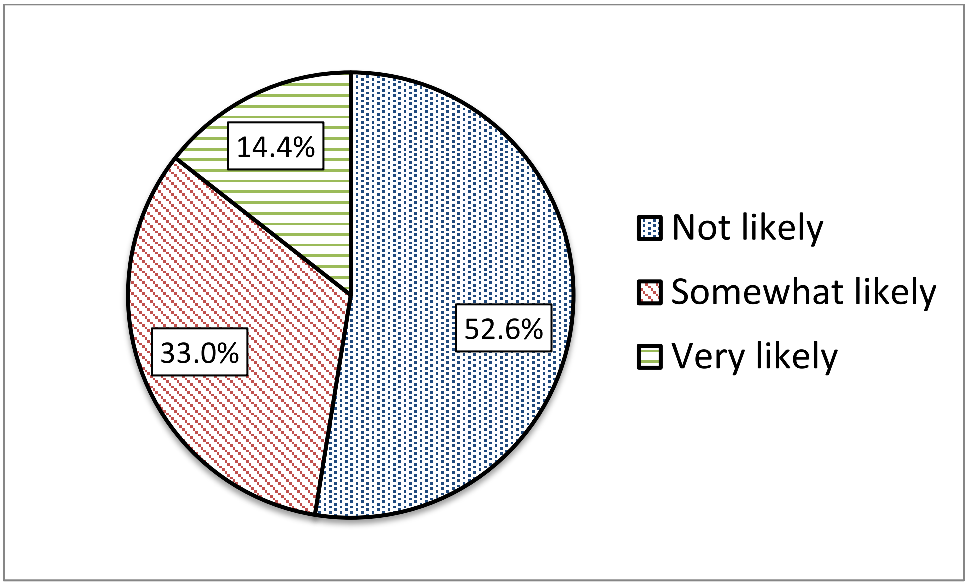

Figure 4.5: Rate of Projects' Durations and Budgets Turning out as Expected

As displayed in Figure 4.5, the durations and budgets of most construction projects in Turkey do not turn out to be as expected or as planned during the execution stage with 52.6% of the respondents stating that. 33.0% of respondents say that projects' durations and budgets somewhat turn out to be as expected while 14.4% of them state that construction projects are completed with durations and budgets very likely turning out to be as planned.

Question 6: At what stage do you develop and/or incorporate work safety measures for a project?

Table 4.1: Frequencies of Occurrences in Project Stages Where Safety Measures are Incorporated into

Project Stage Where Safety Measures are Incorporated into	**Frequency of Occurrence**	**Frequency of Occurrence (%)**
Safety measures are not incorporated	37	38.1

Table 4.1 (cont.)

When site installation is in progress	33	34.0
At the design stage of the project	19	19.6
At the construction stage of the project	8	8.3
Total	**97**	**100**

38.1% of the respondents in the Turkish construction industry do not develop or incorporate safety measures for projects while 34.0% of them incorporate safety measures when site installation is in progress. Few of the respondents integrate safety measures at the design stage (19.6%) and at the construction stage (8.3%) as displayed in Table 4.1. These results indicate that there are serious flaws in work safety planning as there is a high possibility of Turkish construction workers facing occupational hazards and sustaining grave injuries on site.

Question 7: At what stage do you develop and/or incorporate performance analysis and simulation for a project?

Table 4.2: Frequencies of Occurrences in Project Stages Where Performance Analysis and Simulation are Incorporated into

Project Stage Where Performance Analysis and Simulation are Incorporated into	Frequency of Occurrence	Frequency of Occurrence (%)
Performance analysis and simulation are not incorporated	61	62.9

Table 4.2 (cont.)

At the design stage of the project	24	24.7
At the construction stage of the project	12	12.4
Total	**97**	**100**

In Table 4.2, it shows that 62.9% of the respondents in the Turkish construction industry do not develop or incorporate performance analysis and simulation for projects. Meanwhile, there is a small number of respondents that integrate performance analysis and simulation at the design stage (24.7%) and at the construction stage (12.4%). These results indicate that there is inefficient and disorganized execution in construction due to the lack of assessments for construction performance in Turkey.

Question 8: Do you make/have computerized models that can be used for facility management after a project is completed?

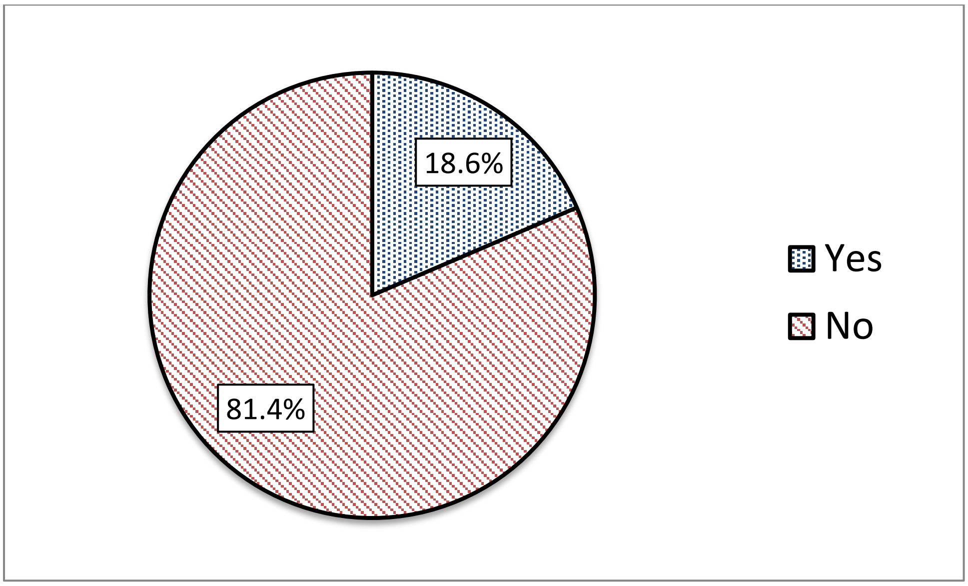

Figure 4.6: Rate of Computerized Models Used for Facility Management

As shown in Figure 4.6, 81.4% respondents state that they do not make or have computerized models that can be used for facility management while 18.6% of them create and share models for management and observation of activities on site. The results show that management of facilities in the Turkish construction industry is mostly based on traditional methods which can be ineffective for maintenance and operation tracking purposes.

Question 9: Do you make/have computerized platforms that can be used for quick information sharing and cooperation with stakeholders during construction stage of a project?

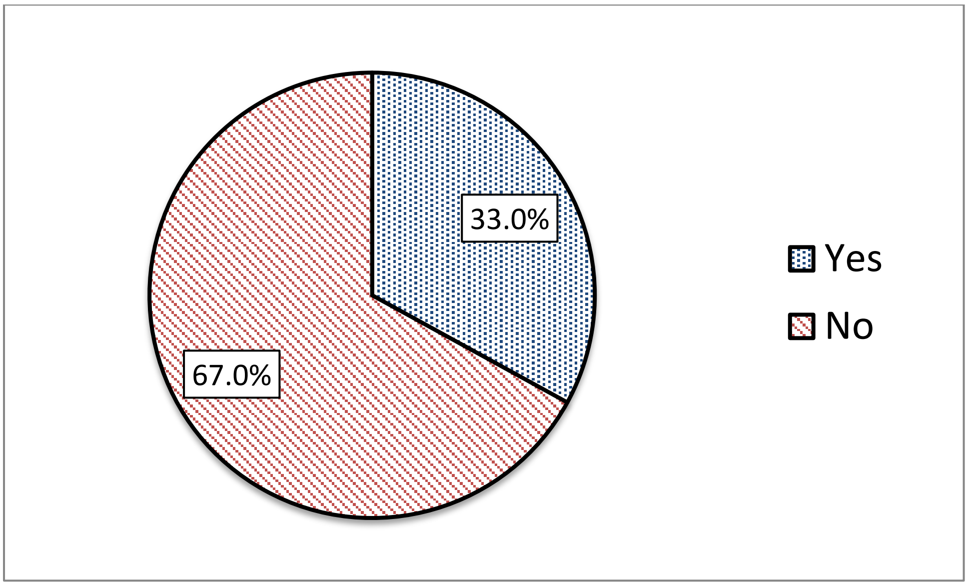

Figure 4.7: Rate of Computerized Platforms Used for Data Sharing and Cooperation

Figure 4.7 shows that most of the respondents in the Turkish construction industry do not make or have computerized platforms that can be used for quick information sharing and cooperation with stakeholders during the construction stage of a project with a percentage of 67.0%. Meanwhile, 33.0% of them state that they can share data and thoroughly communicate and collaborate with other members in the construction stage of a project. The results indicate that since there are not a lot of computerized platforms used for information sharing and cooperation in the Turkish construction industry, conventional methods are the ones used for that purpose which can cause problems and errors in communication during construction, thus making it difficult for a project to be carried out as a team.

Question 10: During design stage, do you take into consideration the sustainability of a project design?

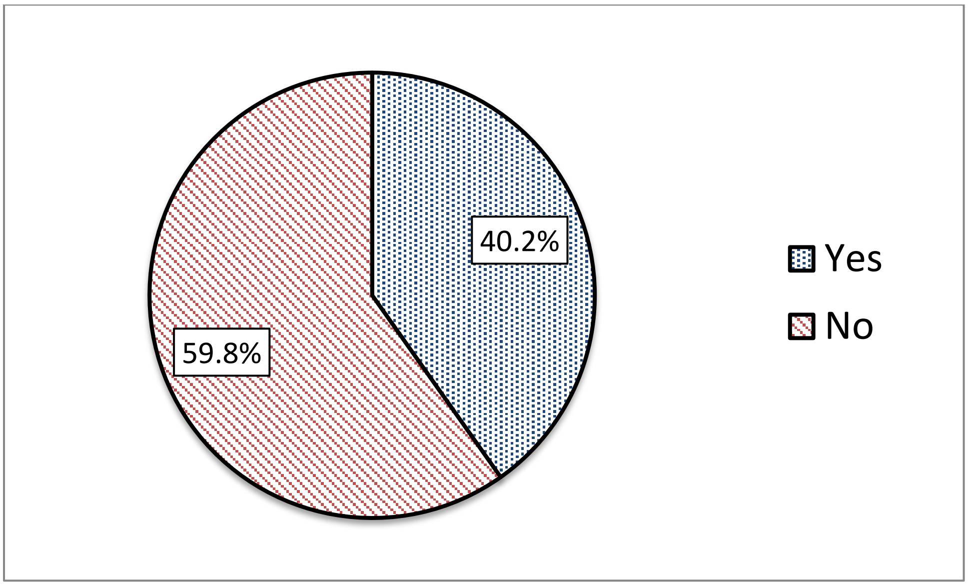

Figure 4.8: Rate of Sustainability being Considered at the Design Stage of a Project

More than half of the respondents do not consider sustainability when designing structures in a project in Turkey with a percentage of 59.8% as shown in Figure 4.8, while 40.2% of them take into account sustainable designs in construction projects. These results show there is not enough knowledge or awareness in the Turkish construction industry about the concept of sustainability in design.

Question 11: Do constructed buildings or structures turn out to be consistent with the ones that are pre-designed?

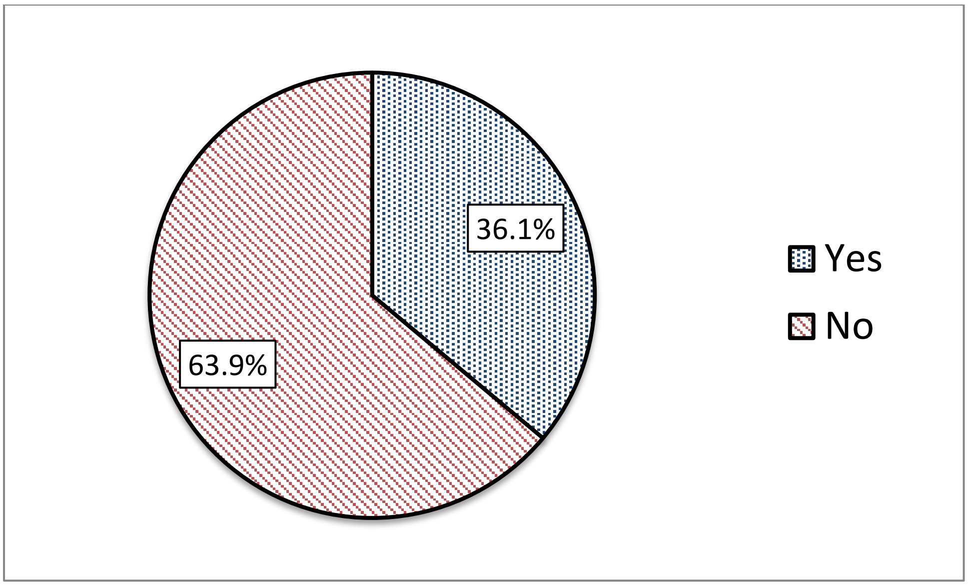

Figure 4.9: Rate of Structures being Consistent with the Ones that are Pre-designed

As displayed in Figure 4.9, 63.9% of respondents state that constructed buildings in Turkey are inconsistent or incompatible with pre-designed structures. Meanwhile, 36.1% of respondents say that construction projects in Turkey are carried out consistently with how they are designed. It seems that since project designs in the Turkish construction industry are prepared using traditional procedures, and since there is a lack of communication between the design team and construction team, these issues may lead to faulty designs and inconsistencies between pre-designed elements and constructed components.

Question 12: What is the main method used in your company for sharing data and information in a project?

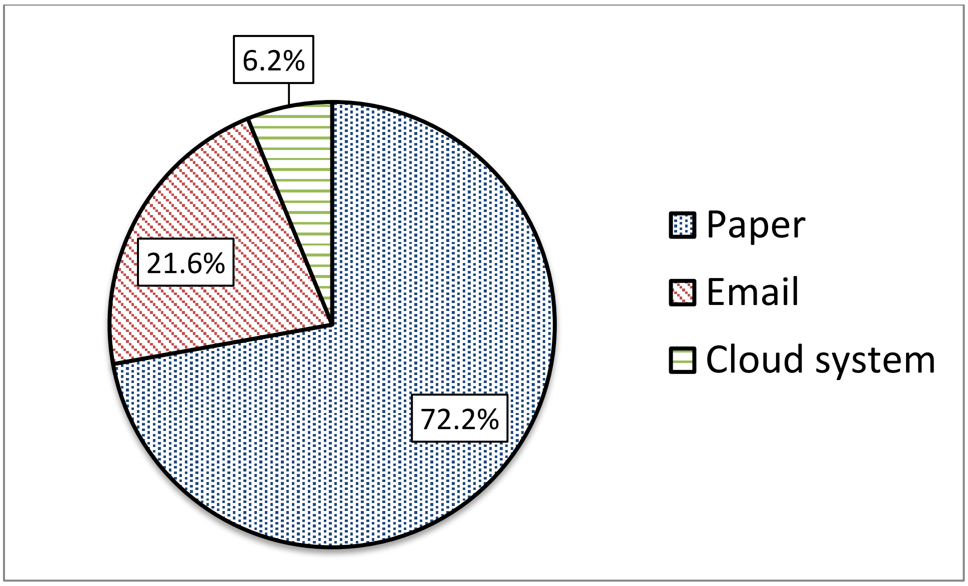

Figure 4.10: Main Methods Used for Sharing Information in a Project

For data and information sharing in the Turkish construction industry, the most commonly used method is through paper documents with a percentage of 72.2% as shown in Figure 4.10. 21.6% of respondents state that they use emails to share information in a construction project while 6.2% of them utilize cloud systems. From these results, it is evident that the Turkish construction industry lags behind when it comes to digital transformation as most organizations and firms still rely on traditional paper documents for information sharing which can lead to a lot of errors in communication and delays in construction projects.

Question 13: Does your firm or organization have any experience in using BIM?

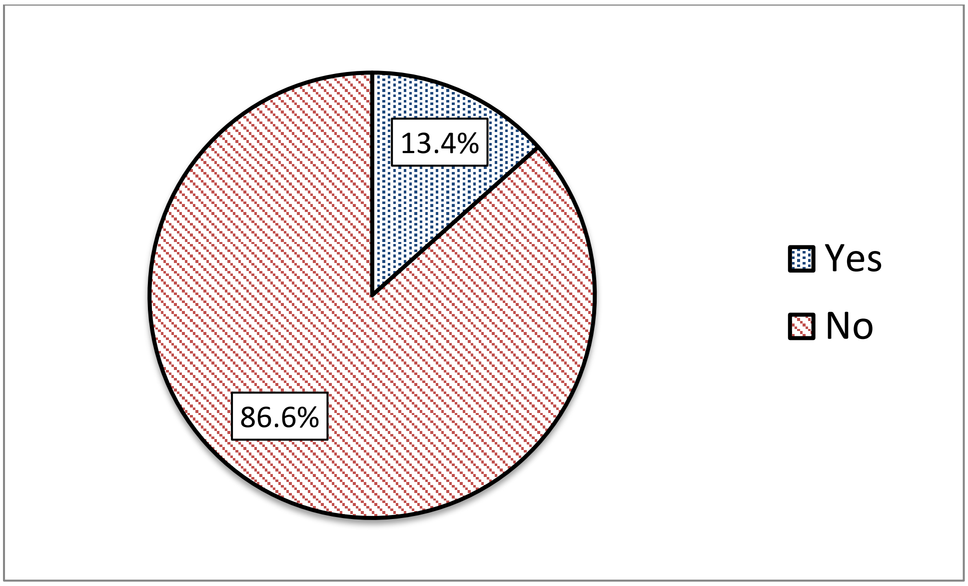

Figure 4.11: Rate of Firms or Organizations with Experience in Using BIM

A huge number of respondents state that their construction companies in Turkey do not have any experience in using BIM with a percentage of 86.6%, while 13.4% of respondents work in firms and organizations that do have experience in implementing the BIM system as shown in Figure 4.11. The results imply that most companies in the Turkish construction industry still use conventional and traditional methods to carry out construction projects in which the reasons behind this can be from lack of knowledge and awareness about the BIM system, shortage of skilled BIM specialists, and lack of importance on the BIM system in universities.

4.3.2 Results of Questions Directed to Respondents in Companies that Use BIM

The rest of the questions in the survey are directed to the respondents that answered “Yes” on question 13, which are only 13 respondents out of 97.

Question 14: Which of the following dimensions does your firm or organization incorporate into the BIM model?

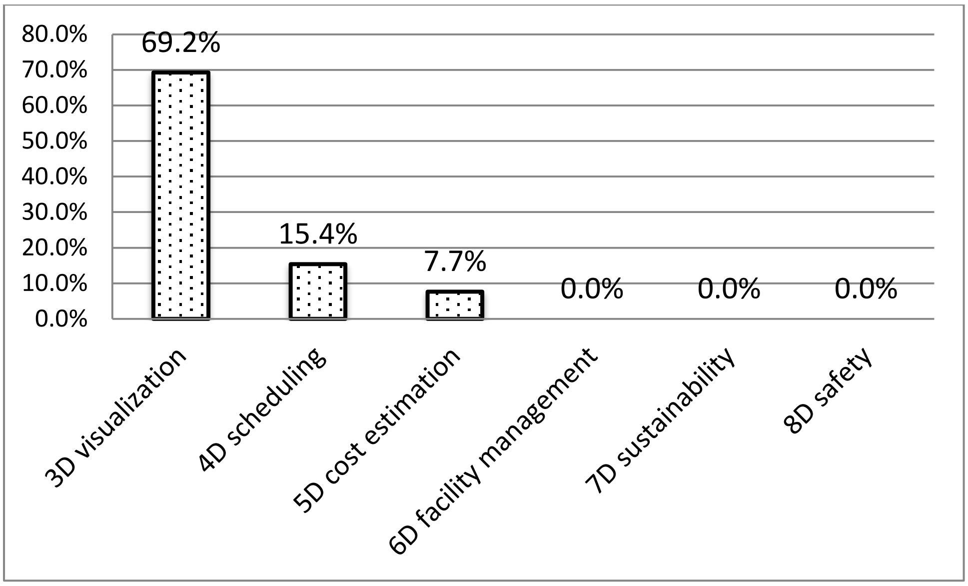

Figure 4.12: Rate of Dimensions being Incorporated into the BIM Model

As shown in Figure 4.12, most firms that use BIM in Turkey incorporate 3D visualization into the BIM model with a percentage of 69.2%. Two of the respondents work in companies that apply 4D scheduling (15.4%) and only one respondent works in a company that apply 5D cost estimation (7.7%). The rest of the dimensions are not integrated by any of the respondents' companies. The results indicate that since most firms in Turkey only incorporate 3D visualization into the BIM model, then BIM is mostly implemented in the field of architectural design. Furthermore, the level of BIM implementation in Turkey is very low because BIM is not utilized to its fullest extent with the integration of dimensions other than 3D.

Question 15: Which of the following benefits does your firm or organization obtain from implementing BIM? (You can choose more than one answer).

Table 4.3: Frequencies of BIM Benefits Obtained by Turkish Firms/Organizations

BIM Benefit	Frequency	Frequency (%)
Less conflicts and clashes on site	10	27.1
Reduced errors in design	7	18.9
Easier monitoring and control of project activities	6	16.2
Enhanced performance of construction	5	13.5
Better utilization of project's budget and time	5	13.5
Better communication between stakeholders	4	10.8
Enhanced management of facilities	0	0.0
Total	**37**	**100**

Since respondents are given the choice to choose more than one answer, the total number of BIM benefits that are frequented are more than the number of respondents. In Table 4.3, the most frequented BIM benefit obtained by Turkish firms in the construction industry is the decrease of clashes on site with a percentage of 27.1%. Since most respondents stated that their firms use BIM for 3D visualization, which can be mostly integrated in the field of architectural design, it is natural that the benefit they obtain by using BIM is the reduction of errors in design (18.9%). The other benefits are fairly frequented by respondent's organizations except one benefit which is the improvement of facility management. The reason for construction companies not acquiring this benefit goes back to them not utilizing the 6th dimension in BIM models which can be used for facility management.

Question 16: Which of the following challenges does your firm or organization encounter when implementing BIM? (You can choose more than one answer).

Table 4.4: Frequencies of BIM Barriers Encountered by Turkish Firms/Organizations

BIM Barrier	Frequency	Frequency (%)
Lack of BIM experts and specialists	11	25.6
Lack of knowledge or awareness about BIM importance	8	18.6
Lack of government support for BIM	7	16.3
High cost of implementing BIM	7	16.3
Difficulty in transitioning from old process to BIM process	5	11.6
Lack of client or owner demand for BIM	3	7.0
Resistance to change from traditional ways of work	2	4.6
Total	**43**	**100**

Just like the previous question, this one also allowed respondents to choose more than one answer. As displayed in Table 4.4, the most frequented barrier for BIM implementation in the Turkish construction industry is the short number of available BIM staff with a percentage of 25.6%, followed by the lack of awareness about the importance of BIM with a percentage of 18.6%. These two barriers can stem from the shortage of BIM training centers and the unavailability of BIM curriculums in Turkish universities which can be factors for people being less aware about the importance of BIM in the construction industry as well as they can be factors for the shortage of personnel that specialize in BIM implementation. Barriers like the lack of support from government and the high cost of BIM implementation are frequented by respondents with the same percentage which is 16.3% which can heavily discourage Turkish construction companies from adopting BIM overall. For the rest of the barriers which are fairly frequented, they focus on the transition to BIM process and the demand of BIM which can badly affect the decision of choosing digital transformation into the BIM process in the Turkish construction industry.

Question 17: Do you think that there is enough academic research and development in the subject of BIM?

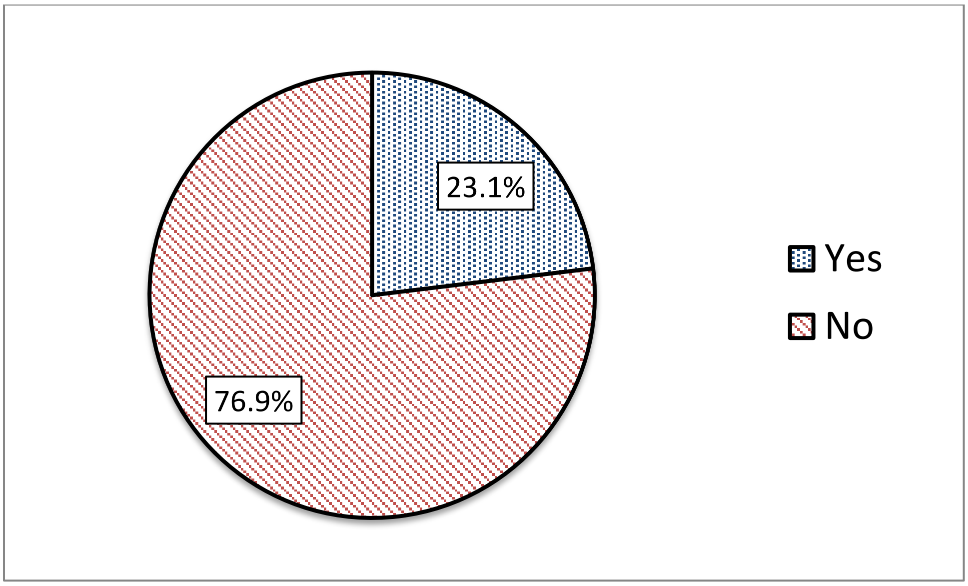

Figure 4.13: Rate of Sufficient Academic Research in the BIM Field

As shown in Figure 4.13, 76.9% of respondents who work in Turkish construction firms that have experience in using BIM think that there is not enough research done in the field of BIM while 23.1% of respondents think otherwise. The results imply that since there is already a minimal number of Turkish construction companies that might transition into the BIM-based work process, more academic research about BIM is needed so other companies can realize its benefits in the construction industry.

Question 18: Do you think that construction projects in Turkey nowadays are handled well without the use of BIM?

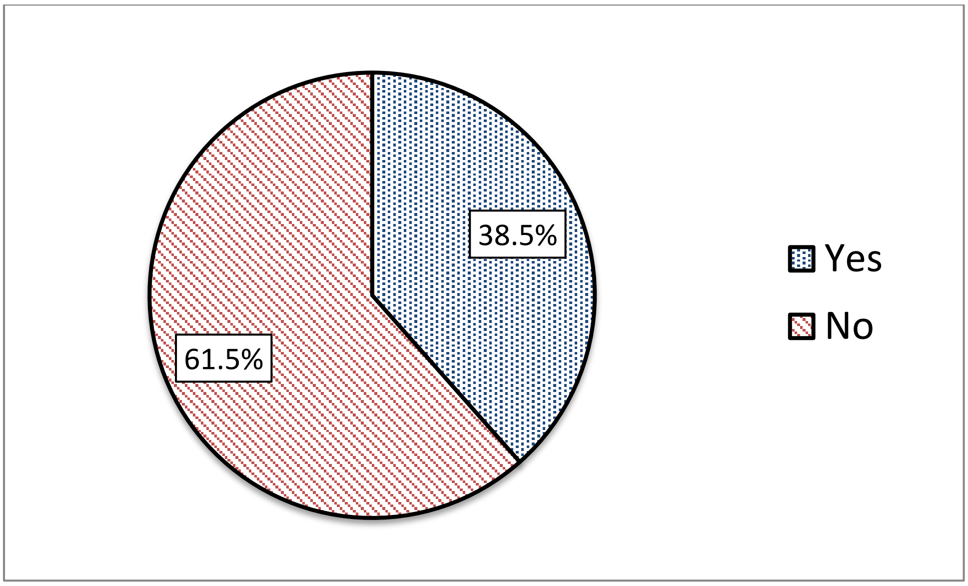

Figure 4.14: Rate of Construction Projects that are Handled Well without BIM Usage

The majority of the 13 respondents think that construction projects in Turkey are not handled well without BIM implementation with a percentage of 61.5% as displayed in Figure 4.14, while other respondents think otherwise with a percentage of 38.5%. With the way the construction industry around the world is rapidly evolving in the technological aspect, it drives organizations and firms to adopt new work processes which may revolve around the use of technologies such as BIM. Since the results show that the Turkish construction industry is still having difficulties handling construction projects using traditional methods, it might serve as a reason to try and adopt BIM processes in the field of construction.

Question 19: Do you believe it is necessary to organize and establish BIM centers in Turkey to help in adopting BIM technology?

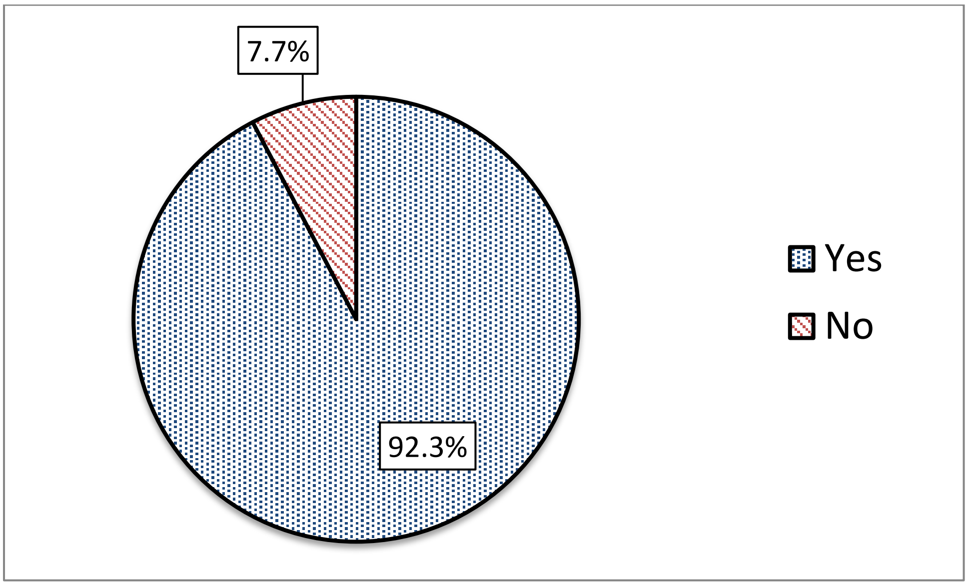

Figure 4.15: Rate of Demand for Establishing BIM Centers in Turkey

12 of the 13 respondents agree with the need for establishing BIM centers in Turkey with a percentage of 92.3% as shown in Figure 4.15. It is necessary to organize the BIM centers in Turkey for many purposes such as assisting BIM users in the right way of utilizing BIM, setting national standards for BIM application in the Turkish construction industry, raising awareness of industry experts, and offering BIM training for beginners. Moreover, BIM centers should be built to raise awareness of BIM implementation and to provide the needed support for change in education and curriculum systems of Turkish universities, which can lead to the creation of BIM standards in the country.

Question 20: Does your firm or organization have a BIM execution plan?

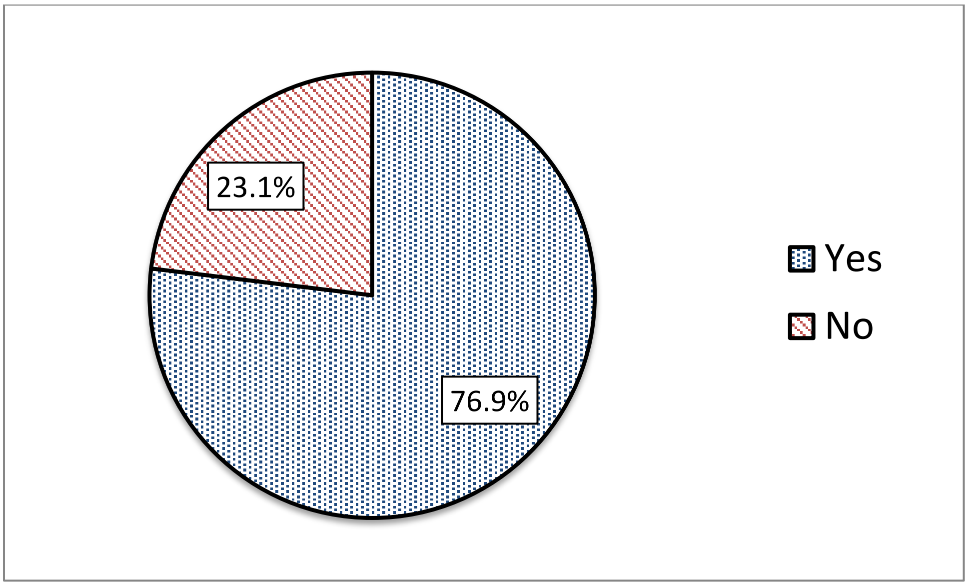

Figure 4.16: Rate of Firms or Organizations with BIM Execution Plans

Most of the respondents' construction companies in Turkey have BIM execution plans with a percentage of 76.9% as displayed in Figure 4.16. The existence of execution plans for BIM implementation brings a good way to understand how BIM can be integrated into a project as well as comprehend how a project can be well-coordinated and give adequate output with the help of BIM.

4.4 Overall Outcome of the Questionnaire Survey

This section will discuss the overall outcome of the questionnaire survey for each of the following factors which are: Technology, construction management, construction performance, information management, facility management, sustainability, and BIM usage, benefits and challenges.

4.4.1 Technology

The outcome of the survey shows that the Turkish construction industry has its own shortcomings when it comes to technology due to several reasons such as the poor interoperability among industry stakeholders, the continuous use of paper-based documents in business practices, and the absence of standardization in technology adoption among members of the industry. Furthermore, a possible limitation in using technological solutions can be due to the language of available programs that could be used in the Turkish construction industry in which some of them can be incompatible to the user's knowledge of a certain language. For example, if there is a program that is available in English language but not in Turkish, this would make it difficult for Turkish users that do not have knowledge in the English language to use that program.

4.4.2 Construction Management

The outcome of the survey shows that construction management in the Turkish construction industry is carried out without digital platforms that could be used for clear communication, cooperation and design which resulted in inefficient management of construction projects and shortage of information and documentation data which would make project activities and tasks become disorganized. These issues, along with the Turkish construction industry being far behind in digital transformation, can be the cause of various errors in construction management which would lead to poor execution and low productivity in a project.

4.4.3 Construction Performance

In terms of construction performance, the survey results indicate that there are crucial errors and mistakes along with a significant amount of wasted time and money in the Turkish construction industry. Moreover, there are possibilities of energy inefficiencies and high carbon emissions which would have a bad effect on the environment.

4.4.4 Information Management

The outcome of the survey shows that due to the common use of conventional procedures in the Turkish construction industry, problems in communication are experienced which make it difficult for a project to be carried out as a team. Furthermore, with the existence of various teams in a project trying to carry out different tasks and activities with no single programming language being used, critical loss of information and data would occur.

4.4.5 Facility Management

The outcome of the survey shows that most people working in the Turkish construction industry do not share projects to be utilized for facility management. The lack of coordination during the maintenance phase and the shortage of data and information about plans of existing structures can badly affect the management of facilities and would make repair and maintenance more difficult to carry out when needed.

4.4.6 Sustainability

In terms of sustainability, the survey results indicate that most people working in the Turkish construction industry do not take the sustainable approach into consideration when executing a project. Even though the construction industry overall is known for mainly consuming non-renewable resources and producing large amounts of waste and carbon emissions during construction, Turkish construction firms still rely on traditional methods in construction and are unaware of the latest technology and sustainable construction approaches, which obstruct the Turkish construction industry of creating and developing sustainable construction practices.

4.4.7 BIM Usage, Benefits and Challenges

The outcome of the survey shows that BIM usage is limited in the Turkish construction industry as traditional means of work are still used in the industry. There are several challenges that prevent BIM from being utilized to its fullest extent in the Turkish construction industry which are the following: Absence of action plans for BIM implementation, lack of BIM experts and specialists in the industry, lack of knowledge or awareness about BIM importance due to university education and curriculum systems not including BIM, lack of government support for BIM adoption, high cost of BIM implementation, and difficulty of transitioning into BIM process.

Although there are obstacles that make it difficult for Turkish construction companies to implement BIM, there are also many benefits obtained by the companies that use BIM, the most important ones are the following: Less conflicts and clashes on site, reduced errors in design, easier monitoring and control of project activities, and improved management of variables like cost, quality and time. These benefits along with many more have great positive impacts on productivity and efficiency as well as on every activity related to information management.

Chapter 5

ONTOLOGICAL FRAMEWORK FOR BIM IMPLEMENTATION IN TURKEY

5.1 Introduction

Since the research results indicate a weak rate of BIM adoption in Turkey, an ontological framework for BIM implementation in the country is made to aid the Turkish construction industry in adopting the technology. The framework is created based on several factors that would improve the adoption process of BIM in the Turkish construction industry. These factors are dependent on three categories which are people, organization and government. The factors that are included in the framework are the following: Training, awareness, government support, BIM education, client demand, BIM standards, and work environment. The relation between the ontological framework and the overall findings of the questionnaire survey is that by introducing the framework, the shortcomings or flaws in the Turkish construction industry that were mentioned in the findings and were based on several factors, can be mitigated or even eliminated with the improvement of the BIM adoption process overall.

5.2 Training

Since the successful adoption of BIM mostly depends on the expertise of the users, providing BIM training for staff and personnel is considered important for the improvement of BIM implementation in Turkey as it raises the technological capabilities of those who want to use BIM. To ease the transition from conventional process to BIM process and to familiarize industry professionals on the use of BIM, BIM training strategies should focus on new workflows and procedures as well as on the utilization of new software and programs. The ones that would be mostly responsible for establishing BIM training centers in Turkey are construction companies and organizations where they would create these training centers for their employees to aid them in using BIM.

5.3 Awareness

Increasing awareness of BIM is crucial as it would help in promoting BIM implementation in Turkey. Raising awareness of BIM and its advantages in the Turkish construction industry can be done in some ways like creating testimonies and documentations backed up by case studies and examples from construction projects where BIM was implemented.

5.4 Government Support

Government support plays a big role in enabling BIM to be implemented in the Turkish construction industry as it can be involved in most of the factors mentioned in the framework by offering BIM training and education initiatives, raising awareness of BIM, demanding the use of BIM as a client, and establishing BIM standards. The Turkish government should try and establish strategic approaches and plans to help the construction industry in adopting BIM. Furthermore, BIM implementation should be encouraged by the Turkish government in public projects and should be facilitated by the collaborative work of private construction companies and the Turkish government in private projects.

5.5 BIM Education

BIM education is quite significant for students in Turkish universities as offering the right curriculums that include BIM would give students the necessary knowledge and awareness about BIM and would provide them with the needed skills and expertise in BIM by familiarizing them with the way BIM is utilized in the construction industry. To have an education system that revolves around BIM, Turkish universities must cooperate with construction companies to acquire standards and guidelines to create an educational program of courses that would be offered to students. Furthermore, the existence of a professional degree after graduation that requires competence in BIM can bring the possibility of increasing the use of BIM technology in Turkey as Turkish construction companies and organizations would contribute to the development of new graduates for their own needs.

5.6 Client Demand

Client demand for BIM implementation is needed to encourage Turkish construction firms and organizations in adopting the technology. However, to increase the overall demand of clients for BIM implementation, the clients themselves must first realize the importance of BIM advantages from a financial point of view. This is where the Turkish government comes in as it can be the largest client which in turn would raise the overall demand of other clients for BIM implementation in the country.

5.7 BIM Standards

To increase the success rate of implementing BIM in construction projects in Turkey, BIM standards need to be provided which would include guidelines for utilizing BIM to its fullest extent which by following these guidelines would lead industry professionals to be capable of using the technology with comprehension and proficiency. The Turkish government together with the help of BIM specialists would be able to create BIM standards in Turkey, and these standards would be improved and refined by other standards from countries that have a more progressive implementation of BIM.

5.8 Work Environment

Establishing a new work environment that supports the use of BIM in the Turkish construction industry, which is the responsibility of top management in construction firms and organizations, can alleviate the difficulties that can come with the transition from old traditional work processes to new BIM work processes. There are several ways to set up a work environment that revolves around the implementation of BIM in a construction company such as the following examples: Offering training and instructions on how BIM can be utilized, allowing industry professionals to understand and be aware of BIM advantages, buying and acquiring BIM software and programs to be used, and giving promotions to those who use BIM.

Figure 5.1 shows the ontological framework for BIM implementation in Turkey which is based on three categories that contribute to the factors that were discussed in this chapter. These categories are people, organization and government.

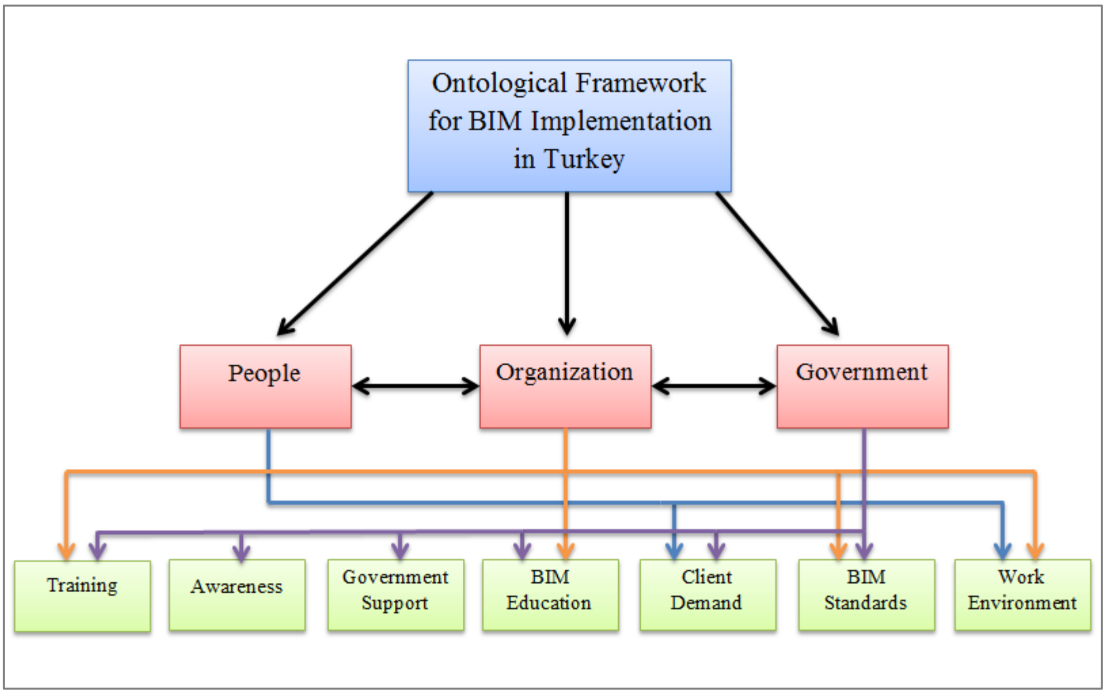

Figure 5.1: Ontological Framework for BIM Implementation in Turkey

Chapter 6

CONCLUSION

6.1 Introduction

In this chapter, the conclusion of the study includes the outcome of the research which is given in several bullet points. Also, recommendations for future studies are pointed out to those who want to conduct a research related to BIM implementation in Turkey.

6.2 Conclusion of the Study

The conclusion of the study includes its findings which are pointed out as follows:

- In terms of technology, the Turkish construction industry has its own shortcomings due to poor interoperability among industry stakeholders, continuous use of paper-based documents in business practices, and absence of standardization in technology adoption among members of the industry. Furthermore, the language of available programs that could be used in the Turkish construction industry can possibly obstruct the use of technological solutions in which some of these programs can be incompatible to the user's knowledge of a certain language. For example, if there is a program that is available in English language but not in Turkish, this would make it difficult for Turkish users that do not have knowledge in the English language to use that program.

- In terms of construction management, no digital platforms are used by the Turkish construction industry for purposes like clear communication, cooperation and design which resulted in inefficient management of construction projects and shortage of information and documentation data which would make project activities and tasks become disorganized. All of these problems along with the Turkish construction industry being far behind in digital transformation are severe as they can cause several errors in construction management which would lead to poor execution and low productivity in a project.

- In terms of construction performance, there are crucial errors and mistakes along with a significant amount of wasted time and money in the Turkish construction industry. Furthermore, there are energy inefficiencies and high carbon emissions which have a bad effect on the environment.

- In terms of information management, the Turkish construction industry experiences issues in communication due to the use of conventional methods of information management which make it difficult for a project to be carried out as a team. Moreover, critical loss of information and data could occur in construction projects because of the scarcity of single programming languages being utilized when there are several teams in a project trying to carry out different tasks and activities.

- In terms of facility management, most construction projects are not shared with organizations in the Turkish construction industry for the purpose of being utilized in the management of facilities. Furthermore, the lack of coordination during the maintenance phase and the shortage of data and information about plans of existing structures can negatively impact facility management and would make repair and maintenance more difficult to be carried out when needed.

- In terms of sustainability, there are not a lot of sustainable approaches taken into consideration when executing a construction project in Turkey, as Turkish construction organizations still rely on conventional processes that are generally not sustainable and are unaware of the latest technology and sustainable approaches in construction which could hinder the creation and development of sustainable construction practices.

- In terms of BIM usage, few construction companies in Turkey use BIM while conventional means of work are still used in the industry.

- In terms of BIM benefits that were gained by the Turkish firms and organizations that implement it, the most important ones are the following: Less conflicts and clashes on site, reduced errors in design, easier monitoring and control of project activities, and improved management of variables like cost, quality and time.

- In terms of BIM challenges that were encountered by the Turkish firms and organizations that implement it, these are the most frequent ones which are the following: Absence of action plans for BIM implementation, lack of BIM experts and specialists in the industry, lack of knowledge or awareness about BIM importance due to university education and curriculum systems not including BIM, lack of government support for BIM adoption, high cost of BIM implementation, and difficulty of transitioning into BIM process.

- After discussing the overall outcome of the survey made in the study, an ontological framework for BIM implementation in Turkey was created to help the Turkish construction industry in adopting BIM. The framework was based on three categories which are people, organization and government and each of them contribute to several factors that would improve the adoption process of BIM in the Turkish construction industry. These factors are: Training, awareness, government support, BIM education, client demand, BIM standards, and work environment.

6.3 Recommendations for Future Studies

The following points are recommendations and suggestions for future studies which are related to the topic of BIM implementation in Turkey:

- There should be a study that would measure the cost savings of implementing BIM in Turkey. In this study, construction projects that were completed without BIM implementation would be checked for any errors that occurred during design or construction. After identifying the costs of fixing these errors done by traditional work procedures, a calculation of BIM implementation costs would commence and then compared with the costs of fixing the errors that could have been prevented if BIM was implemented beforehand, resulting in a "cost-benefit ratio" analysis.

- There should be a study that would predict the overall cost of BIM implementation in Turkey. In this study, cost variables included in BIM implementation would be identified and the cost of each variable perceived in the country would be estimated. After estimating the costs for each variable, a predictive model would be generated which has the ability to predict the overall cost of BIM implementation for Turkish construction companies based on the identified cost variables. The model would then be assessed and evaluated to check its practicality and validity.

- There should be a study that would investigate the education system in Turkish universities and check the state of the availability of BIM courses in these universities. In this study, qualitative data about the state of Turkish universities and their inclusion of BIM courses are collected through in-depth interviews. The results of these interviews would be used to create a detailed roadmap that would help in including educational programs and curriculums that revolve around BIM technology and its implementation.

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APPENDIX

Questionnaire Survey Sample

Questionnaire Survey - An Ontological Study on the State of the Turkish Construction Industry and its Implementation of Building Information Modeling (BIM)

1- **What is your profession in the company you are working in?**

☐ Architect ☐ Civil engineer ☐ Mechanical engineer ☐ Electrical engineer

☐ Academician ☐ Energy expert ☐ Other

2- **Which of the following software/programs do you use for architectural design? (You can choose more than one answer).**

☐ Revit ☐ 3D Max ☐ Tekla ☐ AutoCAD ☐ Sketchup ☐ ArchiCAD

☐ Vectorworks ☐ No idea

3- **Which of the following software/programs do you use for structural design? (You can choose more than one answer).**

☐ Revit ☐ Sta4CAD ☐ Tekla ☐ AutoCAD ☐ SAP2000 ☐ IdeCAD

☐ Probina Orion ☐ ETABS ☐ No idea

4- **Which of the following software/programs do you use for MEP design? (You can choose more than one answer).**

☐ Revit ☐ Catia ☐ AutoCAD ☐ No idea

5- **How likely a project's duration and budget turn out to be as expected or as planned during the execution stage?**

☐ Not likely ☐ Somewhat likely ☐ Very likely

6- **At what stage do you develop and/or incorporate work safety measures for a project?**

☐ Safety measures are not incorporated ☐ When site installation is in progress

☐ At the design stage of the project ☐ At the construction stage of the project

7- **At what stage do you develop and/or incorporate performance analysis and simulation for a project?**

☐ Performance analysis and simulation are not incorporated

☐ At the design stage of the project ☐ At the construction stage of the project

8- **Do you make/have computerized models that can be used for facility management after a project is completed?**

☐ Yes ☐ No

9- **Do you make/have computerized platforms that can be used for quick information sharing and cooperation with stakeholders during construction stage of a project?**

☐ Yes ☐ No

10- **During design stage, do you take into consideration the sustainability of a project design?**

☐ Yes ☐ No

11- **Do constructed buildings or structures turn out to be consistent with the ones that are pre-designed?**

☐ Yes ☐ No

12- **What is the main method used in your company for sharing data and information in a project?**

☐ Paper ☐ Email ☐ Cloud system

13- **Does your firm or organization have any experience in using BIM?**

☐ Yes ☐ No

<u>**The next questions are for those who answered "Yes" on question 13, if you answered "No" then you can skip the rest of the questionnaire**</u>

14- **Which of the following dimensions does your firm or organization incorporate into the BIM model?**

☐ 3D visualization ☐ 4D scheduling ☐ 5D cost estimation

☐ 6D facility management ☐ 7D sustainability ☐ 8D safety

15- Which of the following benefits does your firm or organization obtain from implementing BIM? (You can choose more than one answer).

☐ Enhanced performance of construction ☐ Less conflicts and clashes on site

☐ Better communication between stakeholders ☐ Enhanced management of facilities

☐ Easier monitoring and control of project activities

☐ Better utilization of project's budget and time ☐ Reduced errors in design

16- Which of the following challenges does your firm or organization encounter when implementing BIM? (You can choose more than one answer).

☐ Lack of government support for BIM ☐ High cost of implementing BIM

☐ Lack of BIM experts and specialists ☐ Lack of client or owner demand for BIM

☐ Difficulty in transitioning from old process to BIM process

☐ Resistance to change from traditional ways of work

☐ Lack of knowledge or awareness about BIM importance

17- Do you think that there is enough academic research and development in the subject of BIM?

☐ Yes ☐ No

18- Do you think that construction projects in Turkey nowadays are handled well without the use of BIM?

☐ Yes ☐ No

19- Do you believe it is necessary to organize and establish BIM centers in Turkey to help in adopting BIM technology?

☐ Yes ☐ No

20- Does your firm or organization have a BIM execution plan?

☐ Yes ☐ No