An Investigation of Building Information Modeling Application in Design-Bid-Build Projects

Navid Sanei Sistani

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
January 2013
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Elvan Yılmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Asst. Prof. Dr. Mürüde Çelikağ
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Asst. Prof. Dr. Alireza Rezaei
Supervisor

Examining Committee

1. Prof. Dr. Tahir Çelik
2. Prof. Dr. Özgür Eren
3. Asst. Prof. Dr. Alireza Rezaei

ABSTRACT

Since, Design-Bid-Build (DBB) was the most popular project delivery method at the beginning of previous decade regardless of all its shortcomings, applying new advanced tools can compensate disadvantages of this method. Recently, advanced technology in construction management called Building Information Modeling (BIM) became popular among construction industry. Although, effects of BIM on different aspects of alternative project delivery methods were considered in literature, but adequate efforts on evaluating BIM application in DBB projects have not performed yet. This research aims to investigate effects of using BIM in DBB projects. For this reason, a questionnaire survey was conducted among construction industry practitioners in Iran to evaluate their opinions about using BIM in DBB projects. To assess reliability of questionnaire survey results, a single case was studied to compare cost and time of DBB projects in case of using BIM with real project which was executed without using BIM. According to survey results, BIM has more effects on cost and time in comparison with quality and health and safety from respondents' viewpoints. This claim was verified by studying cost and time in single case and was found out that using BIM could decrease total project costs up to 9.6% and reduce contractor expenses 5.9% of total project cost. Using BIM also could avoid delay in project completion as long as 17% of project duration. Finally, recommendations for construction industry practitioners and suggestions for researchers as future works were made.

Keywords: Project Delivery Method, Design-Bid-Build, Building Information Modeling

ÖZ

Önceki 10 yılın başından beri bazı eksiklikleri olmasına ragmen, “Geleneksel müteahhit seçme metodu”(GMSM) (Design-Bid-Build) en popular yöntemdir ve yeni gelişmiş araçların uygulanması bu yöntemin dezavantajlarını ortadan kaldırabilir. Son zamanlarda, yapım yönetim teknolojisinde gelişen bir model, Bina Bilgi Modelleme (BBM) (Building Information Modelling) inşaat sektöründe popüler olmuştur. Şu ana kadar GMSM’in alternatifleri üzerine BBM uygulamaları konusunda araştırmalar yapılmış olmasına rağmen, GMSM için literatürde BBM uygulaması üzerine yapılmış bir araştırmaya henüz rastlanamamıştır. Bu araştırma, BBM uygulamasının GMSM üzerindeki etkilerini ortaya çıkarmayı amaçlamaktadır. BBM uygulamalarının GMSM üzerindeki etkilerini ortaya çıkarmak için İranda inşaat sektöründe pratik yapanlar arasında bir ankat yapılmıştır. Yapılan anketin güvenilirliğini ölçmek için, bir vaka çalışması yapılarak, GMSM uygulamasında BBM kullanılması ve kullanılması arasındaki zaman ve maliyet farklarının tesbiti yapılmıştır. Anket neticelerine göre, BBM’nin zaman ve maliyet üzerine olan etkileri iş kalitesi, ve iş sağlığı ve işçi güvenliği üzerine olan etkilerinden daha fazladır. Bu netice vaka çalışması ile de yapılmış ve BBM uygulamasının toplam proje maliyetleri üzerinden %9.6 ve müteahhit maliyetleri üzerinden de %5.9 oranında azalmalara neden olmuştur. BBM kullanılması inşaat süresinin uzamasını % 17 oranında önleyebilmektedir. Sonuç olarak, inşaat sektöründe çalışanlara ve ilerideki araştırmacılara tavsiyelerde bulunulmuştur.

Anahtar Kelimeler: Müteahhit Şeçme Yöntemi, Geleneksel Müteahhit Seçme Yöntem, Bina Bilgi Modelleme

To my beloved wife

ACKNOWLEDGEMENTS

I would like to acknowledge my dear supervisor Dr. Alireza Rezaei for supporting my Master thesis research. His guidance helped me in all aspects of research and writing of this thesis. I owe him for my experiences in research.

Beside my advisor, I appreciate Prof. Dr. Tahir Çelik who shed light for me in construction management. He made opportunities for me to working in this area. My sincere thanks go to Dr. Ozan Koseoglu for introducing BIM to me.

I thank specially to my dear friend, Mohamadreza Zadeh Morshedbeik, for sharing his knowledge about planning and scheduling with me.

I would like to thank my parents for their supporting throughout my life. Last but not least, I thank my lovely wife for her kindness and sacrifice.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEC	Architecture, Engineering, and Construction
AGC	Associated General Contractors of America
AIA	American Institute of Architects
AISC	American Institute of Steel Construction
BIM	Building Information Modeling
CAD	Computer-Aided Design
CO	Change Orders
CPM	Critical Path Method
DBB	Design-Bid-Build
GPS	Global Positioning Systems
HSS	Hollow Structural Section
HVAC	Heating Ventilation and Air Conditioning
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical, and Plumbing
PDM	Project Delivery Method
PDS	Project Delivery System
RFI	Request For Information
RFID	Radio Frequency Identification

Chapter 1

INTRODUCTION

1.1 Introduction

Design-Bid-Build (DBB) is also known as “Traditional” project delivery method. In DBB owner has separate contract with designer and contractor. Designer is responsible to prepare drawings, specifications and bid documents based on the owner’s needs. Then competitive bidding will be held to select the contractor based on the lowest bid price for all work required to build the project as specified in bid documents. After construction industry experienced long term use of DBB, the deficiencies of this method appeared.

BIM which refers to Building Information Modeling initially was considered as a tool for design with components instead of lines. It enabled designers to virtually build a wall with all of its components rather than drawing wall with a series of lines which were used in 2D CAD. But now, BIM is extremely developed to efficient tool for model analysis, clash detection, product selection, and project conceptualization. While BIM involves all project parties rather than just designers, it is a beneficial tool not only for design team, but also for construction industry even whole world.

Although DBB is still the most popular method in terms of cost and numbers of implemented projects, researchers have focused on alternative project delivery methods in the last two decades, because of their capabilities in early collaboration. It is obvious that late involvement of contractor in projects will remain as main disadvantage of DBB method, but some disadvantages of this late involvement can be avoided by using collaborative tools like BIM. Investigating BIM application in DBB projects as a starting point for adopting BIM through construction industry, and also to evaluate its benefits in most popular delivery method seem essential.

Two methods for achieving these aims were employed for gathering both breadth and in-depth information. Questionnaire survey evaluated construction industry practitioners' opinions about using BIM in DBB projects and through case study benefits of BIM application were calculated simultaneously.

According to the results, the claim of respondents about effects of BIM on reducing cost and time in DBB projects were approved and their corresponded monetary amounts were calculated by case study. Findings showed that using BIM could reduce owner's costs and contractor's expenses. In addition BIM usage could avoid delays considerably.

1.2 Statement of the Problem

Linear sequence due to necessity of completing design prior to starting construction which leads to time-consuming process of delivery, and detecting design failures that result in Request For Information (RFI) or Change Orders (CO) which cause disputes and aggressive atmosphere between different participants are examples of DBB delivery method defects. While BIM is efficient tool for model analysis, clash detection, product selection, and project conceptualization that result in better quality buildings at lower cost and reduced project duration, it can be very useful to compensate disadvantages of DBB method.

Kuprenas and Nasr (2007)conducted a research on cost performance of DBB project delivery. Hallowell and Toole (2009) provided contemporary DBB model .Different project delivery methods were compared by Neil and Al-Battaineh (2011) and impact of design cost on DBB project performance was investigated (Shrestha and Mani, 2012). Previously, benefits, risks and challenges of BIM were analyzed (Azhar, Hein, and Sketo, 2008), profits of scheduling, estimating, and BIM combination were specified (McCuen, 2008) and business value of adopting BIM was demystified (Aranda-Mena et al., 2009). Gu and London (2010) surveyed BIM adoption in the AEC industry. Becerik-Greber and Kensek (2010) specified research directions and trends about BIM. Benefits of BIM was investigated by Azhar (2011) and was measured by Barlish and Sullivan (2012).

Nevertheless, serious efforts on investigating effects of using BIM in DBB projects have not been yet performed. Figure 1.1 shows the process chart of this study. According to the chart, the process of this research was started by determining the research question as “How useful is BIM application in DBB projects?”

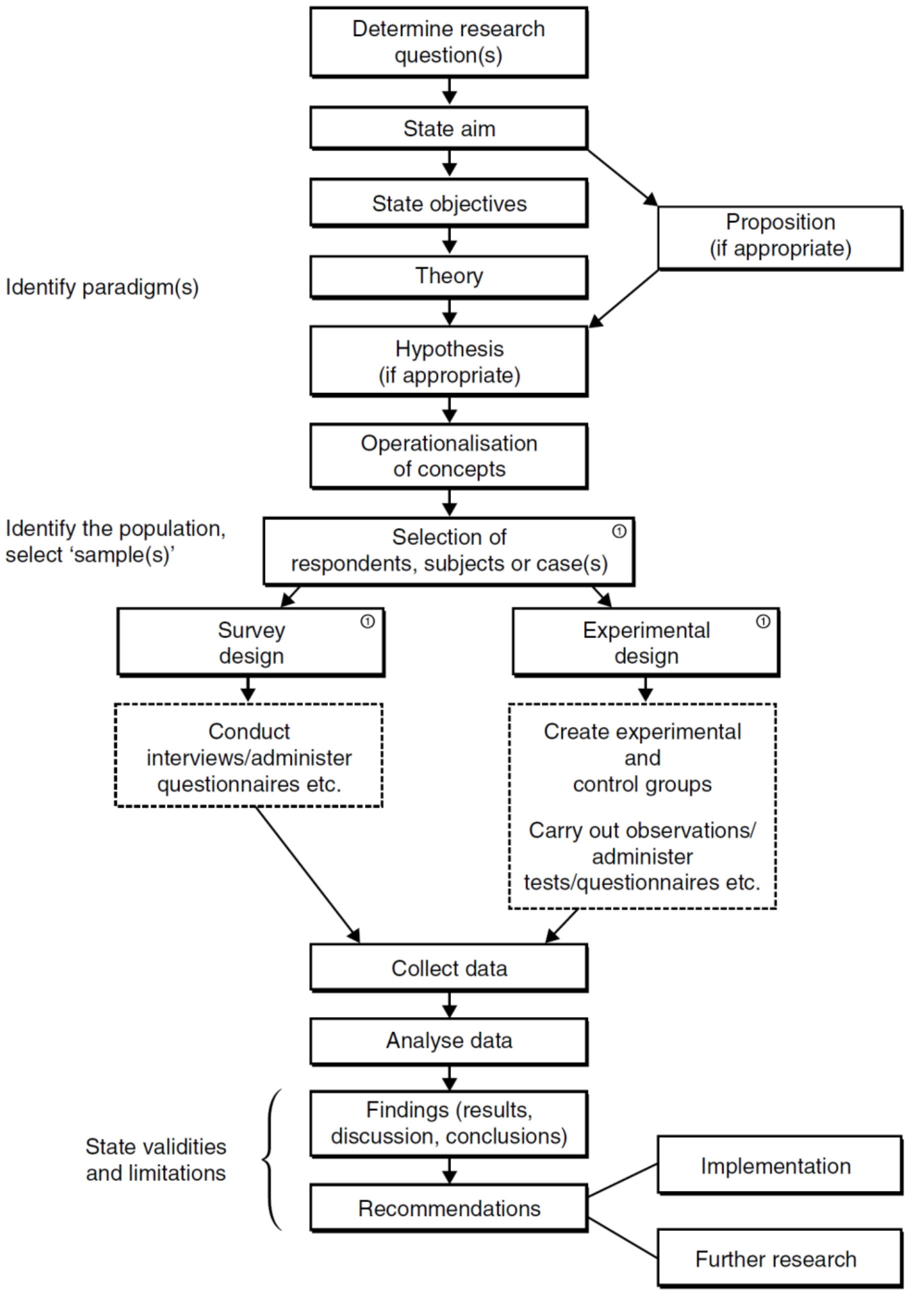


Figure 1.1. Research process (Fellows and Liu, 2009)

1.3 Aims and Objectives

To achieve the aim of this study which was answering to determined research question, following objectives were defined:

1. To investigate to what extent construction management factors are affected by using BIM in DBB projects.

2. To specify most significant barriers to adopting BIM in DBB projects.
3. To determine most significant challenges in using BIM in DBB projects.
4. To calculate the amount of cost saving by using BIM in DBB projects.
5. To compute the amount of delays that can be avoided by using BIM in DBB projects.

1.4 Works Carried Out

To investigate BIM application in DBB projects, the Triangulation Mixed-Method that uses two research methods simultaneously was selected for this study. By questionnaire survey, effect of using BIM on factors of construction management diamond -time, cost, quality, and health and safety- were evaluated. Afterward, most significant barriers to adopting and challenges in using BIM were specified by respondents. Finally, respondents expressed their tendency to participate in BIM training and using BIM in their future projects. According to characteristics of case study which encourages in-depth investigation of particular instances within the research subject, a single-case were studied to investigate effects of using BIM on cost and time of DBB projects.

1.5 Achievements

According to respondents' opinions, out of four factors of construction management in DBB projects, BIM has more effect on reducing cost and time. "Lack of demand from public (government) sector as owner for using advanced tools like BIM" was selected as most significant barrier to adopting BIM and "Lack of specialist (Architect/Engineer) with experiences in using BIM" was most significant challenge in using BIM from respondents' point of view. Finally, more than 93 percent of respondents expressed that they tend to use BIM in their future projects.

According to case study, it was found out that by reducing initial estimated cost and avoiding change orders by using BIM, owners could save at least 9.6 percent of total project cost and contractor could reduce his/her expenses at least 5.9% of total project cost. Change orders and reworks resulted from inaccuracies of design, totally caused 21 days delay in project completion equal to 17% of total project duration which was avoidable by using BIM.

1.6 Limitations and Delimitations

While this study was delimited to DBB projects in Iran and questionnaires were filled out by construction industry practitioners in Tehran (capital of Iran) and Mashhad (second largest city of Iran), the followings are undesirable limitations of this study:

- Low level of awareness about BIM among respondents which might cause to doubt on reliability of questionnaire results.
- Hardware limitations caused by inefficiencies of computer which was used for modeling the studied case.
- Software limitations caused by using student version software for modeling the studied case.
- Limitations caused by inaccuracy or lack of information about the reasons of cost overruns and delays in studied case.

1.7 Thesis Guideline

In chapter 2 Project Delivery Method (PDM) or Project Delivery System (PDS) is defined. DBB is then described; roles and responsibilities of owners, designers, and contractors are discussed in this method; and advantages, disadvantages, and risks associated with DBB are mentioned. Finally, importance of studying this method regarding to its characteristics is exlained.

Chapter 3 aims to define BIM and describe its differences with CAD. Advantages of using BIM for owners, designers, and contractors are discussed, challenges in adopting and using BIM are described and finally, significance of BIM as subject of this study according to its advantages is summarized.

In chapter 4, review of literature represents methods used in previous researches with the similar topics of this study and reasons for choosing each method in this research. Questionnaire survey is then described from designing and distributing to respondents' information. Finally, general information and contractual details of studied case and software used for modeling are explained.

Chapter 5 discusses on questionnaire survey, participants' point of view about level of effectiveness of BIM on construction management factors, barriers for adopting BIM, challenges to using BIM, and their consideration about BIM. In accordance to studied case, effects of using BIM in reducing cost and time in a DBB project are evaluated. Finally, results of this study are summarized.

In chapter 6, initially general conclusion mentions notable findings of this study. Recommendations for construction industry practitioners about using BIM in their projects are made. Finally, some suggestions are made for researchers who tend to work on this topic in their future works.

Chapter 2

DESIGN-BID-BUILD

2.1 Introduction

Although there are different types of methods for delivering projects, no one is perfect for all types of projects and regarding to their advantages and disadvantages, each one is appropriate for specific project. This chapter introduces Design-Bid-Build (DBB) as one of the most important project delivery methods.

In this chapter, Project Delivery Method (PDM) or Project Delivery System (PDS) is defined in the second section. Third section describes DBB, and discusses roles and responsibilities of owners, designers, and contractors, and mentions advantages, disadvantages, and risks associated with DBB. Finally, summary section explains importance of studying this method regarding to its characteristics.

2.2 Project Delivery Methods

Kenig (2004) mentioned owner, designer, and contractor as 'classic triangle of construction' which participate in all projects. Variety of their relationships shape different PDMs. "Project delivery method is the comprehensive process of assigning the contractual responsibilities for designing and constructing a project" (Kenig, 2004).

"A project delivery method equates to a procurement approach and defines the relationships, roles and responsibilities of project team members and sequences of activities required to complete a project" (Walewski, Gibson, and Jasper, 2001). Ohrn and Rogers (2008) defined PDM as "the process through which constructed projects are organized and completed including establishing how the contractor will be selected, the scope of services provided, the type of relationship with owner, and how the contractor will be compensated".

Cost, quality, time, and safety are four considerable factors in managing any construction project which could be achieved by different methods. Performance, trust and cooperation among parties are factors of success or failure of delivery methods. Regarding to uniqueness of every project, each project has its own particular challenges which lead to establish the claim that 'there is no perfect project delivery'. Therefore, selecting the best project delivery method for each project must be performed separately case-by-case (Mahdi and Alreshaid, 2005).

Jackson (2010) stated that "project delivery methods differ in five fundamental ways:

- The number of contracts the owner executes,
- The relationship and roles of each party to the contract,
- The point at which the contractor gets involved in the project,
- The ability to overlap design and construction,
- Who warrants the sufficiency of the plans and specifications".

Design-Build was the typical method for delivering projects in United States up to end of nineteenth century. During second half of nineteenth century, by progressing and specializing the design and construction and entering technological advances in construction industry, the basement of complicated buildings (e.g. skyscrapers and bridges) was founded. This improvement resulted in separation of design and construction firms which led to appearance of DBB project delivery method. Seeking qualification from architects and engineers by federal government as largest purchasers of construction services and demanding to deliver projects based on low bid were two side of the coin which solidified basis of using DBB. Using DBB was continuing for about 150 years (Greenhalgh, 2011).

After construction industry experienced this long term use of DBB, the deficiencies of this method appeared. Linear sequence of design and construction due to necessity of completing design prior to starting construction which leads to time-consuming process of delivery, also detecting design failures that resulted in Request For Information (RFI) or Change Orders (CO) which caused disputes and aggressive atmosphere between different participants were examples of this delivery method defects (Pishdad-Bozorgi and Garza, 2012). To eliminate these defects "the 1996 Clinger-Cohen Act allowed qualifications-based selection of builders using the design-build and construction manager as constructor forms of project delivery" (Smith, Castro-Lacouture, and Oberle, 2009) and alternative delivery methods were risen up.

2.3 Design-Bid-Build

Regardless of all shortcomings, DBB was the most popular delivery method at the beginning of previous decade (almost 90 percent of public buildings and about 40 percent of private buildings in 2002 (Eastman et al., 2011)). As Touran (2009) expressed, "Design-Bid-Build has traditionally been used throughout the United States, and all 50 state codes have given full authority to use this method in their projects. Alternative delivery methods do not have this clear statutory support. Some states do not allow using alternative delivery methods, some have given one-time authority to use an alternative method for a special project, a group of states have put some limits on the application of alternative delivery methods, and a few states require obtaining extra approval in order to use alternative methods".

In DBB owner has two separate contracts with designer and contractor. Designer has responsibility to prepare drawings, specifications and bid documents which regard to owner's needs. Then competitive bidding will be held to select the contractor based on the lowest bid price for all work required to build the project as specified in bid documents (Ohrn and Rogers, 2008). The designer may act as the owner representative to control implementing project by contractor but there is no contractual relationship between designer and contractor. According to the nature of this PDM, bidding cannot be performed before completing the design phase because contractor needs completed drawings and specifications to estimate the bid price. So, it is a linear process which contractor and designer integration is impossible (Kymmell, 2008). Touran (2009) mentioned main characteristics of DBB as follows:

- "There are separate contracts for design and construction.
- Contractor selection is based entirely on cost.
- Design documents are 100% complete."

In DBB the owner can completely check the design outputs especially the details and specifications, which is very useful in complicated projects (Mahdi and Alreshaid, 2005). But inaccuracy and uncertainty of design details is a barrier to use pre-fabrications and offsite fabrications. Prefabrication has less cost and more quality but onsite fabrication constrains cost overruns and delays to project (Eastman et al., 2011).

Eastman et al. (2011) mentioned six reasons which during construction phase may cause to change in designs:

- “Previously unknown errors and omissions,
- Unanticipated site conditions,
- Changes in material availabilities,
- Questions about the design,
- New client requirements,
- and new technologies”.

Whatever was the reason of changes, these challenges required to be met by project participants. In order for each of above reasons to occur, the process of specifying the cause of change, assigning responsibilities, calculating time and cost, and finding solution must be carried out. This process involves a RFI which must be considered by designer or responsible party, then to issue the CO to all parties. As previously discussed, this process leads to increasing time and cost and probably the disputes and claims.

After completely finishing the construction phase, commissioning will be done by testing and controlling building performances. The final part of the contract might be submitting as-built drawings to owner. As-built drawings are usually 2D finalized drawings of the building regarding to changes which were applied on initial designs. This information must be transferred to facility management firms for maintaining and operation of the building. Considering the size of building, interpreting all these details by 2D drawings will be a costly and time-consuming procedure (Eastman et al., 2011).

2.3.1 Owner roles and responsibilities

During the design phase, owners are responsible to describe their needs and expectations from project and provide the requirements to the designers (Mahdi and Alreshaid, 2005). In construction phase, owners have more responsibilities in comparison to design phase. Owner is responsible for interpreting the contract, drawings, and specifications to contractor; also owner must warrant the sufficiency of drawings and specifications for contractor to complete the project. If there are any errors or differences between drawings and owner's needs, the owner has liability to pay cost of extra tasks which is performed by contractor (Jackson, 2010).

Kenig (2004) stated that "although the owner warrants the design and specifications to the constructor, the designer does NOT warrant the design and specifications to the owner. If the designer makes a design error that costs the owner damages, the designer will be liable to the owner only if the error occurred because the designer failed to perform in accordance with the standard of care and skill applicable to the profession at large."

2.3.2 Designer roles and responsibilities

Designer's responsibilities are to design drawings and specifications together with assisting the owner to prepare bid documents. Kenig (2004) mentioned that the designers have two types of duties to owners:

- Duties created by a professional standard of care expected from the designer or engineer,
- And contractual duty established by the contract between the designer and the owner.

Professional standard of care duty is about performing the design at the level which expected from any member of architectural or engineering profession. The standard of care is not addressed in contract and may be established by government or the profession itself.

According to the contract, designer also has duties to prepare drawings and specifications considering the requirements stated in contract (Kuprenas and Nasr, 2007). These duties are in addition to professional standard of care duties and may include scheduling, cost, and approvals.

2.3.3 Contractor roles and responsibilities

The main responsibility of contractor is to perform the minimum requirements of contract to satisfy the owner. In the bidding stage, owner seeks for the least bid price; so the contractor undertakes implementing project with the minimum requirements expressed by drawings and specifications. Of course, owner has this right to ask further tasks by change orders. The contractor accepts the risk of performing project by the bidding price and is free to complete the project by its own means and methods.

2.3.4 Advantages

The most significant advantages of DBB method are as listed below:

Cost: Using DBB, owner benefits by competition which encourages contractor to offer lowest price for tender. "This is important, because construction cost is a large portion of initial project costs" (Kenig, 2004). Furthermore, by completed design drawings and specifications, owner has a certain view of project cost which level of cost certainty is more in lump sum payment method (AIA and AGC, 2011). If there are uncertainties about the quantities, using the unit price method can deliver benefit to owner and contractor does not suffer from risk of fluctuating quantities.

Competition: According to high amount of qualified contractors, in comparison with alternative delivery methods, DBB has highest level of competition (Walewski et al., 2001). This market competition is profitable for owner by receiving proposals with low bid price. There is a potential for owner to increase competition by dividing project to small packages and assigning several contractors for each part (Touran et al., 2009). In addition, this delivery method is very useful for public owners to assign the contractor neutrally and without any political pressure or corruption (Kenig, 2004).

Experience: The DBB historically used by contractors and their experiences in this delivery method made it the best option in terms of contractor experience (Harrington-Hughes, 2002). As this method is known as a traditional delivery method, it is well understood by different parties of construction industry; also considering staff capabilities, experiences in using DBB are significant.

Goals and Objectives: Full control of owner on design phase and completing design prior to commencing construction phase ensure owner to achieving the goals and objectives of the project (Touran et al., 2009).

Control of Project: Regarding to the separate contracts with designer and contractor, the owner can check the quality of design before bid stage and control quality of construction and materials based on completed drawings and specifications mentioned in bid documents. This method has also a well-known procedure for change orders which makes it flexible during construction phase.

Third-Party Agreements: In DBB method, owner has enough time to negotiate with stakeholders and get required agreements before construction phase. Stakeholders are also able to control the completed design prior to assigning contractor.

Laws: Historical usage of this method during last 150 years provided well-structured legal basement for using DBB worldwide. Regarding to selecting contractor by bidding, it is the most reliable method for delivering projects and there is familiarity for authorities in dispute conditions.

Sustainable Design Goals: This method allows owner to consider social and environmental impacts of project and makes opportunity to have a sustainable design. These goals can be achieved by applying recycled materials and including stakeholders inputs into design phase (Touran et al., 2009).

2.3.5 Disadvantages

As previously stated, DBB has disadvantages which were recognized by reviewing the literature and will be described in the following:

Schedule: In DBB method, completing design phase is predecessor of construction phase and the overlapping of these two phases is impossible regarding to the completed design requirement for bidding. This sequential procedure imposes longer schedule than alternative delivery methods (Walewski et al., 2001). This delivery method has also longer schedule growth in comparison with other delivery methods (Scott et al., 2006).

Staffing Required: Regarding to the characteristics of this delivery method, owner has two separate contracts with designer and contractor. The owner deals with designer at the beginning and then with contractor in construction phase. The high level of involvement in different phases of project needs employing a large number of staff by owner (Kenig, 2004).

Complete Design: Completing design prior to construction phase results in lengthy design phase because of high amount of stakeholders inputs and also lead to lack of contractor inputs in design phase (Touran et al., 2009).

Construction Claims: DBB is in first level in terms of high number of claims and disputes. The subject of disputes are authority, responsibility, and quality (Walewski et al., 2001). While the owner is responsible for accuracy of designs, the error claims is prevalent in DBB. Konchar and Sanvido (1998) expressed that one indication of the high number of claims is possibly the highest amount of cost growth in this delivery method.

Adversarial Relationship: In this delivery method, adversarial relationship is very likely especially between owner and contractor. Uncertain boundary of owner and contractor responsibilities is a reason for these two parties to blame each other in case of failures or during disputes (Halpin, 2005).

Communication: Involvement of contractor into project after completing design phase and lack of early communication may lead to oversights and misunderstanding about the project details (Kymmell, 2008). In more crucial circumstances, Pishdad-Bozorgi and Garza (2012) mentioned 'lack and/or failure of collaboration and communication among the parties' as one of the reasons which creates adversarial relationships amongst and between project participants which results in litigation between them.

Change Orders: While the owner is responsible for accuracy of design, in case of encountering with errors in design, owner is liable to financing the changes. Because of this there is no incentive from contractor to decrease the cost of change orders in DBB (Touran, et al., 2009).

Bid Price: One of the most popular issues in failure of DBB projects is offering underestimated price to win the bid. In this condition, contractor tries to compensate the losses by profiting from change orders. This abuse of change orders increases disputes between owner and contractor (Eastman et al., 2011).

Errors: During design phase, errors may rise up because of different reasons. The reasons may be unintentional like human errors or carelessness, or purposeful like including fewer details in drawings to enhancing more profit from reallocating design cost.

Sustainable Construction: Considering late involvement of contractor and lack of contractor inputs in design phase, there is a little opportunity for owner to take advantage of contractor knowledge about sustainable design. So, there is a risk associated with this delivery method to lose sustainable certificates like LEED (Touran et al., 2009).

2.3.6 Risks

In DBB method, owner can divide risk between designer and contractor, but errors in design may result in cost overrun which owner shifts this risk to designer team. This delivery method had used for more than one century, this long term usage provided rich background in terms of laws and standard contract to managing risks associated with DBB. Walewski et al. (2001) noted that “although risks and rewards are easy to understand in this method, disputes often arise over authority, responsibility, and quality.”

Owner may or may not gain profit from separate contracts with designer and contractor depending on the experience of owner and its consultant in managing risks. The most important factor in successful managing of risks in this delivery method is to clearly define scope of project and works in designer and contractor contract. Otherwise the owner encounters with challenges resulting from uncertain duties and responsibilities.

2.4 Summary

Regarding to significance of DBB as the most popular method of project delivery in terms of number and cost of implemented projects by this method, applying new technological means and tools of managing construction project could cover the disadvantages and highlight the advantages of DBB.

In accordance with the characteristics of this delivery method, considering BIM as a managerial tool in DBB projects could be useful from both academic and industrial points of view.

Chapter 3

BUILDING INFORMATION MODELING

3.1 Introduction

Recently, advanced technology in construction industry called Building Information Modeling (BIM) became popular among construction industry. The main questions about BIM are "What are its differences with 3D CAD?" and "What advantages do these differences provide in comparison with CAD?"

In this chapter, second section tries to define BIM and describes its differences with CAD. Next three sections discuss about advantages of using BIM for owners, designers, and contractors. Then, challenges in adopting and using BIM are described and finally, significance of BIM as subject of this study according to its advantages is summarized.

3.2 What Is Building Information Modeling?

3.2.1 Definition

Smith (2007) defined BIM as "a digital representation of the physical and functional characteristics of a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of the model is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the modeling process to support and reflect the roles of that stakeholder."

BIM was considered as a tool for design with components instead of lines. It enabled designers to virtually build a wall with all of its components rather than draw wall with a series of lines which were used in 2D CAD. But now, BIM is extremely developed to efficient tool for model analysis, clash detection, product selection, and project conceptualization (Weygant, 2011).

Eastman et al. (2011) claimed that “Building Information Modeling (BIM) is one of the most promising developments in the Architecture, Engineering, and Construction (AEC) industries that results in better quality buildings at lower cost and reduced project duration”. Also, Weygant (2011) emphasized “this advancement (BIM) created one of the largest cost benefits that the design and construction communities have ever experienced”.

3.2.2 BIM versus CAD

“Just as CAD (computer-aided design) improved upon hand drafting, BIM is improving upon CAD. To put it simply, CAD + specifications = BIM” (Weygant, 2011).

CAD was initially released to facilitate design by drawing lines easily and quickly and not to be worried about erasing papers in case of doing mistakes. These excellences caused saving time and energy in design phase. By developing CAD, it was equipped with capability of drawing different separate line types by categorizing them into different layers. This was the first step in movement into 3D design. By transition from two-dimension lines to three-dimension solids and improvements of 3D software, a revolution in design was happened and the BIM era was begun (AGC, 2009).

Unlike the general belief, 3D design and visualization is not the main characteristic of BIM, while nowadays most of the simple CAD software comprises this ability. The main difference of BIM and CAD is that despite the CAD drawings which are built with lines, in BIM, components are intelligent and contain their own details such as size, material, type etc. Jackson (2010) stated “because of the ‘I’ in BIM, the model can expand beyond the 3D features that allow the architect to communicate the design intent and lets us see the project. The ‘I’ permits us to add the fourth and fifth dimensions of time and cost to the BIM”. While BIM involve all project parties rather than just designers, it is a beneficial tool not only for design team, but also for construction industry even whole world.

3.2.3 Misconceptions regarding BIM

Like every new tool and technology, BIM also has its pros and cons which insist on their reason. Some of these oppositions are based on misunderstandings about BIM and its concept. Deutsch (2011) mentioned some of most important misconceptions about BIM as follow:

- “Productivity suffers during the transition to BIM.
- BIM applications are difficult to learn.
- BIM disrupts established workflows.
- Owners and contractors benefit most from BIM, not the designer.
- BIM increases risk.
- BIM requires a different project delivery method.
- You cannot tell who is responsible for what or who owns the model.
- Anyone can change anyone else’s model.

- BIM blurs the distinction between design and construction.
- The architect is not in "responsible charge" of the design.
- You cannot have some information in the model and some only in 2D details.
- The model cannot be a contract document.
- You cannot rely on the dimensions of the model.
- The architect is subject to more lawsuits from contractors."

3.2.4 BIM adoption

It must be noted that transition from CAD to BIM is a long-term process. Although the obvious advantages of BIM in reducing cost and time and improving quality and health and safety caused that designers moving to use BIM at least two times faster than transition from hand drawing to CAD (Deutsch, 2011), but this transition has been slower than anticipated. Deutsch (2011) noticed that "adopting BIM without a plan can be like taking a trip unaware of all the baggage that can slow you down. Firms may own the software but not yet own the process".

3.3 BIM for Owners

The owners can benefit from using BIM in several aspects to reduce cost and time and improve quality and health and safety. All types of ownership of almost all types of projects can achieve benefits from using BIM; it is obvious that the amount and types of these benefits differ from case to case. In this section, the most important advantageous criteria of using BIM for owners will be mentioned.

3.3.1 Design assessment

According to the scopes of project, the owners' requirements at every phase must be met by designers. While these requirements may change during the design phase, by using 2D drawings and specifications, it will be difficult for owners to assure that projects' functional needs will be met or not (Nam-Hyuk et al., 2008).

Using 3D modeling will make very easier to involve valuable inputs form all stakeholders into project model. Applying changes to designs regardless of the reason of those changes is much faster and easier in BIM model and will be accessible by relevant stakeholders (Wong, Wong, and Nadeem, 2010). Also in terms of demand for additional types of simulation like crowd behavior or emergency evacuation scenarios, these simulations and relative analysis are accurately performed by BIM model (Becerik-Gerber eet al., 2012).

3.3.2 Complex building

Regardless of project type, design outputs must satisfy the minimum requirements of building code and statutory and liability issues. In modern buildings with complex facilities, these issues are became more complicated especially for Mechanical, Electrical, and Plumbing (MEP) systems (Bernstein and Pittman, 2004).

By BIM model, each facility supplier is involved in design and its representative can provide input and review of model which considerably avoid potential reworks. Some facilities must be operable 24 hours in day and 7 days in week, these types of operations usually depend on data communication and need uninterrupted maintenance. BIM models enable owners to virtually review the accessibility and maintainability of facilities (Becerik-Gerber et al., 2012). In addition, using BIM can incredibly reduce claims and disputes between project parties by providing more accurate design by collaboration of MEP suppliers.

3.3.3 Sustainability

Nowadays sustainability becomes popular between owners regarding to its three main aspects. Reducing environmental effects of projects is been taken into consideration by society and may increase the marketability of projects; meanwhile energy consumption analysis can reduce the life cycle cost of projects. Selecting most appropriate materials by analysis of efficient energy consumption during design phase is one of the most significant advantages of using BIM (Bynum, Issa, and Olbina, 2012).

3.3.4 Cost estimate

One the most popular problems which owners in construction industry may face is cost overruns. Main reasons of cost overruns are inaccurate design and unreliable estimates. Jackson (2002) mentioned four reasons which impact estimates reliability as market conditions that change over time, the time between estimate and execution, design changes, and quality issues. BIM provides the basis for accurate estimate by detailed quantities and enables owner to influence project cost at the early phases like conceptual and feasibility phases. Employing BIM at early phases allows owners to compare different design scenarios. “Accurate estimates can be very valuable early in the project, particularly for assessing a project’s predicted cash flow and procuring finance” (Eastman, et al., 2011).

Owners and estimators must be able to respond to design changes quickly to evaluate impact of these changes on overall project budget accurately. BIM is equipped for overcoming these problems by quantity takeoff software. Eastman et al. (2011) emphasized “owners must realize that BIM-based takeoff and estimating is only a first step in the whole estimating process; it does not thoroughly address the issue of omissions. Additionally, the more accurate derivation of components that BIM provides does not deal with specific site conditions or the complexity of the facility, which depend on the expertise of an estimator to quantify. BIM-based cost estimation strategically helps the experienced cost estimators but does not replace them."

3.3.5 Time reduction

Time delays are bottleneck for all delivering products in all industries; construction industry is not exempted in having trouble with delays in project delivery. BIM help owners and project team to reduce time at all phases by several ways (Harty and Laing, 2009). Parametric nature of components in BIM makes prefabrication easier and provides automated update after design changes which leads to faster project completion (Barlish and Sullivan, 2012). Using BIM can increase productivity by providing better understanding among project practitioners. Increasing productivity has positive effects on reducing scheduled times of the tasks.

By integrating 3D BIM model with time scheduling, 4D model will be produced that links the components with their corresponding tasks. 4D modeling gives better understanding about the tasks and their relationships and sequences result to more reliable schedule and plan for construction phase. During the construction phase, it is very valuable to virtually compare the real completion percentage of project with anticipated one according to schedule (Chau, Anson, and Zhang, 2004).

3.3.6 Facility management

During all phases of project, practitioners generate valuable information which will be used by facility managers for operation and maintenance. This information form "As-Built" drawings which must be updated according to final executed components;

also be in usable form for facility managers. Using BIM gives more reliability to owners in commissioning phase to be sure that their operational needs were met. By transition information from whole practitioners to facility manager as BIM model, extra efforts for gathering project data will be avoided and will be resulted to save time and cost. BIM model also can use to assess how maintenance operations and activities in one section affect other sections (Park et al., 2011).

3.4 BIM for Designers

"Building Information Modeling (BIM) can be considered an epochal transition in design practice" (Eastman, et al., 2011). BIM affected all stages of design including conceptual design, architectural design, engineering analysis, and construction-level design. While BIM influences design phase more than other phases, the advantageous using of BIM during design phase is divided into three stages and is described in following.

3.4.1 Design

Designing a construction needs different experts including architects, structural engineers, mechanical engineers, etc. collaborating during design phase. Design outputs are detailed construction components which are traditionally prepared as drawings and specifications. This information is provided by architects and engineers to satisfy owner needs and code requirements. According to wide range of codes and their complicated requirements in some cases in one hand, and different anticipated functions to meet owner needs in other hand, huge amount of data and information is generated during design phase (Kim and Grobler, 2009). BIM makes integrating structural and mechanical systems into design much faster by importing data from analysis software, understanding about details better by BIM 3D model, and executing structures cheaper by facilitating using prefabricated structures.

Synchronizing different software data is practicable by new neutral format called IFC (Industry Foundation Classes: an industry-developed product data model for the design and full lifecycle of buildings, supported by building SMART. It has broad support by most software companies) (Fu et al., 2006). Additional requirements like fire safety, access for the disabled also can be met by using BIM (Becerik-Gerber et al., 2012).

Designers are responsible not only to prepare drawings and specifications, but also to estimate construction cost to assure owner that project cost will not be more than allocated budget. Cost estimating was traditionally performed by multiplying quantities calculated from volumes and areas represented by lines in drawings to unit prices of items described in specifications. All these calculations were done by human and like any other human activities contain mistakes and errors. According to component-based nature of BIM, quantity takeoff is calculated automatically considering the amount of specific materials defined in BIM model. These accurate quantities lead to precise estimated cost for materials and products (Hartmann, Gao, and Fischer, 2008).

Simulation can be very useful for projects needing special attention to spaces and crowd like manufacturing, hospitals, and airports. In these cases, project functions strongly depend on spaces for machinery operation, equipment and personnel activities, or crowd movement. BIM enables designer to evaluate required spaces for efficient function of buildings (Becerik-Gerber et al., 2012).

During the design phase, designers collaborate with engineers and consultants inside or outside of design firm. This collaboration leads to appropriate information which needs to be reviewed to gaining feedback, advice, or changes. In traditional methods this process was performed by meeting in presence of representatives of all stakeholders which was time-consuming and difficult to arrange. Nowadays, each expert firm is able to design their specific elements (e.g. structual or mechanical systems) by professional software which will be integrated together by designer team. The clashes between different systems and elements which were designed separately are detectable by ability of BIM software called "Clash Detection" (Love et al., 2011).

3.4.2 Construction model

Eastman et al. (2011) mentioned three approaches of designers against developing construction model:

1. Traditionally, the design outputs expressed only the intent of designer and owner. In this approach, contractors must develop their own independent model for construction based on drawings and specifications.
2. Designers provide detailed model for further usage in construction, planning, and fabrication. Design model is initiative for developing special model of construction.
3. Collaborative approach which involve designer, contractor, supplier, fabricator, etc. from early design phase. The model is representative of all stakeholders' input data.

While design model expresses only the intents of designer and owner, construction model is representative of all specialists. Construction model contains different service providers' input data like information of MEP systems, precast concrete, and structural steel, which need special design, engineering and fabrication. Considering each of these services delivered by separate organizations, using BIM has notable influences on collaboration between these organizations.

BIM model also can be used as legal and contractual source of information instead of 2D drawing s and specifications. For example, American Institute of Steel Construction (AISC) in its standard stated that in terms of representing structural steel of project in both types of model and drawings, the model will be design of record. Widespread adoption of BIM by varied institutes into their standards is anticipated according to advantage of BIM in better understanding about details (Eastman et al., 2011).

3.5 BIM for Contractors

By using BIM model, contractor can save time and money by reducing errors and reworks. “While some of the potential value of a contractor’s knowledge is lost after the design phase is complete, significant benefits to the contractor and the project team can still be realized by using a building model to support a variety of construction work processes. These benefits can ideally be achieved by developing a model in-house with the collaboration of subcontractors and fabricators” (Eastman et al., 2011). In this section the advantages of using BIM for contractor will be briefly explained.

3.5.1 Clash detection

Traditionally, clash detection was performed by overlaying 2D drawings of different systems on light tables. In CAD age, this process was done manually by CAD software which overlaid CAD layers to identify conflicts. These manual approaches are time-consuming, costly, prone to error, and require that drawings be correct (Hardin, 2011).

Depending on level of defined information in BIM model, different types of clash detection can be performed. “Soft clash” detection may vary from clashes between components in individual system to clashes between different systems like structural and mechanical systems. In well-defined BIM models, “Hard clash” is detectable to assure about sufficient space between components of different systems for adequate access, insulation, safety, or maintenance. For example, spaces between mechanical and structural systems like distances between steam boiler and floor, walls, and roof (Eastman et al., 2011).

3.5.2 Quantity takeoff and cost estimating

While designer can achieve profit from using BIM for accurate quantity takeoff and cost estimating from early stages of design phase, contractors also benefit from BIM model in different aspects. The BIM software capability in reporting numbers of components, area and volume of spaces, and quantities of materials can help contractor during bidding, construction and commissioning phases. BIM model provides accurate quantity takeoff; in addition, even it is not recommended to use estimated cost calculated by BIM software for bidding, but it can be considered as initial estimate by estimators (Hartmann et al., 2008). Although the BIM models provide estimating by accurate quantities, they are not replaceable with estimators. Estimators play important role in construction industry and must not be confused as just multiplying quantities to their related costs. For estimating in addition to quantities and cost many factors like access conditions and implementing difficulties must be considered which are not comprehensible by BIM software (Eastman et al., 2011). Using BIM also decreases the bid cost by reducing the uncertainty of materials quantities.

3.5.3 Construction planning

Bar charts were of the first methods created for planning and scheduling the projects which by programmer efforts were transformed to planning software like Microsoft Projects and Primavera P3. These software known as Critical Path Method (CPM) software, enable planners to create and update tasks and define their relationships and sequences and calculate critical paths and floats (Ospina-Alvarado and Castro-Lacouture, 2010). Although these software have substantial excellence in comparison with bar charts, they are associated with some deficiencies in visualization of activities or linking with design or building model. As long as the CPM software remain solitary, it will be difficult for stakeholders to understand schedule and project progress. 4D model results from adding time as fourth dimension to 3D model which can be created easily by using BIM and lead to comprehensible scheduling.

3.5.4 Project control

During the construction phase, there are many factors which influence project and must be under control by understanding project status. Project control varies from schedule and cost control systems to systems for procurement and safety. While all these systems are about project components, in order to using these systems without linking them with design or building model, it will be needed to enter components information manually. BIM model can support project control team by accessing to the quantities and other required detail of components, also providing potential to analyze project completion visually (Hwang and Liu, 2010). Eastman et al. (2011) mentioned five areas of using BIM to control project as “Variances between budget and actual cost, Project status, Procurement purchasing, Procurement tracking, Safety management.”

3.5.5 Prefabrication

Contractors prefer to reduce costs and risks associated with labor and improve quality by using prefabricated or offsite fabrication components. Today, widespread range of components are produced in factories and deliver and assembled or apart to project sites for installation (AGC, 2009). However, using prefabrication requires precise planning and accurate design details which is not possible easily by 2D drawings. In addition to accurate design information, BIM enables contractors to enter 3D geometry, material specifications, finishing requirements, delivery sequence, and timing before and during the fabrication process (Rowlinson et al., 2010). Early involvement of fabricator and subcontractors in preparing BIM model reduces time by verifying and validating the model instead of paperwork required in terms of using 2D drawings.

3.5.6 Onsite usage

Contractors must be assured that constructed project is according to geometry of drawings and functionality of specifications. The BIM model can be used to compare actual building with model in terms of compatibility. Although the BIM model is accurate and avoids the mistakes in design phase, human errors may occur in construction phase which must be identified and remedied as soon as possible. BIM introduces variety of advanced technologies to construction industry which can be used onsite in project. Examples of using these technologies are Laser scanning technologies for verifying situation or preparing as-built details, Machine-guidance technologies for grading and excavation activities, Global Positioning Systems (GPS) technologies to verify locations, and Radio Frequency Identification (RFID) tags for tracking of component delivery and installation (Gruen, Behnisch, and Kohler, 2009).

3.5.7 Lean construction

"Lean is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" (Best and De Valence, 2002). The Construction Industry Institute (CII) (2005) defined lean construction as "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of a constructed project."

Eastman et al. (2011) mentioned four areas for synergy of BIM and lean construction:

- Use of BIM reduces variation.
- BIM reduces cycle times.
- BIM enables visualization of both construction products and processes.
- BIM supports a number of lean principles in the design stage.

3.6 Challenges

Using BIM needs changes in all aspects of construction industry from skills of practitioners to relationships and contractual agreements between them. During this transition construction industry faces with different challenges. In this section, most notable expected challenges will be described.

3.6.1 Legal issues

Legally, it is challenging to determine explicit ownership for design, engineering, construction and fabricator models and to define responsibilities for accuracy of model. Another problem is to answer who must pay for models, and who has the copyright? Some professional groups like the American Institute of Architects (AIA) and the Associated General Contractors of America (AGC) address these issues and make efforts to cover them by providing contractual guidelines like “ConsensusDOCS 301 BIM Addendum”.

3.6.2 Collaborating issues

The most significant collaborative issue is software interoperability. Although the IFC format facilitates using BIM software, some problems still arise according to using different software or even different versions of individual software. Another solution for this problem is using model server which contains its own difficulties considering network security, define accesses and permissions for different users and etc. If design teams do not create a BIM model, the contractors must develop their own model which could be time-consuming and costly. Even if the designers use BIM, their model may do not contain sufficient details for utilization in construction phase. These issues are challenging and can harm to collaboration among project participants (Fallon and Palmer, 2007).

3.6.3 Procedure change issues

Like other new tools and technologies, at first stages, BIM accompanies with misunderstandings and uncertainties. While BIM transforms the methods and process of executing construction projects, this transition needs basic changes in construction industry, not to do same things in different way. Acquiring software, training, and upgrading hardware are necessary but not enough for using BIM. It must be noted that to achieve benefits from using BIM, comprehensive understanding about BIM technology, its related process, and methods for implementing it are required. The transition from using 2D drawing to BIM model associates with risks like other changes which must be assessed, analyzed, and managed (Deutsch, 2011).

3.7 Summary

Although using BIM in DBB projects is very challenging because of participation of contractor after finishing the design phase, “it is not uncommon for contractors to create their own construction models in addition to using the architecture model. As a matter of fact, the construction benefits are so great that many contractors are opting to use BIM even if the architects and engineers they are working with are still delivering the design in a 2D CAD format” (Jackson, 2010). Since it is critical for contractors to be pioneer in adopting BIM to gain its advantages even in absence of models made by designer and according to the characteristics of BIM, advantages of its usage in DBB projects were considered as subject of this study.

Chapter 4

METHODOLOGY

4.1 Introduction

To achieve research objectives, selecting proper research method must be performed. Selection of research method in this study is based on review of previous research studies, specifications of each method, available resources (cost and time), and existed limitations and delimitations.

In this chapter after introduction, review of literature represents methods used in previous researches with the topics similar to this study and reasons for choosing each method in this research. Second section comprehensively describes questionnaire survey from designing and distributing questionnaires to respondents' information. Finally, general information and contractual details of studied case and software used for modeling are explained.

4.2 Review of Literature

Kuprenas and Nasr (2007) used case study to conduct a research on cost performance of DBB project delivery. Two years later, Hallowell and Toole (2009) provided contemporary DBB model again with using case study. For exploring the validity of methods to analyze project delivery of high performance building, Swarup et al. (2010) carried out a questionnaire survey; this method was also applied in 'Piloting Evaluation Metric for Sustainable High-Performance Building Project Delivery'

(Korkmaz, Riley, and Horman, 2010). Using case study, Different project delivery methods were compared by Neil and Al-Battaineh (2011).

Case study was also utilized to investigate impact of design cost on DBB project performance (Shrestha and Mani, 2012).

Benefits, risks and challenges of BIM were analyzed by reviewing previous surveys and studying a case (Azhar, Hein, and Sketo, 2008). Case study was also used to specify profits of scheduling, estimating, and BIM combination (McCuen, 2008) and to demystify business value of adopting BIM (Aranda-Mena et al., 2009). Gu and London (2010) surveyed BIM adoption in the AEC industry; also Becerik-Greber and Kensek (2010) specified research directions and trends about BIM by questionnaire. Using case study, benefits of BIM was investigated by Azhar (2011) and was measured by Barlish and Sullivan (2012).

According to the review of literature, for subjects of this study, Design-Bid-Build delivery method and Building Information Modeling, case study and survey (especially questionnaire) were found to be the most appropriate and popular methods among researchers.

Case studies encourage in-depth investigation of particular instances within the research subject (Fellows and Liu, 2009). Gerring (2006) stated that “the case study is typically focused on within-case variation.” Gillham (2000) emphasized that ”the meticulous description of a case can have an impact greater than almost any other form of research report.”

The questionnaire is one of the most popular and valuable instruments of data collection (Lavrakas, 2008). Questionnaires can be used even in cases which respondents are not completely aware of the subjects (Bryman, 2008). “If the questionnaire is well constructed, processing the data can also be fast and relatively straightforward, especially by using some modern computer software. They are also very versatile, which means that they can be used successfully with a variety of people in a variety of situations targeting a variety of topics” (Dörnyei and Taguchi, 2010).

Figure 4.1 shows different areas which each type of study covers. “A particular management research project may require and involve more than one method of data collection. The different research methodologies and techniques are simply a set of tools that the researcher can use to address the particular consultancy and research problem” (Lancaster, 2005). Considering these issues, it was decided to use a mixed-methods research design consisted of case study and questionnaire survey.

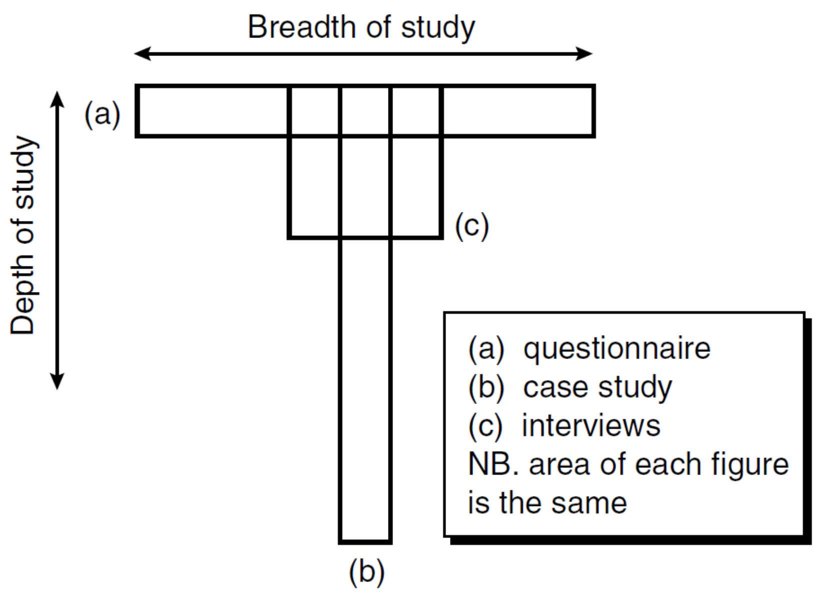


Figure 4.1. Breadth versus depth in 'question-based' study (Fellows and Liu, 2009)

Between types of mixed-methods research design, which differ from each other in terms of sequence of using methods, the Triangulation Mixed-Methods Designs was selected for this study. Triangulation uses two or more research methods simultaneously to investigate the same thing (Fellows and Liu, 2009; Lavrakas, 2008).

4.3 Questionnaire Survey

As previously stated, a questionnaire survey as a part of compounded methodology was conducted among construction industry practitioners. As Brown (2001) defined, "questionnaires are any written instruments that present respondents with a series of questions or statements to which they are to react either by writing out their answers or selecting from among existing answers."

4.3.1 Design of questionnaire

A questionnaire including closed-ended questions was designed based on the literature review to answer the research questions. A sample questionnaire is appended in Appendix A. "A closed-ended survey question is one that provides respondents with a fixed number of responses from which to choose an answer. It is made up of a question stem and a set of answer choices (the response alternatives)" (Lavrakas, 2008).

The questionnaire was divided into four main segments:

- Personal information
- Knowledge and experiences of BIM
- Definition of BIM, and
- Ideas about BIM

The first part was consisted of closed-ended questions to find out respondents personal information by selecting among nominal categories. These questions were about the parties of construction industry which respondents were involved, and were separated into: owner, designer, and contractor. Then the level of their company, in terms of maximum number and cost of the projects that annually they are permitted to execute, was asked. Finally, they categorized their job experience into: less than five years, between five and ten years, between ten and fifteen years, and more than fifteen years.

In second part, knowledge of BIM was asked by this question; “How much are you familiar with Building Information Modeling?” Respondents chose between following four choices: “Not familiar”, “Just heard its name”, “A little familiar”, and “Absolutely familiar”. The experience of using BIM was determined by a question with two options: “Yes, I used”, and “No, I did not use”.

Regarding to low level of awareness about BIM among Iran’s construction industry practitioners which was found out in previous study by Sistani and Rezaei (2012), a brief definition of BIM was presented in the third part. In addition to definition of BIM, most important advantages of using BIM like clash detection, differences of BIM with 3D CAD, properties of projects designed by BIM, and two of most popular BIM software (GRAFISOFT ArchiCAD and Autodesk Revit) were given in this part for better understanding of BIM.

The forth and the main part of questionnaire was placed in last section. This part consisted of questions with unipolar rating scale. Rating scales is most popular one in research questionnaire which ask respondents to make an evaluative judgment by selecting one of the categorized alternatives. The categorized alternatives indicate different degrees of a certain category (Dörnyei and Taguchi, 2010). Alternatives ranged in Low-to-high sequence which indicated a unipolar conceptualization, whereby the low end represented the absence of the concept of interest and the high end represented a great deal, in this case expressed the effect, from ineffective to extremely effective (Lavrakas, 2008).

Respondents' opinions about the effects of BIM usage in DBB project delivery were asked by four questions. Effect of using BIM on factors of construction management diamond; time, cost, quality, and health and safety were evaluated by respondents, and then in next questions they ordered these factors from most affected to the least.

Afterward, the ratio of effectiveness of shortages which caused to not applying BIM in Iran's construction industry was determined for five main deficiencies. After these questions, one blank line was placed for another shortage which respondents thought must be in this section, and they could rank its effectiveness as previous questions. As same as the former section, in next section, respondents' opinions in terms of barriers to using BIM through DBB projects were evaluated. Two last questions were about respondents' tendency to participate in BIM training and using BIM in their projects.

4.3.2 Testing and validating

For testing the quality of questionnaire, according to Saris and Gallhofer (2007) these three steps were done:

- "Check on face validity
- Control of the routing in the questionnaire

- Use of a pilot study to test the questionnaire”

For this reason, after checking the face and routing in the questionnaire, 5 graduate students of Construction Management in Civil Engineering Department were asked to fill out the first draft of questionnaire as a pilot study, and then questionnaire was discussed by them one after another. The results of pilot study were analyzed statistically by Microsoft Excel and the standard deviations of the answers were calculated. The highest amount of the answers’ standard deviations was 1.03, which confirmed the answers of questionnaires’ validity. According to discussions with respondents of pilot study, little changes were performed, and then the final questionnaire was completed and distributed.

4.3.3 Respondents

Total numbers of 60 questionnaires were sent to 5 civil engineers and they were requested to distribute them among architects and engineers engaged in construction industry in designer, contractor, or owner parties. The questionnaires were filled out in the way of One-to-One administration by a civil engineer for further assistance.

“One-to-One administration refers to a situation when someone delivers the questionnaire by hand to the designated person and arranges the completed form to be picked up later (e.g., handing out questionnaires to colleagues at work). This is a much more personal form of administration than mail surveys and therefore the chances for the questionnaires to be returned are significantly better. The personal contact also allows the questionnaire administrator to create a rapport with the respondent, to explain the purpose of the enquiry, and to encourage cooperation” (Dörnyei and Taguchi, 2010).

Iranian construction companies are divided into five levels according to their size. Respondents were selected from companies with different scales in terms of annual income. Respondents' distribution in terms of size of their companies is shown in Figure 4.1.The number and cost of projects each company permitted to execute annually is limited for each level (Table 4.1).

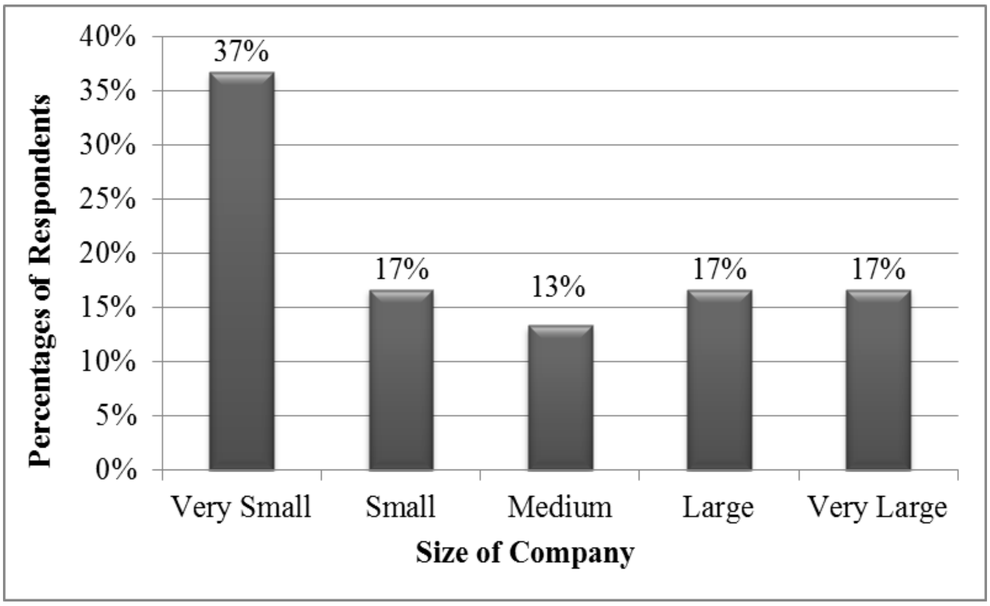


Figure 4.2. Percentages of respondents in terms of size of their companies

Table 4.1. Companies' size in terms of maximum cost and number of projects

Characteristics / Size	Maximum costs of projects per year (US Dollar)	Maximum numbers of projects per year
Very Small	650,000	4
Small	1,860,000	3
Medium	3,720,000	3
Large	7,430,000	3
Very Large	14,860,000	3

4.4 Case Study

"A case study is a detailed study of a single individual, group/organization, or event/project" (Fellows and Liu, 2009). The case can be studied by different types of data collection varied from review of records to interview with participants. Hancock and Algozzine (2006) stated that "case study research is richly descriptive, because it is grounded in deep and varied sources of information." The number of cases depends on different factors, "The nature of the in-depth data collection, limited access to cases, and the extreme nature of the case are reasons for study single case" (De Vaus, 2001; Fellows and Liu, 2009). Based on these three reasons, single-case was studied in this research.

Because of popularity of DBB method among public sector, they are experienced in using this method; so an ordinary office building was selected as a case of this study. This building is client office of a power plant. The reason for selecting this project as case was using steel gable frame consisting of welded columns and beams as structure of this building. Such structure must be fabricated offsite and needs accurate details and experienced technicians for assembly and installation. Since the building was part of a power plant project, the designer and contractor of project were extra-large companies and the owner was Ministry of Energy of Iran. Details and specifications of the project are presented in next section.

4.4.1 Details and specifications

Some of drawings of studied case are depicted in Appendix B. Details of project contract like the name of stakeholders and conditions of contract agreement are illustrated in Table 4.2.

Table 4.2. Contractual details of studied case

Project Name	Thermal Power Plant (2×325 MW) (Client Office)
Owner	MINISTRY OF ENERGY Iran Power Development Co. (I.P.D.C.)
Designer	Ghods Niroo Engineering Company G.N.E.C.
Consultant	Energy and Industry Consultants
Contractors	Hirbod Niroo Company Mabna Niroo Company Azaran Company
Project Delivery Method	Design-Bid-Build
Type of Contract	Lump Sum
Project Cost	775812 ($)
Project Duration	89 (Workdays) 123 (Days)

Architectural and structural specifications of project such as detail types and materials of foundation, structure, roof, external and internal walls, and total areas of project are depicted in Table 4.3.

Table 4.3. Specifications of studied case

Area	650 m^2
Type of Structure	Steel Gable Frame
Material of Structure (Columns and Beams)	Plate Girder (Welded Steel)
Foundation Type	Spread Footing Foundation
Material of Foundation	Reinforced Concrete
Exterior Walls	35 cm (20 cm clay brick work + 5 cm Rockwool Inulation + 10 cm Brick Facing)
Interior Walls	20 cm (Clay Brick Work)
Supporting Structure of Roof	Purlin and Struts with Bracing
Outer Layer of Roof Systems	Sandwich Panel
Ceiling Systems	Knauf Ceiling

4.1.2 Modeling

To evaluate effects of using BIM on project's time and cost, the project was modeled by using six software. These software and their usage will be described at following.

Autodesk Revit Structure: Structural components were designed by 2012 version of this software. Spread footing foundation consisting of reinforced concrete type C25 at level of -1.10 was executed and base plates were placed. Supporting structure of roof including struts, bracings, and purlins were also designed by Revit Structure. This software only supports the standard steel components (e.g. I-shaped, HSS-shaped (Hollow Structural Section), L-shaped, C-shaped, and T-shaped cross-sections and bars); so for designing the columns and beams, AutoCAD Structural Detailing software was used.

AutoCAD Structural Detailing: In accordance with the structural frame containing plate girders, the detailed columns and beams were designed by 2012 version of this software. AutoCAD Structural Detailing is professionally developed to design uncommon structures providing widespread range of elements and different types of connections. For synchronizing data between AutoCAD Structural Detailing and Autodesk Revit Structure, an extension was installed on Autodesk Revit Structure.

Autodesk Revit Architecture: As it is obvious this software was used for designing architectural components. External and internal walls, doors and windows, flooring and ceiling, and plastering are some examples of the designed components with 2010 version of this software. Autodesk Revit Architecture contains variety of materials and components families to facilitate designing all details in all types of buildings in 3D environment. This software provides walkthrough animations, quantities, and material takeoff as well.

Autodesk Revit MEP: Mechanical components like boilers, HVAC (Heating Ventilation and Air Conditioning) ducts and air terminals, plumbing components like pipes, plumbing fixtures, and sprinklers, and electrical components as switch boards, cable trays and conduits can be designed by this software. Since the studied project in this research did not contain central mechanical systems, just electrical and plumbing components and systems were designed by the 2012 version of Autodesk Revit MEP.

Autodesk Navisworks Manage: For applying time as fourth dimension to building model, detecting clashes, integrating 3D models created by different experts (Architectures, Structural Engineers, and Mechanical Engineers) and creating animation walkthrough, this software was used. There are three types of this software; Manage, Simulate, and Freedom. Autodesk Navisworks Manage version 2010 was used in this study for 4D modeling by integrating 3D models with Microsoft Project scheduling. Control project outcomes, workflow, and progress of project are other capabilities of this software.

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Introduction

According to the outputs of questionnaire survey and case study, the results were analyzed to evaluate opinions of construction industry practitioners about advantages, barriers of adopting, and challenges of using BIM in DBB projects, then the most notable advantages of using BIM from viewpoint of questionnaire participants was assessed in case study.

This chapter starts with introduction and then regarding to questionnaire survey, participants' point of view about level of effectiveness of BIM on construction management factors, barriers for adopting BIM, challenges to using BIM, and their consideration about BIM are discussed in second section of this chapter. In accordance with studied case, in third section effects of using BIM in reducing cost and time in a DBB project are evaluated. Finally, results of this study are summarized in last section.

5.2 Questionnaire Survey

At the first of questionnaire, respondents were asked about their level of familiarity with BIM to assess their knowledge about BIM. As Figure 5.1 reveals, more than two-third (67%) of respondents were completely unfamiliar with BIM, 13% of them just heard the term "BIM", and twenty percent were a little familiar with BIM. In accordance with that, none of respondents were completely familiar with BIM;

generally speaking, the level of awareness about BIM among construction industry practitioners is evaluated as low.

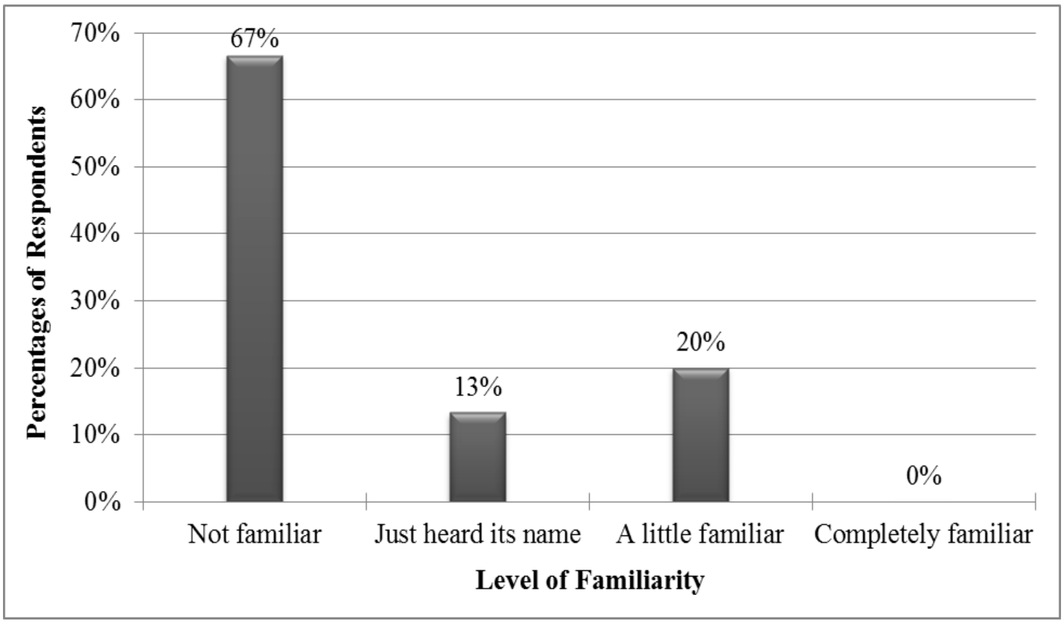


Figure 5.1. Level of familiarity with BIM

Because of predicted low level of awareness about BIM, a brief definition of BIM and its significant characteristics were jammed into questionnaire to provide little knowledge of BIM to answer further questions.

5.2.1 Advantages

Rate of advantageous effects of using BIM on factors of construction management diamond; cost, time, quality, and health and safety were asked one by one. The question was close-ended with Likert scale answers varied from “No effect” to “Extreme effect”. The weighted means of respondents’ answers to each of these four questions are calculated as shown in Figure 5.2.

BIM has maximum effect on “Reduce cost” of DBB projects from participants’ point of view with significant difference to other factors. Considerable difference between weighted means of first and second factors explains confidence level of respondents about the effects of BIM on this factor.

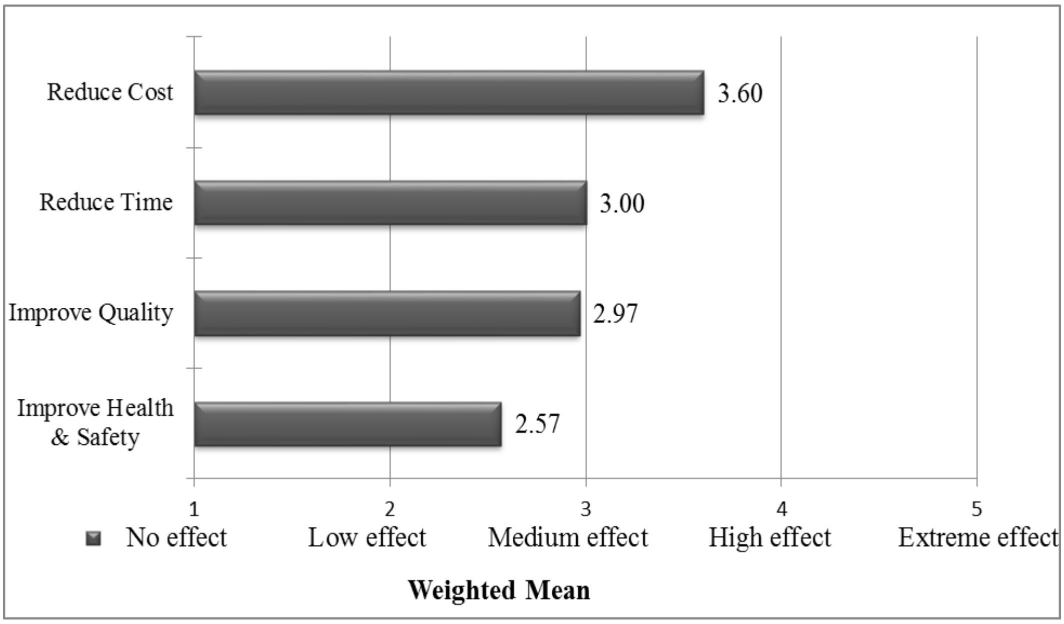


Figure 5.2. Effects of BIM on construction management factors

“Reduce time” and “Improve quality” are very close with 3.00 and 2.97 weighted means respectively. “Improve health and safety” is placed at the bottom of the list in range of low to medium effect with weighted mean of 2.57. According to the answers to this question, reduce cost and time is considered as the most significant advantages of using BIM in DBB projects and validity of this claim is verified by studying the case which will be discussed later.

5.2.2 Adopting barriers

Adopting BIM like other new technologies requires some prerequisites like specific regulations and standards, changes in procedures and attitudes, and supply and demand system. Four barriers to adopting BIM were nominated and respondents were asked to specify rate of their effect on using BIM. As shown in Figure 5.3, first three factors have very close weighted means. Lack of demand of public sector, legislation and standards, and supply of private sector for BIM are most significant barriers to adopting BIM from respondents' opinion. Lack of private sector participation in large project is located at the end of list with 3.00 weighted mean.

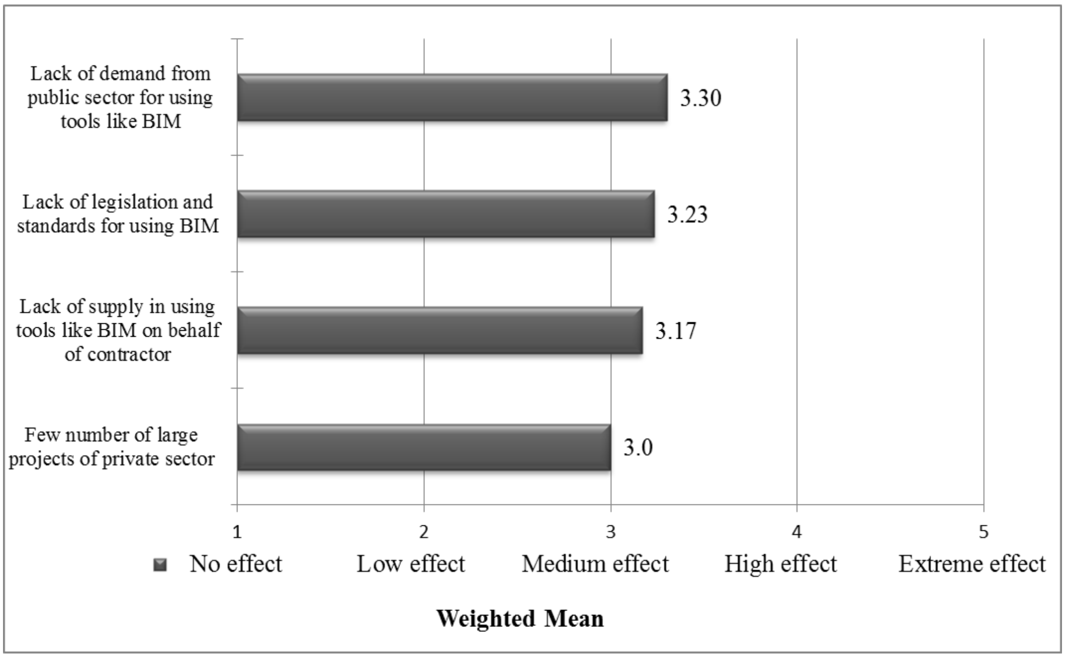


Figure 5.3. Level of effectiveness of barriers to adopting BIM

While there are not adequate standards and legislation for using BIM, neither public sector demands for using BIM, nor private sector supplies BIM usage. The question "Who must be pioneer in adopting BIM?" reminisce ancient question that "Which came first, chicken or egg?"

5.2.3 Using challenges

The respondents were asked about challenges which anticipated to occur during using BIM in DBB projects. Participants selected the level of effectiveness for each challenge separately. Figure 5.4 illustrates the weighted means of answers.

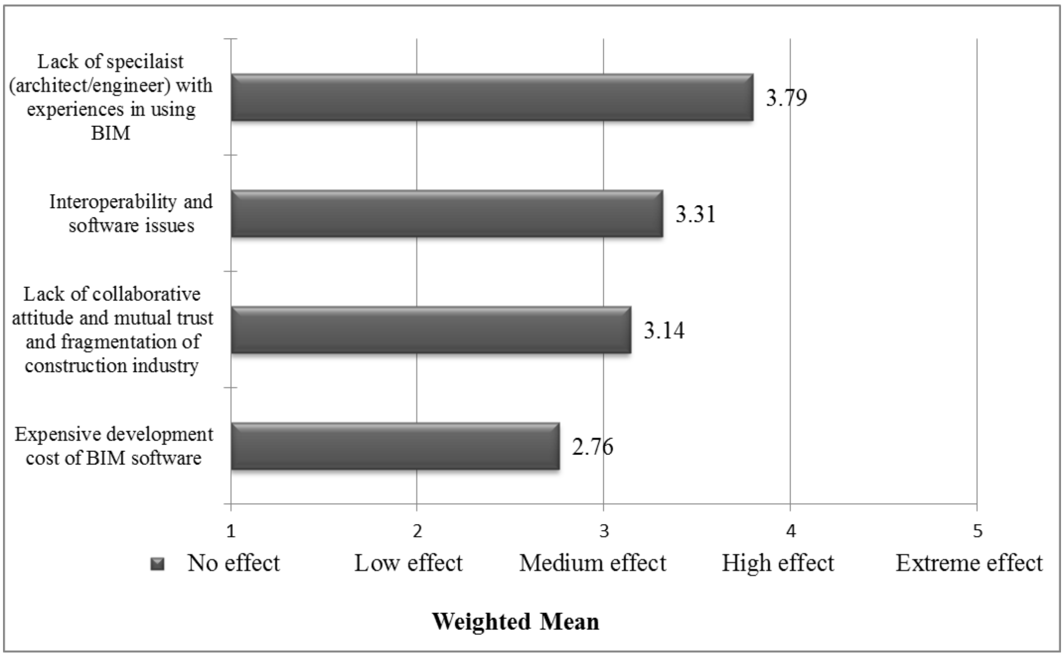


Figure 5.4. Level of effectiveness of challenges in using BIM

As can obviously be seen, lack of specialist in BIM with great difference is located at the top of the list with 3.79 as weighted mean. Interoperability and software issues and lack of collaborative attitude and mutual trust are next significant challenges in using BIM from respondents' point of view with 3.31 and 3.14 weighted means respectively. Development cost of BIM positions far distance as last challenge in using BIM. Weighted mean of 2.76 is interpretable considering, companies paying initial cost of developing BIM once forever as investment which will be usable in long-term for many projects.

5.2.4 Future of BIM

At the beginning of questionnaire, respondents answered to question "Have you used BIM in your projects up to now?" 97 percent of them stated that they have not yet used BIM. To assess how much awareness about BIM affects respondents' opinion, at the end of questionnaire they were asked "Do you tend to using BIM in your future projects?" Figure 5.5 shows the percentages of respondents in terms of their answers to this question.

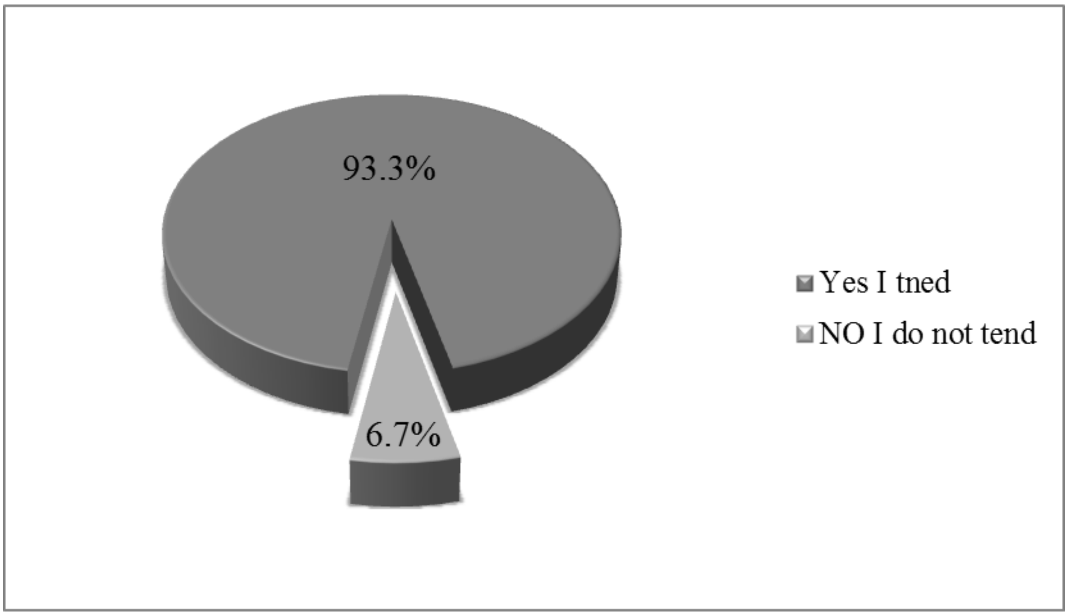


Figure 5.5. Answers to "Do you tend to using BIM in your future projects?"

While initially 67% of respondents were completely unfamiliar with BIM and only three percent of them experienced using BIM in their projects, after introducing BIM, more than 93 percent expressed that they tend to use BIM in their future projects. This information states, there is high motivation among construction industry for using BIM if the adequate legislation and BIM specialists exist.

5.3 Case Study

As mentioned in methodology chapter, to assess respondents' opinion about advantages of BIM in reducing time and cost of DBB projects, a project was studied. To evaluate effects of BIM on time and cost of project, detailed model of project was initially designed by Autodesk Revit Architecture and Autodesk Revit Structure software (Figure 5.6 and Figure 5.7).

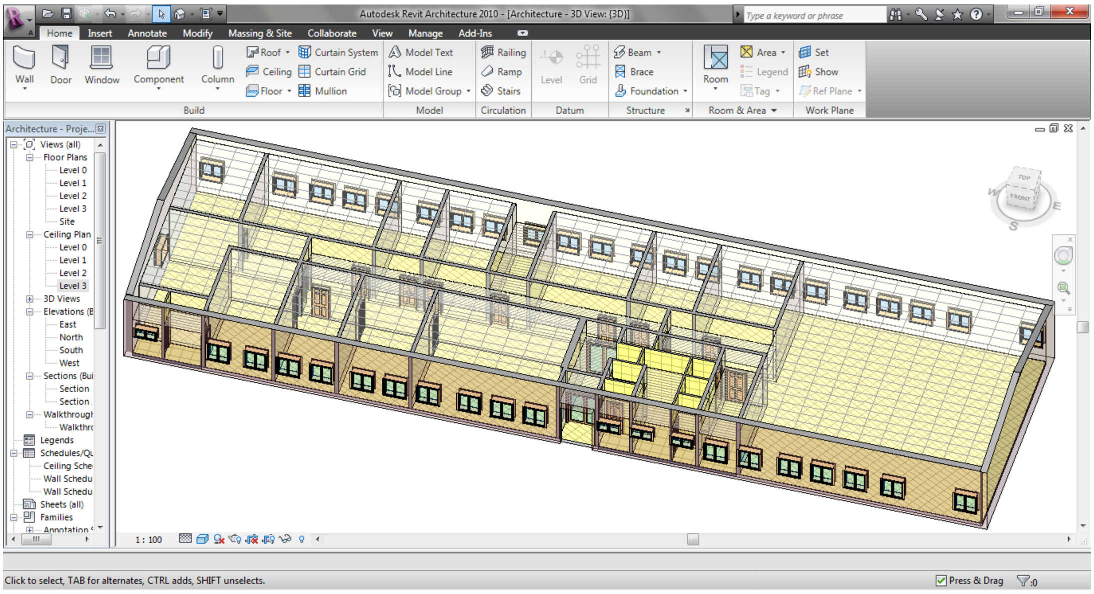


Figure 5.6. Autodesk Revit Architecture Model

After completion of BIM model, comparisons in areas which BIM can reduce the cost and time were performed between real project (without BIM) and in case of using BIM model during construction phase of project. To compare construction phase in cases of using BIM and without using BIM, software output data with progression reports of real project were compared.

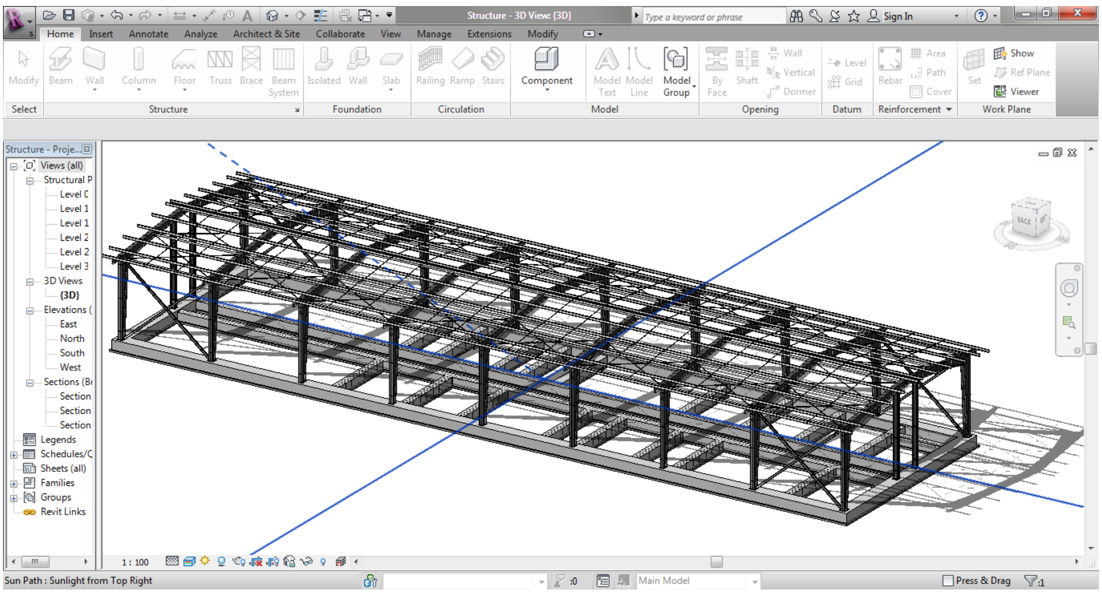


Figure 5.7. Autodesk Revit Structure Model

5.3.1 Estimated costs

Considering review of literature, cost estimating is one of the most significant and effective areas of using BIM that help owners to save their money by providing more accurate cost estimate. To evaluate the effects of using BIM in cost estimating, estimated cost proposed by contractor as record cost in contract was compared by costs calculated from multiplying quantities extracted from related software to its corresponding cost in unit price. Figure 5.8 shows a sample of quantity report and its corresponding components in Autodesk Revit Structure which were used for estimating cost by using BIM.

For providing proposed tender cost, Iranian's contractors extract most expensive activities which totally cost at least 65% of total project cost according to initial estimation provided by owner in bidding documents. They calculate the real price of these activities by multiplying their quantities to real price which computed by themselves. Afterward, dividing computed price of these activities with contractor price to those prepared in bidding documents get a coefficient. This coefficient will be multiplied to total estimated cost of project to get the total proposed tender cost of project.

While cost of all tasks and quantities of their required materials do not differ notably with and without using BIM, quantities and cost of most expensive activities with at least 65% of estimated cost by owner which were selected by contractor to calculate the total project cost for proposing as tender cost in case of lump sum, were considered in this section. The quantities of these activities' materials and cost of their execution were compared in cases of estimated without using BIM with extracted from BIM software.

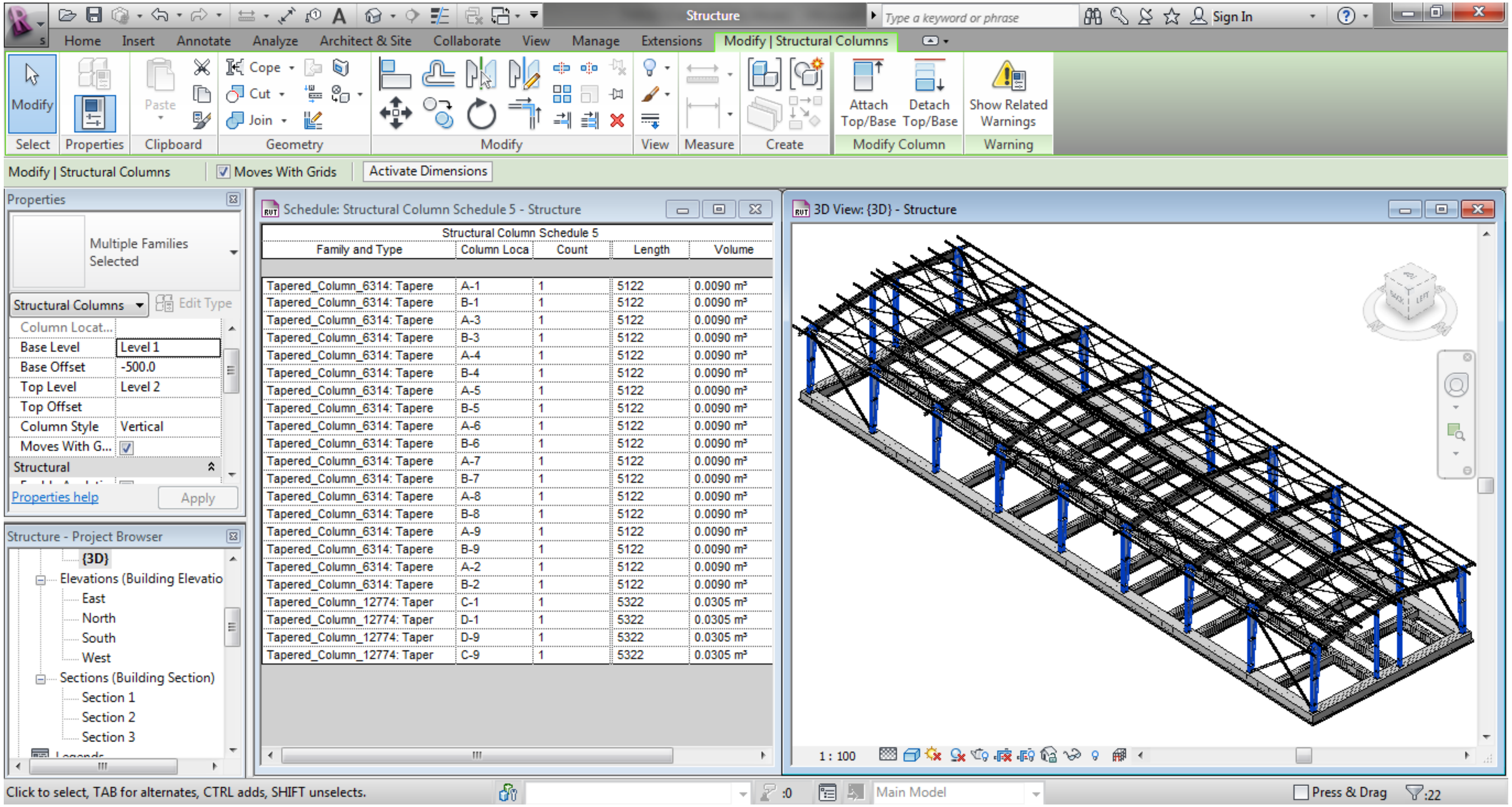


Figure 5.8. Sample of quantities report in Autodesk Revit Structure

Table 5.1 illustrates seven most expensive components which totally cost 68.1% of project initial cost estimate provided by owner. For each component its amount in bill of quantity regarding to bidding documents, amount in BIM model extracted from related software, bidding cost obtained from multiplying amount in bill of quantity to unit price, BIM cost calculated from multiplying amount in BIM model to unit price, and finally difference between Bidding cost and BIM cost were represented.

Table 5.1. Quantities and costs in bidding documents and BIM models

Component \ Details	Amount in Bill of Quantity	Amount in BIM Model	Bidding Cost (Percentages of Total Cost)	BIM Cost (Percentage of Total Cost)	Cost Difference (Percentage of Total Cost)
Steel Bars (kg)	10712	8600	7.1%	5.7%	1.4%
Reinforced Concrete (m^3)	124	104	4.4%	3.7%	0.7%
Brick Walls (m^3)	331	298	16.9%	15.2%	1.7%
Steel Columns (kg)	8482	7258	9.7%	8.3%	1.4%
Steel Beams (kg)	9880	8437	8.9%	7.6%	1.3%
Steel Purlins (kg)	12274	11479	13.9%	13.0%	0.9%
Bracings, Struts & Sagrods (kg)	5399	4301	5.9%	4.7%	1.2%
Total			66.8%	58.2%	8.6%

Since the project was executed in Iran and prices were determined in local currency, for avoiding confusion of currency exchange and better understanding about rate of saving in terms of total costs, the prices are represented in percentages of total cost which were initially estimated by owner. As Table 5.1 shows, using BIM for quantity takeoff and initial estimating could reduce at least 8.6% of total project cost. BIM increases accuracy of quantity takeoff which leads to reduce cost of project for owner, in addition reduces risks associated with under estimating which can seriously harm project quality.

While four of seven most expensive activities are about structural frame which can be prefabricated offsite, using BIM not only provides more accurate estimating for these components, but also by providing accurate geometry and details of components facilitates using prefabrication that decreases cost of labors and improves quality by using manufacturing products.

5.3.2 Reworks costs

Reworks are of most important factors of cost overruns and disputes in projects. In studied case, design uncertainties leaded to arise reworks because of two different reasons; change orders and misinterpreting of design details. Whatever the reasons of change orders are, resulted reworks cost for owners; but if the owner can prove that reworks arise because of contractor failures or mistakes, contractor will be responsible for the reworks and their relative costs.

Subcontractor was assigned for supplying sandwich panels and their joints and executing them as roof. The unit price contract included the price of supplying per square meter of sandwich panels, per kilogram of joint systems, and executing per square meter of sandwich panels. Because the contract was unit price, neither contractor paid attention to execution details of sandwich panels, nor subcontractor requested such information from contractor. Less than one week before starting day of executing roof, subcontractor estimated amount of materials required for executing about 550 square meters and brought half of these amounts for starting their work and asked contractor for implementation details of roof. By reviewing the implementation details by subcontractor, they realized that designed joint system of roof was inadequate and asked contractor to inform owner.

Contractor submitted RFI about joint system of sandwich panels to owner. Since the drawings and specifications did not contain adequate details about executing sandwich panels, owner asked designers to provide sufficient details for sandwich panels' joint system. After that the details of sandwich panels' joint systems had been modified by designer and the change order was handed over to contractor for implementation. This change order resulted in addition of about 1% to project cost.

Simultaneously with assigning the contractor, owner employs a supervisor to control the project execution regarding to drawings, specifications and codes. In terms of project size, supervisor can be a single person or a big firm. In some cases, the designer offers such services to owner according to their contractual agreement. In the studied case, consultant was responsible to provide supervisory duties as a part of consulting services. These duties were performed as monthly inspections by experts from different engineering fields.

According to progression reports, in the third monthly inspection and three days after that contractor had started ceiling execution, support system of ceiling was disqualified by supervisor of the project. For making decision about support system of ceiling, ceiling execution had been stopped and two days later, a meeting was held in presence of contractor, supervisor, and owner representative. At the end of this meeting, contractor was convinced that misinterpreted the drawings and had to demolish executed ceiling and participants admitted that more clear details be provided for contractor by RFI.

Table 5.2 shows the different costs related to reworks resulted from misinterpreting of drawings and details by contractor. Contractor had executed about 150 square meters of ceiling which afterward was demolished regarding to dissatisfaction of project supervisor. Contractor spent for executing and demolishing 150 m^2 of ceiling, 1.1% and 0.2% of total project cost respectively.

Table 5.2. Rework related costs

Description	Cost (Percentages of Total Cost)
Executing 150 m^2 ceiling	1.1%
Demolition 150 m^2 ceiling	0.2%
Cost of ceiling interpreted by contractor	4.3%
Supervisor's satisfactory ceiling cost	5.8%
Difference of contractor estimation with real cost	1.5%
Total additional cost for contractor	2.8%

The contractor also claimed that executing ceiling in which way to satisfy supervisor imposed an extra charge equal to 1.5% of total project cost in comparison with the contractor's estimated cost. These activities altogether cost for contractor as 2.8% of total project cost.

Using BIM provides much more details than traditional 2D drawings and specifications which could avoid mentioned extra costs resulted from lack of required details or misinterpreting existing information. In addition, BIM enables users to analyze designed models with codes and regulation requirements to prevent from aggressive relationships between designer, contractor, and supervisor.

5.3.3 Delays costs

Increasing indirect costs especially overhead costs may lead to cost overruns in projects. As previously mentioned, RFI, CO, and reworks had happened in the studied projects because of different reasons and resulted to some delays. These delays will be explained comprehensively in next sections. However the project included delays with other reasons, but because they were not avoidable by using BIM, they are not included in this study.

Table 5.3 illustrates the costs which delays imposed to contractor. The contractor determined overhead costs as 18% of total project costs. Regarding to this amount and project duration (123 days), daily overhead cost was calculated about $1135. By multiplying this number to 21 days delay, total delay cost is determined as 3.1% of total project cost. Using BIM could avoid these delays and contractor could earn about 24000 Dollars by saving related overhead costs.

Table 5.3. Overhead and delays costs

Name	Description	Amount
Total cost	Direct Costs + Indirect Costs	775812 ($)
Total Overhead Cost	18% of Total Cost	139646 ($)
Total Project Duration	Workdays + Holidays	123 (Days)
Daily Overhead Cost	$\frac{\text{Total Overhead Cost}}{\text{Total Project Duration}}$	1135 ($)
Total Delay	Workdays + Holidays	21 (Days)
Total Delay Cost	Total Delay×Daily Overhead Cost	23835 ($)
Delay Cost	Percentage of Total Cost	3.1%

5.3.4 Change order delay

Projects may involve with delays resulted from different reasons. The effects of delays on project cost were described previously. While BIM provides accurate and detailed model instead of 2D drawings and specifications, it can reduce time of project by avoiding delays resulted from RFIs.

As stated before, in the studied project RFI was sent first to owner for roof's sandwich panels' joint system. This procedure involved submitting RFI to owner representative, sending RFI from owner representative to designer, modifying drawing and specifications by designer and this procedure occurred vice versa to hand over details to contractor. This procedure lasted five workdays and resulted to increase project total duration as 7 days (Figure 5.9).

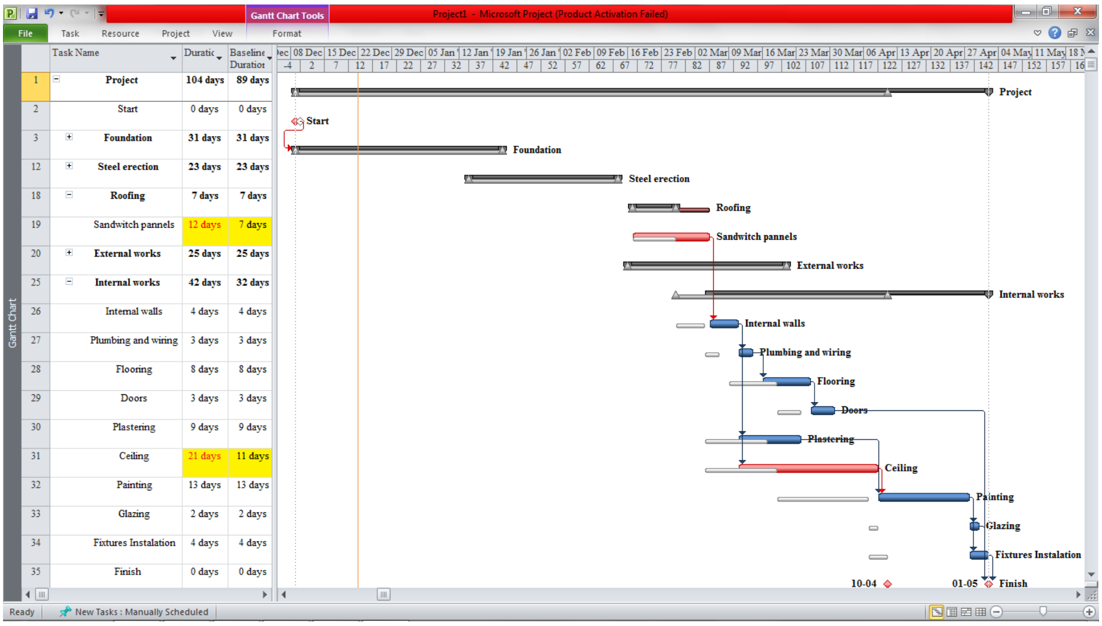


Figure 5.9. Effects of design's inaccuracies on duration of project

5.3.5 Rework delay

Another reason of delay was misinterpreting of contractor about ceiling support system which caused RFI and rework. Contractor started ceiling implementation, after spending three days for executing about 150 m^2 of ceiling; implementation was stopped by supervisor's order for two days. In third day a meeting was held, decisions were made and then RFI was sent to owner and demolishing the implemented ceiling was started simultaneously. RFI's response was returned to contractor after five days. It can be obviously seen in Figure 5.9 that these 10 workdays delay led to extend duration of project 14 days more than schedule.

Avoiding delays is not only important in terms of time and faster delivering the project, but also leads to notable cost saving considering overhead costs resulting from delays. In addition, in most of cases contractor may lose because owner has right to decrease predefined amount from total project cost as his/her loss, considering contractual agreement conditions. Using BIM can reduce time of project and avoid delays corresponding to design uncertainty and misinterpreting of drawings and specifications by providing more accurate and detailed 3D models.

5.4 Summary

According to the questionnaire survey, respondents believed that using BIM in DBB projects affects time and cost more than other management factors. This claim was assessed by studying a case; project of an office building executed by DBB method. Considering project drawings and specifications, different models were designed to compare the time and cost between using 2D drawings and specification as performed in real project with cases using BIM models. For this reason, real project documents and records consisting bidding and tender documents, contractual agreements, and progression reports were reviewed accurately and contexts which using BIM can reduce time and costs were assessed.

Time and costs in selected contexts were compared and the results which were shown by tables and figures approved respondents' claim that using BIM reduces time and costs in DBB projects. The overall assessment of this study will be described in next chapter.

Chapter 6

6. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

According to the results of questionnaire survey and case study and discussions in previous chapter, overall assessment of this study and concluding from findings will be reported in this chapter.

In this chapter, initially general conclusion of this study's results with mentioning notable findings is represented. In third section, recommendations for construction industry practitioners about using BIM in their projects are made. Finally, some suggestions are made for researchers who tend to work on this topic in their future works.

6.2 Conclusion

To investigate the application of BIM in DBB projects, sixty practitioners in construction industry were asked about usage of BIM in DBB projects. According to respondents' opinion, out of four factors of construction management, BIM has more effect on reducing cost and time in comparison with improving quality and health and safety in DBB projects.

Through different barriers to adopting BIM, "Lack of demand from public (government) sector as owner for using advanced tools like BIM", "Lack of legislations and standards for using BIM", and "Lack of supply in using advanced tools like BIM on behalf of contractor" were selected factors by respondents in order of the importance.

"Lack of specialist (Architect/Engineer) with experiences in using BIM", "Interoperability and software issues (using different software or versions file format etc.)", and "Lack of collaborative attitude and mutual trust and fragmentation of construction industry" were most significant challenges in using BIM, respectively from respondents' point of view.

As the answer of last question of questionnaire survey, more than 93 percent of respondents expressed that they tend to use BIM in their future projects. Considering low level of awareness about BIM through participants of questionnaire survey and to improve reliability of study's results, effects of using BIM on reducing cost and time in DBB projects were assessed by a single-case study.

In comparison with traditional cost estimating methods which calculates quantities manually, using BIM's quantity takeoff for initial estimating could reduce at least 8.6% of total project cost. Furthermore, change order was resulted in adding about 1% to project cost. By reducing initial estimated cost and avoiding change order by using BIM, owners could save at least 9.6 percent of total project cost.

From contractor's viewpoint, using BIM could prevent from expenses of demolitions and reworks that altogether cost for contractor as 2.8% of total project cost. Demolitions and reworks also led to delays which totally cost as 3.1% of total project cost for contractor. Using BIM could totally reduce contractor's expenses at least 5.9% of total project cost.

Change orders and reworks not only lead to cost overrun by increasing direct and indirect costs, but also result in being behind schedule which causes delay in project completion. Change order resulted to increase project total duration as 7 days and reworks extended duration of project 14 days more than scheduled. Inaccuracies of design totally caused 21 days delay in project completion equal to 17% of total project duration which was avoidable by using BIM.

Finally, it must be noted that the effects which represented in this study are most significant measurable effects of BIM on project’s cost and time, but not all effects of BIM.

6.3 Recommendations for Practitioners

Regarding to characteristics of DBB method, involvement of designer, contractor, supplier, fabricator, etc. from early design phase is impossible. So, using collaborative approach to prepare a model to be representative of all stakeholders’ inputs data (Intimate BIM) is impossible. According to these issues, following two approaches can be used in DBB projects.

Starting point for adopting BIM could be applying BIM to traditional approach. While traditionally the design outputs express only the intent of designer and owner, contractors must develop their own independent model for construction based on drawings and specifications (Lonely BIM). Designers prefer this approach because by not being responsible for providing construction information but only design intent, eliminate their liabilities for construction issues. While this approach requires repetitive cycle of submittals, design reviews, and corrections, this approach must be noted only as a starting point for adopting BIM and a step for transition to further approaches.

In further approach, designer provides detailed design model as initiative for developing special model of construction for further usage in construction, planning, and fabrication and sharing its information between different practitioners of project (Social BIM). However, designer may refuse to be involved in this approach because of its liabilities, but this approach is strongly recommended as most appropriate approach for using BIM in DBB projects.

While facing with unexpected situations during initial experiences of adopting and using BIM is most likely, regardless of using BIM's approach, employing consulting services is essential.

6.4 Recommendations for Further Studies

According to low level of awareness about BIM among respondents, to obtain more reliable findings in this area, interviews with BIM experts will be very valuable to provide more reliable responses. In addition, interviews with practitioners who participate in projects with 3D design to evaluate more reliable responses about barriers to adopting BIM and challenges in using BIM must be performed.

While quality and health and safety are two of four factors of construction management diamond, considering effects of BIM on these factors as subject of future studies will be very useful for improving quality and health and safety through DBB projects.

REFERENCES

AGC. (2009). Contractors' Guide to BIM (Second ed.): The Associated General Contractors of America.

AIA, and AGC. (2011). Primer on Project Delivery (Second ed.): The American Institute of Architects and The Associated General Contractors of America.

Aranda-Mena, G., Crawford, J., Chevez, A., and Froese, T. (2009). Building information modelling demystified: does it make business sense to adopt BIM?. *International Journal of Managing Projects in Business*, 2(3), pp. 419 - 434.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, 11(3), pp. 241-252.

Azhar, S., Hein, M., and Sketo, B. (2008). *Building Information Modeling (BIM): Benefits, Risks and Challenges.* Paper presented at the 44th Associated Schools of Construction National Conference, Auburn, Alabama.

Barlish, K., and Sullivan, K. (2012). How to measure the benefits of BIM — A case study approach. *Automation in Construction*, 24(0), pp. 149-159.

Becerik-Gerber, B., Jazizadeh, F., Li, N., and Calis, G. (2012). Application Areas and Data Requirements for BIM-Enabled Facilities Management. *Journal of Construction Engineering and Management*, 138(3), pp. 431-442.

Becerik-Gerber, B., and Kensek, K. (2010). Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends. *Journal of Professional Issues in Engineering Education and Practice*, 136(3), pp. 139-147.

Bernstein, P. G., and Pittman, J. H. (2004). Barriers to the Adoption of Building Information Modeling in the Building Industry. *Autodesk Building Solutions White Paper*.

Best, R., and De Valence, G. (2002). *Design and Construction*: Taylor and Francis.

Brown, J. D. (2001). *Using Surveys in Language Programs*: Cambridge University Press.

Bryman, A. (2008). *Social Research Methods*: Oxford University Press, USA.

Bynum, P., Issa, R., and Olbina, S. (2012). Building Information Modeling in Support of Sustainable Design and Construction. *Journal of Construction Engineering and Management*.

Chau, K., Anson, M., and Zhang, J. (2004). Four-dimensional visualization of construction scheduling and site utilization. *Journal of Construction Engineering and Management*, 130(4), pp. 598-606.

CII. (2005). Lean Principles in Construction RS191-1: Construction Industry Institute.

De Vaus, D. (2001). *Research Design in Social Research*: SAGE Publications.

Deutsch, R. (2011). *BIM and Integrated Design: Strategies for Architectural Practice*: John Wiley and Sons.

Dörnyei, Z., and Taguchi, T. (2010). *Questionnaires in Second Language Research: Construction, Administration, and Processing*: Routledge.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*: John Wiley and Sons.

Fallon, K. K., and Palmer, M. E. (2007). General Buildings Information Handover Guide. *Principles, Methodology and Case Studies (NISTIR 7417), August*.

Fellows, R. F., and Liu, A. M. M. (2009). *Research Methods for Construction*: John Wiley and Sons.

Fu, C., Aouad, G., Lee, A., Mashall-Ponting, A., and Wu, S. (2006). IFC model viewer to support nD model application. *Automation in Construction*, 15(2), 178-185.

Gerring, J. (2006). *Case Study Research: Principles and Practices*: Cambridge University Press.

Gillham, B. (2000). *Case Study Research Methods*: Bloomsbury.

Greenhalgh, B. (2011). *Introduction to Building Procurement*: Taylor and Francis.

Gruen, A., Behnisch, M., and Kohler, N. (2009). Perspectives in the reality-based generation, n D modelling, and operation of buildings and building stocks. *Building Research and Information*, 37(5-6), pp. 503-519.

Gu, N., and London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19(8), pp. 988-999.

Hallowell, M., and Toole, T. (2009). Contemporary Design-Bid-Build Model. *Journal of Construction Engineering and Management*, 135(6), pp. 540-549.

Halpin, D. W. (2005). *Construction Management*: Wiley.

Hardin, B. (2011). *BIM and Construction Management: Proven Tools, Methods, and Workflows*: Wiley.

Harrington-Hughes, K. (2002). *International Transit Studies Program: report on the Spring 2001 Mission : Design-build transit infrastructure projects in Asia and Australia*: Transportation Research Board, National Research Council.

Hartmann, T., Gao, J., and Fischer, M. (2008). Areas of application for 3D and 4D models on construction projects. *Journal of Construction Engineering and Management*, 134(10), pp. 776-785.

Harty, J., and Laing, R. (2009). *Drivers for Change in Construction Procurement and its Impact on Management.* Paper presented at the Second International Conference in Visualisation, 2009.

Hwang, S., and Liu, L. Y. (2010). *BIM for integration of automated real-time project control systems.* Paper presented at the Construction Research Congress.

Jackson, B. J. (2010). *Construction Management JumpStart: The Best First Step Toward a Career in Construction Management*: John Wiley and Sons.

Jackson, S. (2002). *Project cost overruns and risk management.* Paper presented at the Proceedings of Association of Researchers in Construction Management 18th Annual ARCOM Conference, Newcastle, Northumber University, UK.

Kenig, M. (2004). *Project Delivery Systems for Construction*: Associated General Contractors of America.

Kim, H., and Grobler, F. (2009). *Design Coordination in Building Information Modeling (BIM) Using Ontological Consistency Checking.* Paper presented at the Computing in Civil Engineering (2009).

Konchar, and Sanvido. (1998). Comparison of U.S. Project Delivery Systems. *Journal of Construction Engineering and Management*, 124(6), pp. 435-444.

Korkmaz, S., Riley, D., and Horman, M. (2010). Piloting Evaluation Metrics for Sustainable High-Performance Building Project Delivery. *Journal of Construction Engineering and Management*, 136(8), pp. 877-885.

Kuprenas, J., and Nasr, E. (2007). Cost Performance Comparison of Two Public Sector Project Procurement Techniques. *Journal of Management in Engineering*, 23(3), pp. 114-121.

Kymmell, W. (2008). *Building information modeling: planning and managing construction projects with 4D CAD and simulations*: McGraw-Hill.

Lancaster, G. (2005). *Research Methods in Management*: Taylor and Francis.

Lavrakas, P. J. (2008). *Encyclopedia of Survey Research Methods*: SAGE Publications.

Love, P. D., Edwards, D., Han, S., and Goh, Y. (2011). Design error reduction: toward the effective utilization of building information modeling. *Research in Engineering Design*, 22(3), pp. 173-187.

Mahdi, I. M., and Alreshaid, K. (2005). Decision support system for selecting the proper project delivery method using analytical hierarchy process (AHP). *International Journal of Project Management*, 23(7), pp. 564-572.

McCuen, T. L. (2008). Scheduling, Estimating, and BIM: a Profitable Combination. *AACE Transactions, 2008*, pp. 11-19.

Nam-Hyuk, H., Kyung-Min, M., Ju-Hyung, K., Yoon-Sun, L., and Jae-Jun, K. (2008). *A Study on Application of BIM (Building Information Modeling) to Pre-design in Construction Project.* Paper presented at the Third International Conference on Convergence and Hybrid Information Technology, 2008.

Neill, A., and Al-Battaineh, H. (2011). *Compare Risk Allocation for Different Project Delivery Methods in Canada*. Paper presented at the 2011 Conference and Exhibition of the Transportation Association of Canada, Edmonton , Canada.

Ohrn, G., and Rogers, T. (2008). *Defining Project Delivery Methods for Design, Construction, and Other Construction-Related Services in the United States.* Paper presented at the ASC Conference, Auburn, Alabama.

Ospina-Alvarado, A., and Castro-Lacouture, D. (2010). *Interaction of Processes and Phases in Project Scheduling Using BIM for A/E/C/FM Integration.* Paper presented at the Construction Research Congress 2010: Innovation for Reshaping Construction Practices.

Park, J., Kim, B., Kim, C., and Kim, H. (2011). 3D/4D CAD Applicability for Life-Cycle Facility Management. *Journal of Computing in Civil Engineering*, 25(2), pp. 129-138.

Pishdad-Bozorgi, P., and Garza, J. M. d. l. (2012). Comparative Analysis of Design-Bid-Build and Design-Build from the Standpoint of Claims. *Construction Research Congress 2012*, pp. 21-30.

Rowlinson, S., Collins, R., Tuuli, M. M., and Jia, Y. (2010). *Implementation of Building Information Modeling (BIM) in Construction: A Comparative Case Study*. Paper presented at the AIP Conference Proceedings.

Sanei Sistani, N., and Rezaei, A. (2012). *BIM Implementation in Developing Countries.* Paper presented at the 10th International Congress on Advances in Civil Engineering, Middle East Technical University, Ankara, Turkey.

Saris, W. E., and Gallhofer, I. N. (2007). *Design, Evaluation, and Analysis of Questionnaires for Survey Research*: Wiley.

Scott, S., Molenaar, K. R., Gransberg, D. D., and Smith, N. C. (2006). *Best-value procurement methods for highway construction projects*. Washington, DC: Transportation Research Board of the National Academies.

Shrestha, P. P., and Mani, N. (2012). Impact of Design Cost on Design Bid Build Project Performance, *Construction Research Congress 2012*, pp. 1570-1579.

Smith, D. (2007). An Introduction to Building Information Modeling (BIM). *Journal of Building Information Modeling*, *Fall 2007*, pp. 12_16.

Smith, V. R. R., Castro-Lacouture, D., and Oberle, R. (2009). Effects of the Regulatory Environment on Construction Project Delivery Method Selection, *Construction Research Congress 2009*, pp. 211-218: American Society of Civil Engineers.

Swarup, L., Korkmaz, S., Horman, M., and Gultekin, P. (2010). Exploring the Validity of Qualitative Methods to Analyze Project Delivery of Sustainable, High Performance Buildings *Construction Research Congress 2010*, pp. 1427-1436.

Touran, A., Gransberg, D. D., Molenaar, K. R., Ghavamifar, K., Mason, D. J., and Fithian, L. A. (2009). A Guidebook for the Evaluation of Project Delivery Methods, *Transit Cooperative Research Program*. Washington, D.C.: Transportation Research Board.

Walewski, J., Gibson, G. E., and Jasper, J. (2001). *Project Delivery Methods and Contracting Approaches Available for Implementation by the Texas Department of Transportation*: Center for Transportation Research, Bureau of Engineering Research, University of Texas at Austin.

Weygant, R. S. (2011). *BIM Content Development: Standards, Strategies, and Best Practices*: John Wiley and Sons.

Wong, A. K. D., Wong, F. K. W., and Nadeem, A. (2010). Attributes of Building Information Modelling Implementations in Various Countries. *Architectural Engineering and Design Management*, 6(4), pp. 288-302.

APPENDICES

Appendix A

Questionnaire sample

First Page **Personal Informations**

In which party of construction industry do you work?

1) Owner ☐ 2)Designer ☐ 3)Contractor ☐

In which type of construction project your company participate? And how much is the maximum price for project which your company annualy permited to execute?

1)Buildings ☐ 2)Water Sysytems ☐ 3)roads ☐

1) 2) 3) 4) 5)

Education: Profession:

Job Experience:

1)Less than 5 years ☐ 2)Between 5 and 10 years ☐ 3)Between 10 and 15 years ☐ 4)More than 15 years ☐

Knowledge and Experiences of BIM

To some extent do you familiar with "Building Information Modeling" BIM ?

1)Not familiar ☐ 2)Just heard its name ☐ 3)A little familiar ☐ 4)Completely familiar ☐

Have you used BIM in your projects up to now?

1)Yes, I have used ☐ 2)No, I have not used ☐

Definition of BIM

In Building Information Modeling by using software like "Autodesk Revit" and "GRAFISOFT ArchiCAD" you build a construction with real elemetns (e.g.). A BIM model is a digital 3D representation of physical and functional characterisitics of a building. As example for designing window you just have to enter the related dimension like length and width and specify its place on wall, automaticaly a hole is dug and the window is placed on wall. If you increase length and width of window, the hole grow simultaneously and if the heghit of the door which you place in a wall be higher than wall it will warn. Significant difference between BIM model and a standard 3D CAD model is in saving information of constroction process with all details. This details contain instances like material specifications (weight, color, size etc.), instalation and assembly guide, products garanty services, component cost informations etc. one of the most significant properties of BIM is clash detection. Clash detection can identify, display, and report the clash between different components and systems in 3D model. Report of BIM software about crossing a structure beam from plumbing duct is an example.

Ideas About BIM

According to definition and specifications presented about BIM please answer following questions about using BIM in Design-Bid-Build projects:

How much affect using BIM does have on **reduce project time**?

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

How much affect using BIM does have on **reduce project cost**?

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

How much affect using BIM does have on **improve project quality**?

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

How much affect using BIM does have on **improve project health and safety**?

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Second Page

In your opinion using BIM on which of these criteria does have more affect? (1 for lowest and 4 for highest)

Reduce Time ☐ Reduce Cost ☐ Improve quality ☐ Improve Health & Safety ☐

Followings are reasons of not using BIM in Design-Bid-Build projects, how much they affect on not using BIM?

Lack of demand from public (government) sector for using construction management advanced tolls like BIM (in the reason of unmotivation of public sector for reduce cost and time):

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Few number of large projects of private sector (as leader in applying technologies like BIM to reduce cost and time):

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Lack of supply in using construction management advance tools like BIM on behalf of contractor:

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Lack of legislation and standards for using BIM

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

If you think another criteria is effective, please write it and specify extent of its effect

. . . .

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

In terms of using BIM in Design-Bid-Build projects, following criterias can be arised as barriers in using BIM, you think how much is their effcet?

Lack of specilaist (architect/engineer) with experiences in using BIM:

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Interoperability and software issues (using different software or versions file format etc.):

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Expensive development cost of BIM software:

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Lack of collaborative attitude and mutual trust and fragmentation of construction industry:

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

If you think another criteria is effective, please write it and specify extent of its effect

. . . .

1)No affect ☐ 2)Low affect ☐ 3)Medium affect ☐ 4)High affect ☐ 5)extreme affect ☐

Totally how do you evaluate using BIM as a managerial tool in Design-Bid-Build projects?

1)Useless ☐ 2)With negative effect ☐ 3)Ineffective ☐ 4)With positive effect ☐

According definition of BIM, in possible way to do you tend to being more familiar with this tool by training courses?

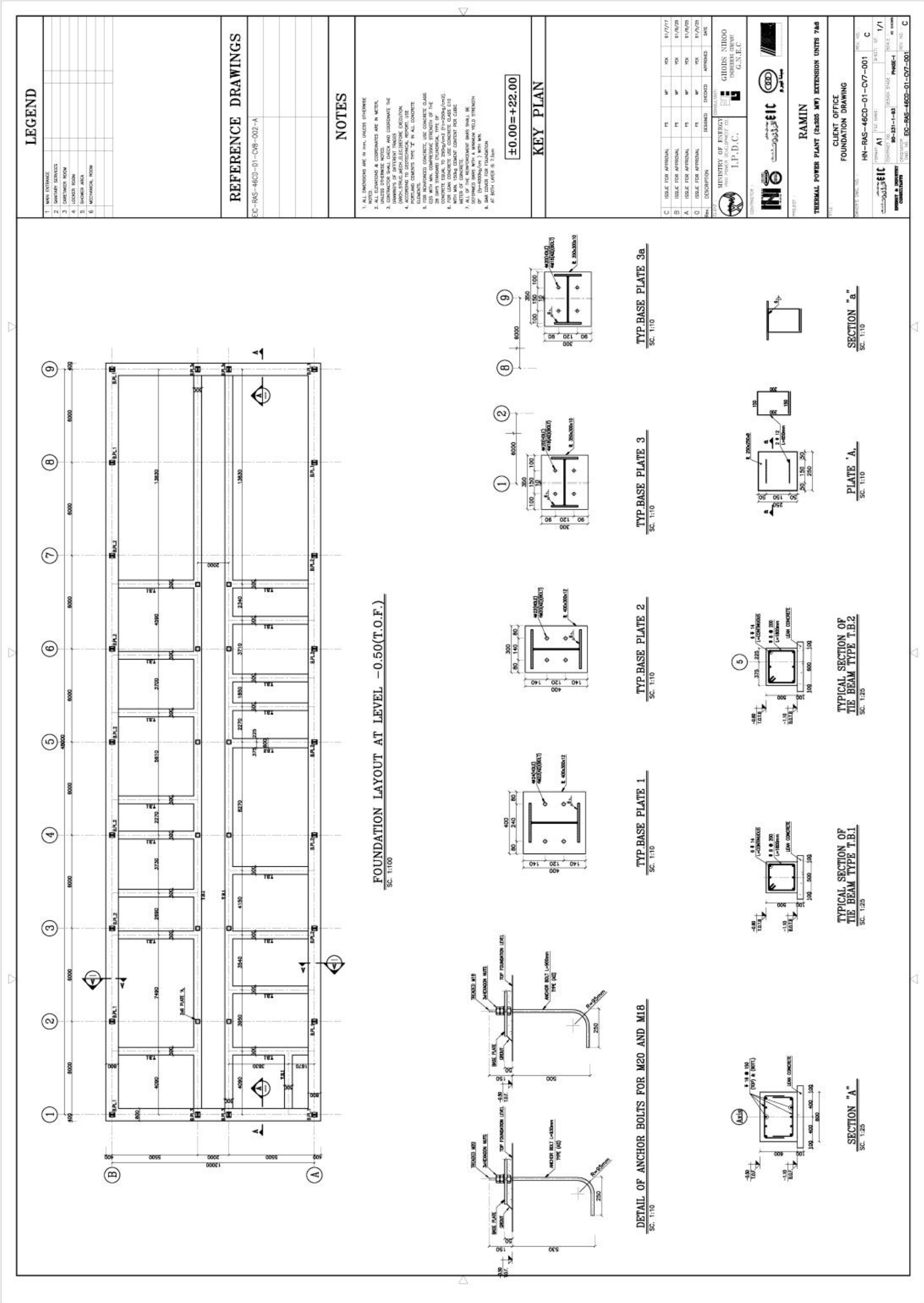
1)Yes I tned ☐ 2)NO I do not tend ☐

Do you tend to using BIM in your future projects?

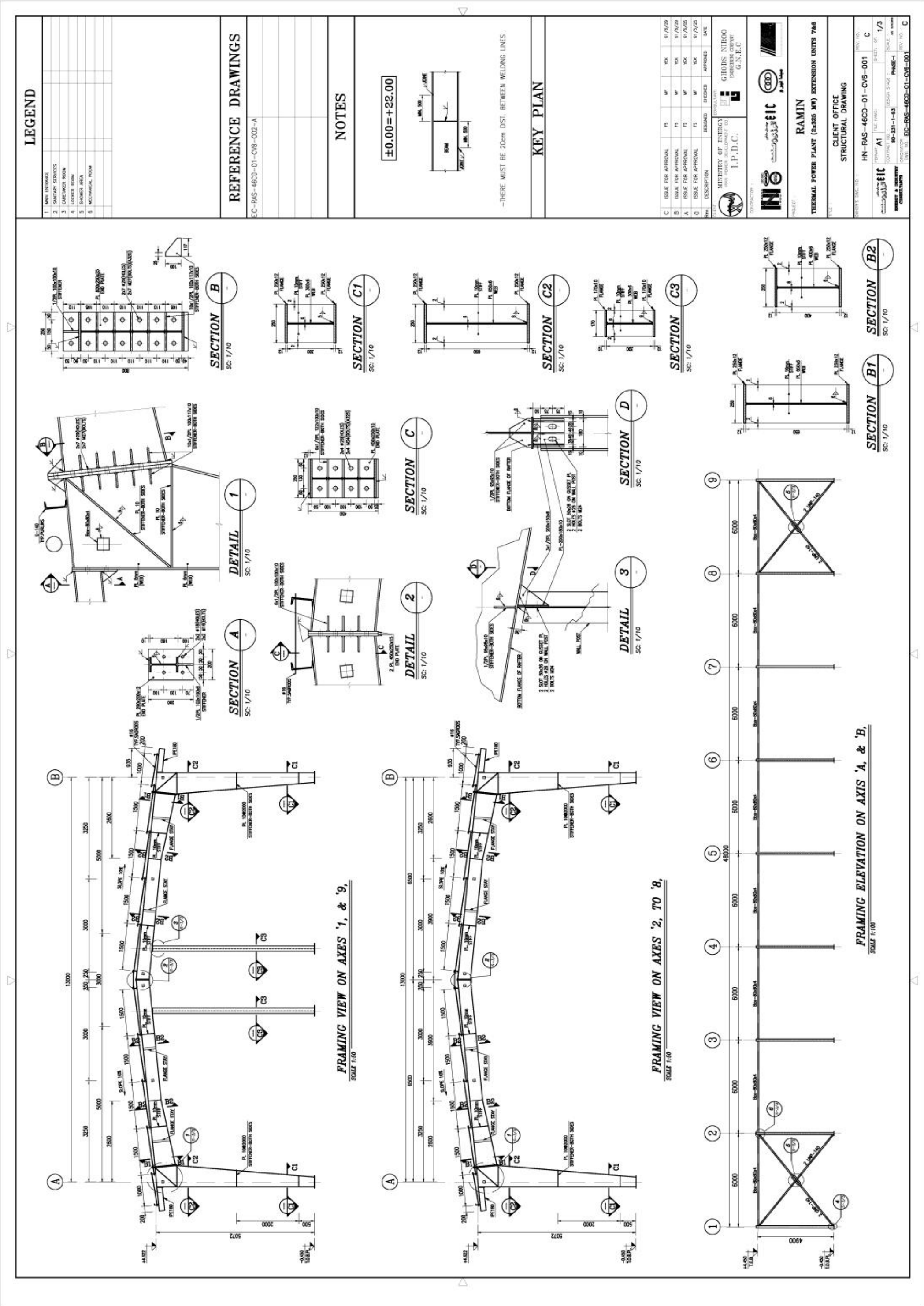
1)Yes I tned ☐ 2)NO I do not tend ☐ **Thanks for your cooperation**

Appendix B

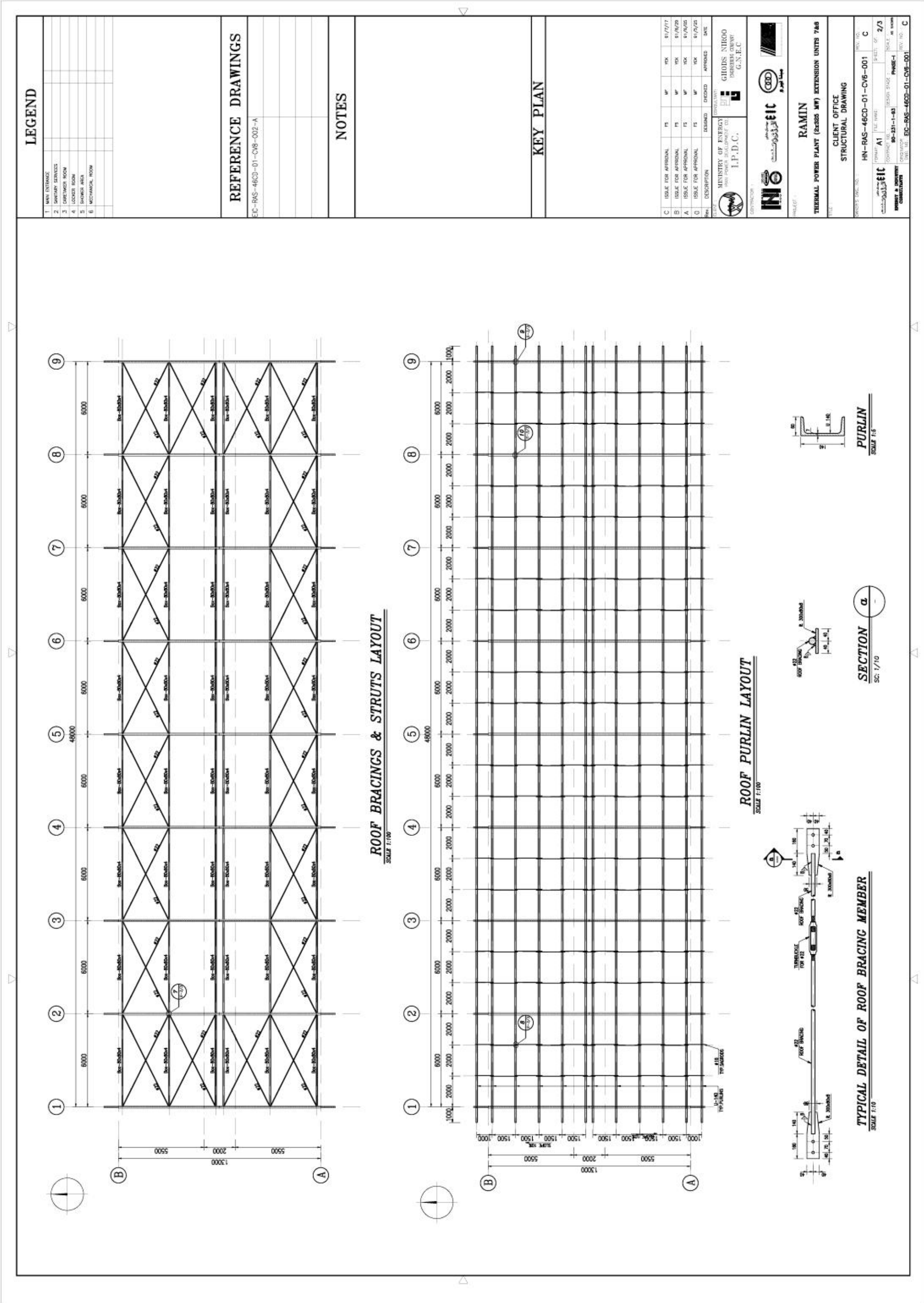
Foundation plan of the case study



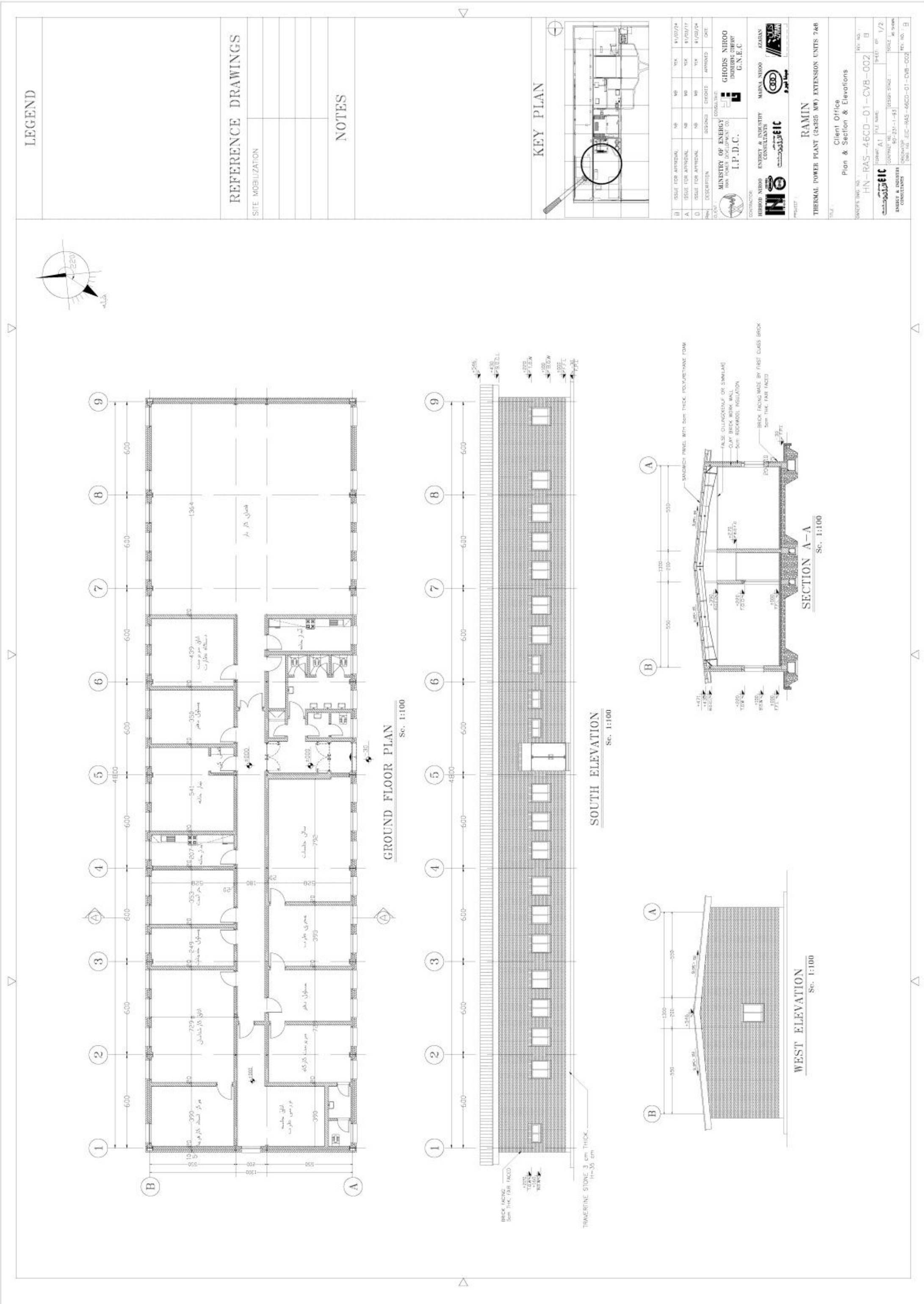
Frame plan of the case study



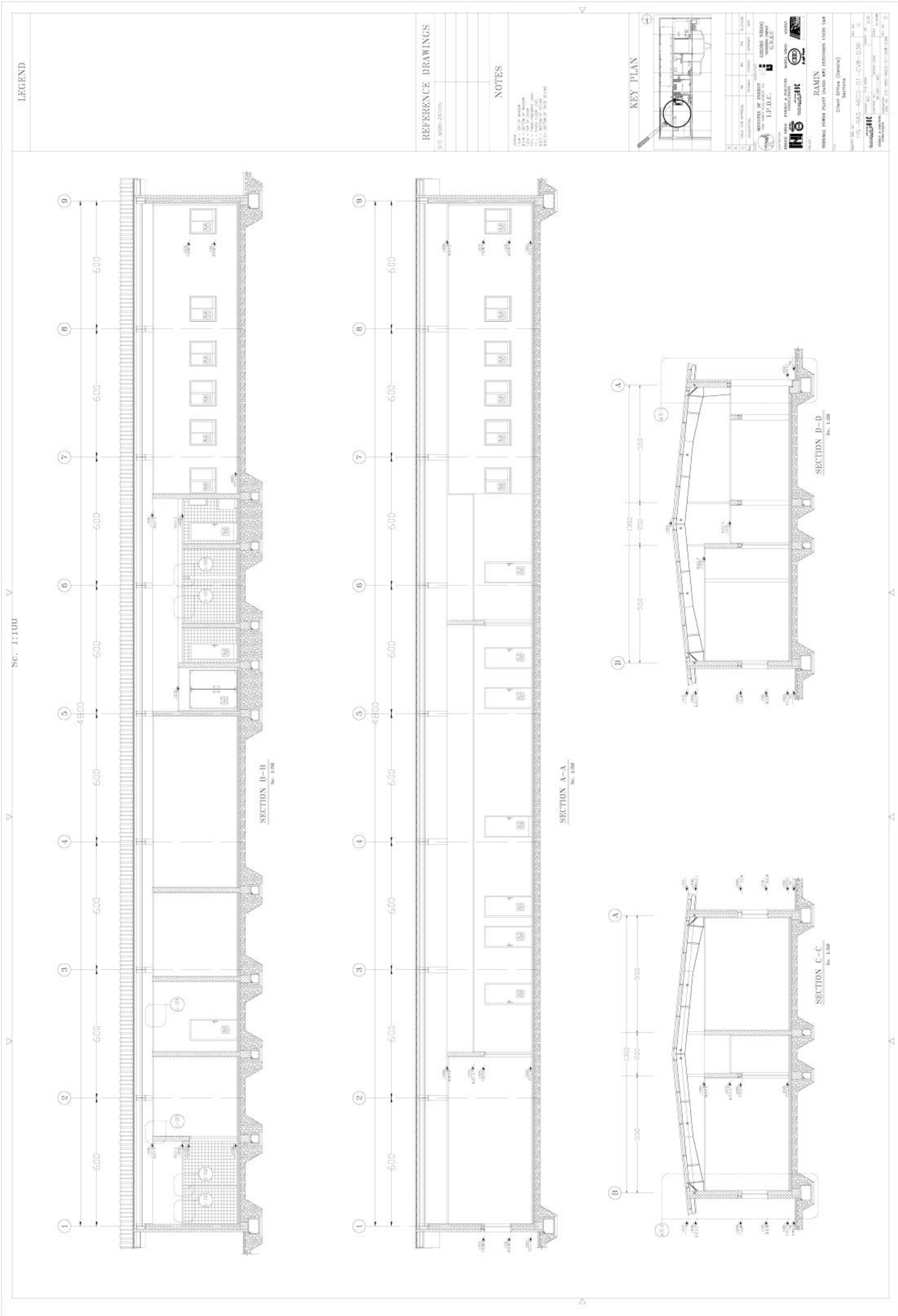
Roof plan of the case study



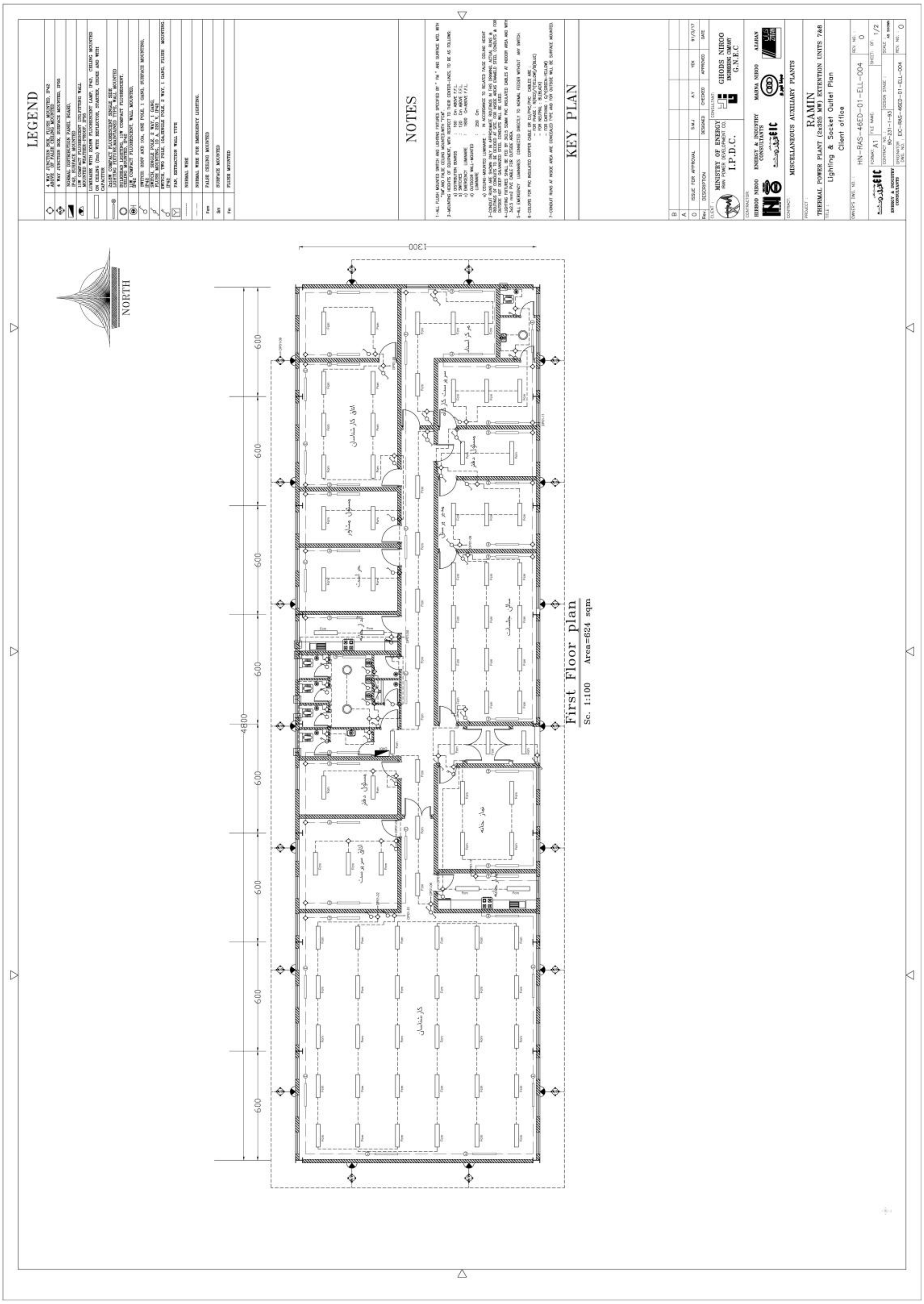
Architectural plan of the case study



Sections of the case study



Electrical plan of the case study



Plumbing plan of the case study