An Najah National University
Faculty of Graduate Studies

Investigating the Adoption of Building Information Modeling (BIM) in Design Stage of Construction Projects
(Saudi Arabia as a Case Study)

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Dedication

To my father

Mother

And my special Fiancee

Acknowledgment

I would like to thank Almighty Allah for giving me strength and power to finish this research.

I want to thank my supervisors Dr. Ihab Hijazi and Dr. Ahmed Saleh for their continuous attention and coordination. Also, I want to thank Dr. Hikmat Ali for his help at the beginning of this research.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحت عنوان:

بحث تطبيق تكنولوجيا نمذجة معلومات المبنى في مرحلة التصميم للمشاريع الانشائية (المملكة العربية السعودية كحالة دراسية)

Investigating the Adoption of Building Information Modeling (BIM) in Design Stage of Construction Projects (Saudi Arabia as a Case Study)

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Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and not has been submitted elsewhere for any other degree or qualification.

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List of Abbreviations

BIM	Building Information Modeling.
AEC	Architecture, Engineering and construction.
KSA	Kingdom of Saudi Arabia.
SAGIA	Saudi Arabian General Investment Authority
UK	United Kingdom
USA	United States of America
CAD	Computer Aided Design.
FM	Facility Management.
PP	Process Protocol.
DO	Design Offices.
AR	Augmented Reality.
AASHTO	American Association of State Highway and Transportation Officials
SSD	Stopping Sight Distance
PSD	Passing Sight Distance
HR	Human Resources
MEP	Mechanical, Electrical, Plumping
GIS	Geographic Information Systems
QDA	Qualitative Data Analysis
RIBA	Royal Institute of British Architects
ROI	Return On Investment
DBB	Design-Bid-Build
DB	Design-Build
CII	Construction Industry Institute

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Abstract

Building information modeling (BIM) is a topic that takes interest of many researchers in the field of construction management around the globe. Further, recently business reports show that BIM is spreading out among the AEC industry firms especially in UK and USA. Thus, predicting the same to be in the Middle East region sounds rational thinking.

The aim of this research was to assess the design process of construction projects to identify its main problems and to find out if BIM can overcome these problems and enhance the process of design, for the achievement of this goal Saudi region was chosen as case study considering two different cases, the first case was with construction firm that don't implement BIM in its design and construction processes, where the second case was with construction and design firm that partially implement BIM in its design processes.

Qualitative approach was deployed in data collecting and analysis processes. The data was inductively analyzed using computer software (QDA Miner) based on grounded theory. The data was gathered through

two different tools, semi-structured interviews were conducted with the first case's firm employees, and questionnaire was used with second case's firm employees as a type of structured interview.

The results of data analysis uncovered that the first firm deals with projects following DBB approach such that the firm modifies the designs that come as part of tender's documents, and the process of modification is very time consuming, in addition, it suffers from too many other problems most of them are managerial problems.

On the other hand, the second firm was found following DB approach in its projects, so the firm do the design and construction works. The firm implements BIM partially in the design's operations specifically in the detailing stage, the stage where the design is transformed into drawing, and the respondents assured that BIM has benefits and save a lot of time and money. However, the process of design at early stages also suffers from many problems like communication problems with the client and the high rate of change orders during the design and construction stages.

The research concluded that the design process in construction projects in Saudi region has problems regardless the project's delivery system, though one of them may be better than the other. Moreover, BIM was found as the proper solution to overcome the design problems in both cases based on case 2 respondent's observations that clarified the benefits

of BIM at detailing stage, and the literature review about how BIM can solve each problem of design.

However, the implementation of BIM is not that easy, the results stated that BIM implementation has barriers like the cost of implementation and lack of experienced people in BIM. These barriers should be erased to achieve successful BIM experience.

Based on the previous findings, the research recommended that BIM implementation should be in the whole process of design to benefit from the full potential privileges of BIM. In addition, the movement toward BIM under the current conditions of Saudi market and the barriers of implementing such technology should be performed gradually. Therefore, it is recommended to start with a prototype project such that controlling the process of implementation and observing the effect of BIM will be easier.

Chapter One

Introduction

1.1 Overview

Construction is one of the largest nation's industries and plays a powerful role in sustaining economic growth, in addition to improve the quality of life. Therefore, the development of this industry is essential to the nations and people wellbeing.

With the technology revolution and the raise of computers, the construction industry was developed simultaneously, starting from papers through the Building Information Modeling (BIM). BIM is a process by which a digital representation of the physical and functional characteristics of a facility are built, analyzed, documented, and assessed virtually, then revised iteratively until the optimal model is documented (Yalcinkaya and Arditi, 2013).

The business value analysis is the way to determine the health and wellbeing of the firm in the long run. It's includes financial, managerial and customers value forms. Each firm seeks for increase its profitability and gains a higher level of customer satisfaction with more fluent managerial processes. However, the construction process flows through several complex stages from the planning stage to the operation, maintenance…etc. which increases the probability of omissions and errors

that’s increase the cost and affect the quality of the final products, in other word, affect the value gained by the firm. Here, the question is “Does the BIM improves the value gained by the firms along the value chain of construction industry?”

While BIM is rapidly expanding around the globe, there are significant differences between construction companies’ experience with business benefits from BIM in various regions (McGraw Hill, 2014). This study will be conducted on Saudi Arabia as it is one of the largest construction markets in the Middle East (Ventures Middle East, 2011) to find if the applying of BIM is really conservative.

1.2 Definition of BIM

BIM has been defined by many authors, but the precise definition has yet to be agreed (Ezcan et al, 2013). Succar (2009a) defined BIM as "*a set of interacting policies, processes and technologies*" which generating a "*methodology to manage the essential building design and project data in digital format throughout the building life-cycle*" cited from (Penttila, 2006). Yalcinkaya and Arditi (2013) defined BIM as "*process by which a digital representation of the physical and functional characteristics of a facility are built, analyzed, documented and assessed virtually, then revised iteratively until the optimal model is documented*". Another definition of BIM was by Underwood and Isikdag (2011); "*The information management process throughout the lifecycle of a building which mainly focuses on enabling and facilitating the integrated way of project flow and*

deliver, by the collaborative use of semantically rich 3D digital building models in all stages of the project and building lifecycle." Al mohannadi et al (2013) cited this definition from Aranda-Mena et al (2009);"*a) a software application, b) process for designing and documenting building information, and c) an approach to practice and advance the profession which requires implementation of new policies, contracts, and relationships amongst project stakeholders*".

The common thing between the previous definitions is that BIM is a digital or virtual representation of the building, also it's a process that allows managing information of the project throughout its lifecycle in a collaborative and integrated method among the project parties. Where, Succar (2009a) and Aranda-Mena et al (2009) definitions argued that BIM also requires implementation of new polices and regulations to control the process of BIM adoption. Therefore, for the purpose of this study, any of these two definitions can be adopted because it's more comprehensive than the others.

1.3 Facts about Construction Industry in KSA

- The construction sector in the KSA is the largest and fastest growing market in the Arabian Gulf. One quarter of the ongoing projects in the Gulf which is estimated by $1.90 trillion are located in Saudi Arabia (U.S – Saudi Arabian Business Council, 2009).

- The Kingdome constructs six economic cities as the following table explains:

Table 1.1: Six economic cities information, source (SAGIA).

SIX ECONOMIC CITIES PROJECT

Economic City	King Abdullah Economic City (Rabigh)	Jizan Economic City (Jizan)	Prince Abdulaziz bin Musaed Economic City (Hail)	Knowledge Economic City (Madinah)	Tabuk Economic City (Tabuk)	Eastern Province Economic City
Area (sqkm)	168	103	156	4.8	135	n/a
Investment (US $Bn)	53	27	8	7	50	n/a
Jobs (mn)	1	.05	.055	.02	.4	n/a
Population (mn)	2	.25	.3	.15	1	n/a
Focus	Ports, logistics, light industry & services	Heavy industries, agro-industries, social development	Logistics, agribusines, minerals & construction material	Knowledge-based industries, tourism	Logistics, trade & Industry, environment	Energy, Resource
Scheduled Completion	2016	2011	2018	2014	n/a	n/a

Source: SAGIA

- The construction sector has a great potential for growth, especially the housing sector as the Saudi population rising at rate of 2.50% a year (U.S – Saudi Arabian Business Council, 2009).

- According to the expert's estimates, the Kingdome will spend about $400 billion on large infrastructure projects over the coming five year (U.S – Saudi Arabian Business Council, 2009).

Building on the above mentioned facts, the KSA construction market can be considered as rich environment that has a great opportunity to prevent wasting a lot of money considering the amount of investments and

the diversity of projects. Such investments should motivate rethinking about the current construction industry processes and how to develop it by deploying innovative tools and processes. Therefore, this study come as a step on the way of developing the processes of construction focusing on the design process.

1.4 Design Process

In literature, the construction processes is divided into many stages and phases, for example, RIBA plan of work (2013) divided the construction process into seven phases among them four related to design process. The design processes and its products like models and drawings act as input to the whole construction process. Therefore, it is necessary to evaluate the process of design to find if it has problems or not. According to Vantenn et al (2015) problems in the design process negatively affect the whole project lifecycle in terms of productivity and increasing cost. Moreover, the cost of change at the design stage is low which make it the best stage of project for value realization (Samset, 2008).

In the light of this, this research will focus on the design process in the construction process due to its important role in the wellbeing of the whole project lifecycle in terms of cost, time, and quality.

1.5 Problem Statement

The traditional view of construction process is that it is a set of subsequent activities that can be managed and processed in ordered linear

way. However, the real image is not as it looks like, the frequent failures to complete construction projects on time and budget indicates that the process is neither ordered nor predictable. Examinations reveal that the construction process is complex, nonlinear, and dynamic phenomenon (Bertelsen, 2003).

The proposed country-KSA- invests much money in developing the infrastructure of the country. As mentioned earlier, the government intention is to build more seaports, airports, roads and economical cities which will support the economy growth of KSA. However, the main problem faces the construction firms is to finish the projects on time and budget with the desirable quality which decreases the profit margin of these firms and prohibit the plan of development. There are many reasons of wasting time and money, it could be due to design errors, weak project control, ineffective communication, repeated work…etc. Tilley (2005) stated that rework and document insufficiency come as a result of poor management at early stages of design. Since the focus of this research is on design process; the first problem is to identify the current design process and its main problems.

The large content of information and the dynamic nature of construction require an efficient tool that can deal with this complexity in a systematic way which saves time, minimizes the cost and effect of change. Since BIM is the proposed tool in this research, investigating the ability of

BIM to overcome the design process problem is the second issue that should be figured out in this research.

1.6 Research Questions

The construction project passes through many stages and to move from one stage to another, each stage must be finished properly to avoid errors in the next stage. The design stage is one of the important stages in the project lifecycle, for this reason the following questions need to be answered in this research:

1- What are the main stages that design process passes through?

2- What are the main problems that face the designers during the design process?

3- Is the adoption of BIM can overcome the problems of the design process?

4- What are the main barriers of BIM implementation in the construction projects?

1.7 Significance

The significance of this study arises from the significance of BIM itself. BIM is argued to be a motivator for change aims to reduce industry fragmentation, enhance its efficiency and effectiveness. Hence, this study will analyze the design process of construction projects and identifies the

main problems that face the designers. Moreover, the effects of these problems on the design and the whole lifecycle of project will be identified. Then, the study will investigate if the adoption of BIM is the solution to avoid the design problems through determining the main potentials of BIM. Building on this, the study provides a case study evidence on the efficiency of BIM in enhancing the project's lifecycle which in turn will support the development of the construction industry and provides a better chance for economy growth.

1.8 Research Methodology

In order to answer the research questions, the research should follow a clear and appropriate methodology that fit the research questions. The research could follow two main approaches, quantitative approach like surveys or the qualitative approach like interviews. Roshan and Deeptee (2009) stated that qualitative approach is an exploratory method to collect, analyze and interpret the data captured from human behaviors while quantitative approach collect, analyze and interpret the data captured from numerical patterns. So what is the appropriate approach for this research?

The first question is asking about the design process of construction projects in Saudi region which is undefined process, also the second question is asking about the problems that face the designers during the design stage. Thus the research is exploring all of these things, Creswell (2012) and Sauro (2015) discussed that it is better to follow the qualitative approach when the research exploring something not defined well. Also

they stated that qualitative research is preferable to understand the context and the environment, so understanding the challenges that face the designers.

Moreover the third question is asking about the role of BIM in solving the design process problems and its potential to enhance the facility lifecycle. Using quantitative approach to answer this question requires to deal with firms that already adopted BIM in their process, such that they can provide numerical information about the effect of BIM on the process like providing time estimate to finish the shop drawings using BIM software, number of design revisions before and after using BIM, number of clashes at construction stage before and after BIM adoption..etc. However, the study area is Saudi Arabia and the number of firms that could provide such information is not enough to be considered as representative sample in quantitative research. According to Building Smart survey the BIM adoption in the Gulf region is 25%, and most of those BIM adopter are using it for visualization only. Hence, the qualitative approach is more suitable to derive the required data to answer the research questions from the people mindset.

1.9 Thesis Structure

This research consists of six main chapters. The first chapter provides an introduction for the research report. The second chapter shapes a background about the BIM topic from previous researches. In the third chapter, the methodology of this research is explained in details in terms of

sampling process, performing interviews and data analysis procedure. The fourth chapter contains the data analysis process and the extracting of results. In addition, chapter five provides a detailed discussion of the research result and the final chapter introduces conclusion and recommendations of the research.

1.10 Summary

This chapter provided an overview on the construction industry and its importance with explanation of the image of the construction process in the first section. Further, the chapter gave the definition of BIM from literature in the second section. Then, some facts about the investments of Saudi Arabia was shown in numbers in the third section. The fourth section answered why the research focuses on the design process. In the fifth section the problems that this research concerns about has been discussed. And the sixth section clarified the main questions that this research should answer. The seventh section talked about the significance of this research and what it will add to the construction industry. In addition, in section number eight the research methodology and the reasons of using it have been explained. Finally, the last section provided the structure of this research report.

Chapter Two

Background

2.1 Construction Industry and BIM

The construction process is complex because it requires different parties to deal with each other, those parties could be people, firms or governmental agencies and every one of them has its own way of managing things. Moreover, the process itself passes through different stages and each stage has its own professionals and goals. Hence, due to this interaction and movement from stage to stage, problems could arise and cause wasting of time and money. So, the following section introduce an overview on the challenges of the construction industry and its drivers.

2.1.1 Challenges of the Construction Industry

The construction industry faces many difficulties and challenges around the globe. Castro (2009) stated that construction is suffering from cost overruns and low productivity as a result of design changes, communication problems, lack of skilled labors and unexpected site conditions. Latham (1994) and Al Hashash (2014) clarified that construction industry in the UK has problems like weak communication and coordination.

According to a study conducted on the Qatari construction industry by Almohannadi et al (2013) delivery on time, delivering high quality

products, staying with budget and consistent communication and collaboration are the main challenges of Qatari construction industry. Moreover, the study revealed that the main drivers for these challenges are poor design integration and poor communication.

Also, Nader et al (2013) discussed that the reliance on paper-based communication will increase the information fragmentation which leads to communication and coordination problems that delay the project delivery.

Likewise, Indian construction industry suffers from difficulties in construction due to the current work system and methodologies which cause waste and negatively impact the project performance (Sawhney and Singhal, 2013).

In the light of the above, most problems are caused as a result of weak design integration and design changes, communication and coordination problems and fragmented information. Oscar (1983) and Al-Hashash (2014) stated that ninety percent of problems in site comes as a result of inadequate information. Therefore, this research will concentrate on the design process with a little focus on communication and documentation.

2.1.2 BIM Drivers and BIM as Solution for the Challenges

In the previous section the industry challenges have been discussed, and found that the design process problems are main factor for industry problems arising. In literature, the studies show that the construction

industry practitioners try to minimize the projects problems by adopting different project managing systems like design-build, integrated project delivery system, design-bid-build…etc.

However, this section provides an overview about a proposed solution to overcome the problems of the design process and the whole construction process. The proposed solution is building information modeling (BIM).

Building information modeling is a modern concept of managing construction projects which is being more important day by day and it is the focus of developed countries (Ezcan et al, 2013). Almohannadi et al (2013) stated that there is a strong relation between perception of the construction difficulties and the usage of BIM as a method to overcome these difficulties.

Likewise, Sawhney and Singhal (2013) stated that top management realization for the potential of BIM is a main driver for BIM implementation. Moreover, they revealed that technology advancement and improving the current work system and methodologies are main drivers for BIM implementation too.

So, What BIM can add to the construction industry and to the design process in particular? While the maximum effect of BIM on a project would be in the design phase because of the high chance to affect the cost (Hergunsel, 2011).

Messner (2009) provided a summary that shows BIM benefits at each stage of a facility lifecycle. This summary is shown in the following figure:

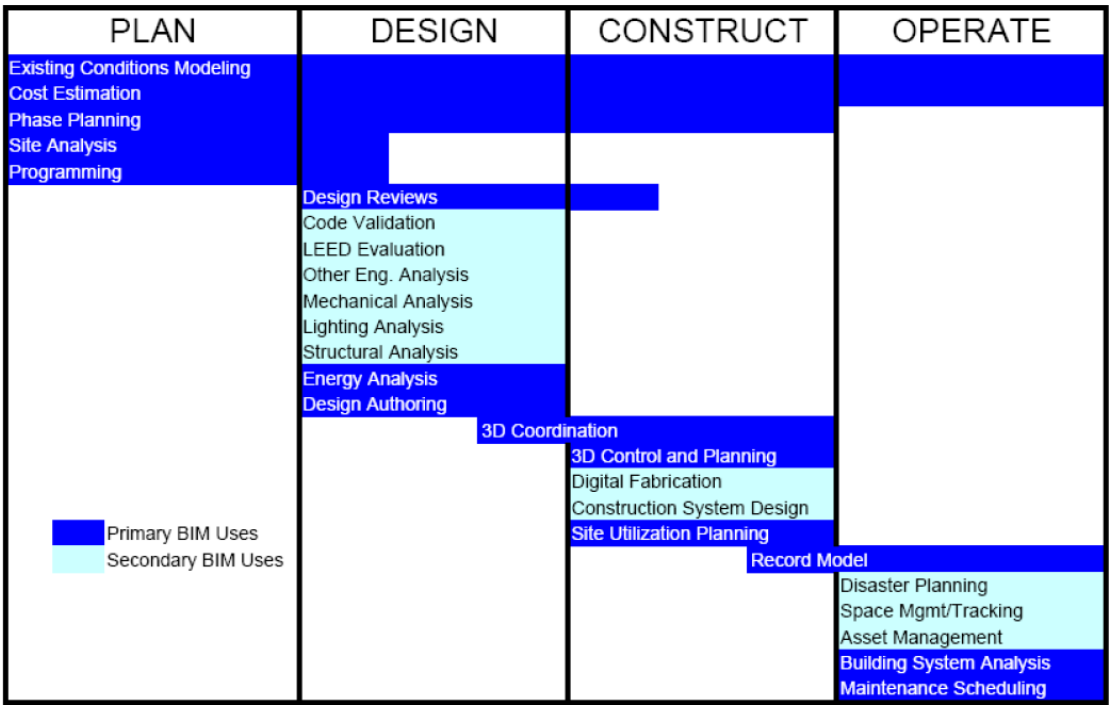

Figure 2.1: BIM benefits at each stage of facility lifecycle (Messner, 2009)

The figure concludes that BIM has benefits at all stages of facility lifecycle starting from planning stage up to the operation and maintenance stage. The focus of this study is the design stage, and one of the most important BIM privileges at this stage are better design reviews and design authoring which can be called "Constructability Reviews" – Which will be discussed in the upcoming sections-. Moreover, the figure clarified that BIM has potentials in movement from one stage to another like "3D coordination" which is very important to move from design stage to construction stage.

However, the following table summarizes the main benefits of BIM at each stage of a facility lifecycle according to different references:

Table 2.1: BIM benefits according to different references

Lifecycle Stage	BIM Benefits at Each Stage	Reference
Planning Stage	- BIM can provide different scenarios with accurate representation which helps in decision making process and allows for cost and effect comparisons. - BIM allows the integration of models that representing the existing conditions of the project site in 3D form like LiDAR. - BIM is useful for noise mapping by integration of information from BIM models and GIS. - BIM would be helpful for communicating public information and future plans with people.	- Autodesk (2015). - Autodesk (2015). - Cheng and Anumba (2015). - Liebech (2013).
Design Stage	- 3D coordination between different disciplines like MEP in order to detect clashes of design. - BIM can save half of the time and cost that spent using traditional design methods. - BIM helps designer to understand the performance of roadway by trying different traffic volumes against different options of road design. - Scheduling and cost estimation: BIM models can generates time schedules, cost estimates and cash flow reports which is very essential for communication of	-Hergunsel (2011). - Yan and Damian (2013). - Autodesk (2015). - Shou et al (2015). - Autodesk (2011).

	designs with contractor. Also, they are very important for the construction stage management. - BIM provides flexibility in changing the design regardless how many time the data has changed.	
Construction Stage	- BIM can be used for deriving models and information for fabrication purposes. - BIM allows for generating cut and fill models that can be integrated with cutting machines, as a result enhancing the speed and accuracy of work. - BIM models can be used for safety planning of the construction site.	- Hergunsel (2011). - Autodesk (2015). - Shou et al (2015).
Operation Stage	- BIM helps in reducing the human resource at operation stage. - If the BIM model has updated continuously through the construction stage till the end of construction, the final resulting model called "As Built Model" and it can be considered as a record that helps in future maintenance operations. - Facility management activities.	- Yan and Damian (2013) and Autodesk (2002). - Autodesk (2015). - Shou et al (2015).

Further, the study of Sawhney and Singhal (2013) identified the impact of BIM on the project performance, the results showed high relative enhancement in the design phase like "better design management", "reduced errors and omissions" and "better coordination of documentation". Besides that, the study stated that the importance of BIM extends to the construction phase like reduced rework and reducing conflict during construction.

Also, Nader et al (2013) discussed that the adoption of BIM will enhance the exchange of information and reduce the waste and inefficient activities.

2.1.3 BIM Barriers

As in case of any technology BIM has barriers that prevent the firms from deploying it. According to Almohannadi et al (2013) study, firms do not implement BIM because they "have not asked to use BIM" and "do not have the appropriate people".

While, according to Sawhney and Singhal (2013) the main barriers of BIM are "Mindset of people", "Lack of skilled workforce", "Lack of awareness about BIM" and "Cost of implementation". Nader et al (2013) stated that deployment of BIM should be performed in parallel with employee development and process improvement, also top management should create a clear vision and suitable business environment.

Similarly, Ezcan et al (2013) revealed that having a wide national strategy will facilitate the implementation and organizational role should be more efficient. Thus, absence of the national strategy can be considered as a barrier for wide BIM deployment.

Moreover, Yan and Damian (2013) concluded that firms have a weak willingness to invest in BIM because its financial benefit not approved by a case studies yet. Also, they claimed that people consider the current technology is enough and they resist to learn new things.

2.2 Design Process

As mentioned before, this research aims to answer the research questions about the design process and the problems face the designers. Hence, this section will introduce literature review about project delivery systems and its relation with the design process, stages of design, and the constructability of designs.

2.2.1 Project's Delivery Systems

Construction projects have multiple delivery systems like integrated project delivery system, construction manager, and the commonly known systems design-bid-build (DBB) and design-build (DB) systems. The Construction Industry Institute CII (2002) provided definitions for the last two systems as:

- **Design-build (DB)**: in this approach, the owner hires one entity to do both the design and construction works (one contract). Hence, the construction and design start simultaneously. Moreover, construction aspects from different disciplines are integrated in the design such that the coordination and collaboration among the owner and the designers is relatively high. Usually in this approach the design-builder takes the contractual risk.

- **Design-bid-build (DBB)**: this is the most common delivery system especially for public projects, where the owner hires a designer to deliver all the required design documents, then the owner performs a bidding process to hire contractor to do the construction works, usually the lowest

price is chosen. There is no contractual relationship between the designer and contractor, so the owner takes the risk of missing information and designs. This approach is linear process such that the construction cannot be started till the full design is delivered.

Actually, it is the owner responsibility to decide the appropriate delivery system to achieve his goals. Tyson Building Corporation (2005) stated that when the owner selects the delivery system he should consider time available to build the facility, the complexity of the building, available time and expertise od in-house staff, budget constraints and how much the risk that owner willing to assume during the building process.

In fact, both systems have advantages and disadvantages, and this was clarified by Fernane (2011) as the following tables illustrate:

Table 2.2: Advantages and Disadvantages of DBB delivery system

Advantages	Disadvantages
Owner controls design and construction.	Requires significant owner expertise and resources.
Design changes easily accommodated prior to start of construction.	Shared responsibility for project delivery.
Design is complete prior to construction award.	Owner at risk to contractor for design errors.
Construction cost is fixed at contract award (until Change Orders).	Design and construction are sequential, typically resulting in longer schedules.
Low bid cost, maximum competition	Construction costs unknown until contract award.
Relative ease of implementation.	No contractor input in design, planning, or value engineering (VE).
Owner controls design/construction quality.	

Table 2.3: Advantages and disadvantages of DB delivery system

Advantages	Disadvantages
Single entity responsible for design and construction.	Minimal owner control of both design and construction quality.
Construction often starts before design completion, reducing project schedule.	Requires a comprehensive and carefully prepared performance specification.
Construction cost is known and fixed during design; price certainty.	Design changes after construction begins are costly.
Transfer of design and construction risk from owner to the DB entity.	Potentially conflicting interests as both designer and contractor.
Emphasis on cost control.	No party is responsible to represent owner's interests.
Requires less owner expertise and resources.	Use may be restricted by regulation.

However, Change et al (2010) concluded that DB projects provides better performance. Also, Tyson (2005) and CII (2002) study in collaboration with Pennsylvania State University realized that DB projects outperforms DBB projects in terms of cost performance, schedule control, number of change orders and quality of end product with reduced rework.

2.2.2 Stages of Design

The focus of this research is on the design process of construction projects, and there are a lot of guides that explain the stages of design whether it is for a building or infrastructure. Hence, this section will provide an example on the stages of design according to the U.S. Department of Transportation guide. The following figure illustrates the stages of highway development as it was mentioned by the U.S. Department of Transportation.

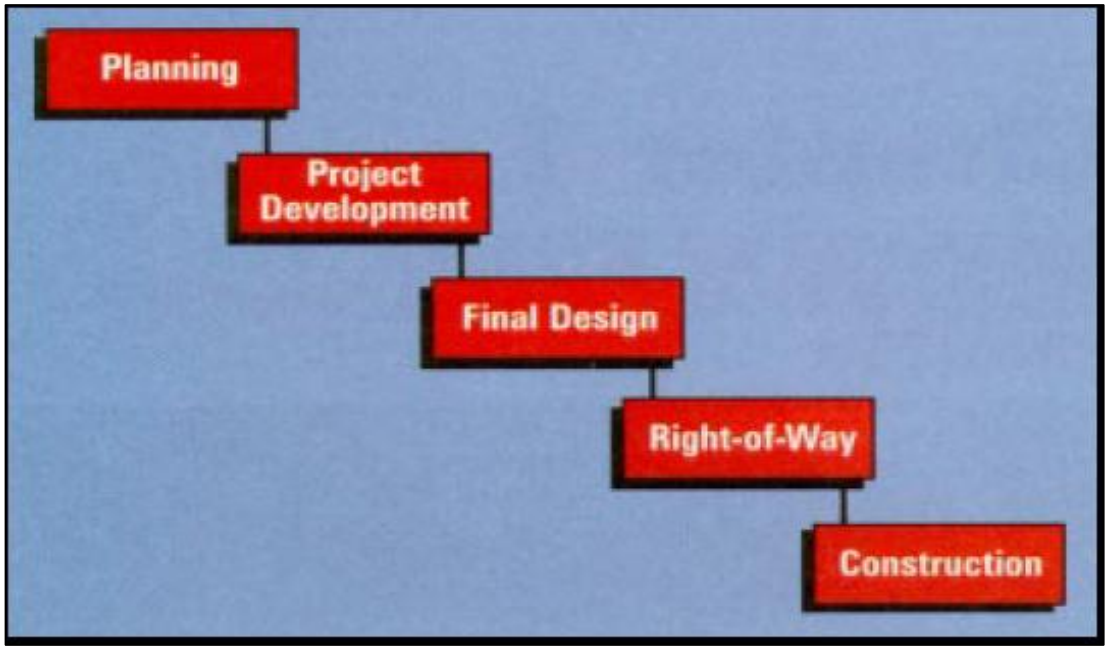

Figure 2.2: Highway development Stages

They also discussed that the final design features can mostly affected by the first three stages of planning, project development and final design.

- Planning stage: At this stage the need for highway or highway improvement is addressed and identified with involvement of the public. Moreover, the effects of the proposed project on the surrounding area should be considered regarding many factors like cost, safety, environmental quality and physical characteristics.

- Project development stage: this stage includes refinement of the purposes of the project. Further, alternatives are developed and evaluated regarding its effects on the environment. Also, the major design features is identified at this stage.

- Final Design stage: at this stage the plans, estimates and specifications of needed quantities and materials are prepared to be

ready for bidding process. At this stage the designers should be aware to be flexible in their designs such that a minor changes to the original concept can be made in order to have a better final product.

- Right-of-way and construction stage: At this stage the bedding process is performed and the contractor is selected. As mentioned before, minor changes in design may be necessary, therefore the involvement of the design team at this stage is also necessary. After finishing this stage, the highway will be ready for operation.

The U. S. Department of Transportation emphasizes that though these stages are distinct, there is an overlap and coordination among the project parties, including designers, throughout the stages of project development.

2.2.3 Constructability in Design

Many studies in literature have discussed the challenges of design process in construction projects. Mendelsohn (1997) and (Anderson et al 1999) discussed that constructability has an essential role in the planning and design phases due to its potential in minimizing changes, disputes and delays at construction stage. (Anderson et al 1995) stated that "*constructability is often portrayed as integrating construction knowledge, resources, technology and experience into the engineering and design of a project*".

Consequently, performing constructability reviews requires a technology tool that allows integration of different fields of engineering with the ability of discovering clashes and omissions, and reinforce all of that with high quality representation of a facility. Unlike the traditional 2D CAD tools, BIM tools can provides a perfect environment to perform constructability reviews for the designs.

However, (Anderson et al 1999) have performed a study to find out the reasons of weak constructability in highway project's designs considering design firms and construction firm's points of view. The reasons concluded by the study are:

Design Firms Observations

1. Inadequate coordination of designs, plans, and specifications.
2. Lack of experience and knowledge.
3. Poor communication and feedback.
4. Inadequate time and funds for constructability.
5. Unavailability of early review of designs.
6. Uncoordinated timing, phasing, and scheduling.

Construction Firms Observations

1. Unclear designs, plans, and specifications.
2. Poor scheduling and phasing of construction.

3. Lack of communications and feedback.

4. Unavailability of design review.

5. Lack of experience and knowledge.

2.3 Documentation process

Referring to section 2.1.1, fragmented documents and inadequate information are considered as main reasons for projects failure. Thus, the documentation process is essential for the consistency of information and project success.

The American Institute of Architects defined (2015) documentation as physical things like paper, drawings, contracts, material submittals..etc. Electronic things like emails, text messages, visual recording..etc. And anything related to the firm's record.

These records should be kept in a suitable way to achieve many objectives. According to ISO 9001:2015 the objectives of documentation are:

1- Communication of information: documents are tool for transmission of information and the type of information depends on the firm products and processes.

2- Sharing of knowledge.

3- Evidence of conformity: to assure that what was planned has actually done.

4- To keep the firm experience in order to use it in development purposes.

The “Quality in Construction” website provides some essential tips for document controlling in construction projects regardless the size of the project and regardless the method of documentation, it can be considered as minimum requirement of document controlling:

1- Accessibility: The construction team should have easy access to any document related to their job in any time.

2- Changes on documents: The construction team should be always informed with any changes or update on any document (especially drawings). Else, there is a large margin of risk that people working in site with outdated drawings or materials.

3- Quick inform of changes: There is a need to immediately inform the construction team with changes on drawings or documents. It can be by marking, clouds..etc.

4- Coding system: every document or drawing should have a unique code in order to facilitate tracking of document.

5- Previous revisions: once the document or drawing approved, the previous revisions should be removed or stored away from the project in order to avoid inappropriate use.

6- Status of document: the construction team should be informed with the status of document or drawings in their hands. It could be by a stamping system or anything else.

7- Source of information: It is essential to have one source of distributing information and it should be known by all construction team. Any document or drawing comes from any other source should be considered invalid to use in site.

2.4 Qualitative Data Analysis

In order to answer the research questions, this research has followed up the qualitative data analysis as a method to collect and analyze the data. The following subsections explains the definition of qualitative data analysis, why it could be selected and the procedure of this method of analysis.

2.4.1 Definition

According to (Gibbs, 2002) qualitative data analysis can be defined as a set of procedures that let the researcher understand, explain and interpret the situation and the people being investigated. Burnand et al (2008) stated that the analysis of qualitative data follows two main approaches: the deductive approach and the inductive approach. They argued that in deductive approach the researchers tested their own theories against the data. While, in inductive approach the researchers have little or no predetermined thoughts about the theory. Moreover, they clarified that

inductive approach is more flexible, comprehensive, and most common in analyzing data. In addition, deductive approach researchers are narrow, primal and unproductive (T. Egan, 2002) and (Glaser and Strauss, 1967). Deniz and Lincolen (2005) discussed that qualitative data analysis follows inductive and analytical strategy. Pope, ziebland, Mays (1999) and Burnand et al (2008) assures that thematic content analysis is the most common inductive approach in analyzing qualitative data, this method is also called grounded theory.

2.4.2 Grounded Theory

Woods, Gapp, King (2016), Glaser (1978) and Hage (1972) defined grounded theory as " *set of categories that are related to one another to form a framework that explains the main concerns of the participant in relation to the research area and shows how this concern is resolved and managed*". Grounded theory study provides a new theory based on participant lived experiences (Fassinger, 2005) and (D. Barrnett, 2012). Moreover, grounded theory demonstrates complications in practitioners experiences (D. Barrnett, 2012). Charmaz (2006) concludes that grounded theory provides more flexibility and focus than many methods. He also claims that with grounded theory, the researcher can refine the process of gaining data and as a result refine the collected data.

In fact, everything the researcher could learn during the research can be considered as data, Barneyg G. Glaser says "All is Data" (cited in Charmaz, 2006, P16). Likewise, Charmaz (2006) discussed that the

researchers like graduate students have an advantage point while they can start a research project based on their concrete background in their disciplines. However, the researcher should be open to new things as much as possible during the research.

2.4.3 Qualitative Data Analysis Tools

Peter and Wester (2004) stated that qualitative analysis has to be done in three ways, observation, interpretation and selection. Chowdhury and Quant (2015) discussed that the researcher can collect data through various methods such as observation, interviews practitioners and written discourses. Hence, the interviews are the most common in qualitative studies (A. Saleh, 2013) and (Egan, 2002), it had been adopted in this research. According to Bowers (1988) interviews may be structured, unstructured or semi-structured, he concludes that structured interviews are not suitable for grounded theory studies. However, in literature structured and semi-structured interviews are considered compatible with grounded theory studies. The researcher could use semi-structured interviews in order to gain more focused information and he can lead the conversation using persuading words (K. Duffy, C. Ferguson, H. Watson, 2000). In addition, they assures (Rose, 1994) debates that in semi-structured interviews the researcher can follow up with respondent answers to gather information related to significant issues that could be related to research questions.

2.4.4 Grounded Theory Procedure

Peter and Wester (2004) stated that in qualitative analysis the analytical frame arise during the research project itself. However, (K. Punch, 2009) explains that data analysis should starts with coding. He defined code as label, tags or names, hence coding means connect these tags or labels with data. Moreover, he discuss the types of coding as follows:

- Open coding: is generating abstract categories from data, these abstract categories considered as building block of the theory. The codes derived by open coding are descriptive more than inference codes.

- Axial coding: is the next step of qualitative data analysis, it comes to connect the codes generated by open coding (Strauss and Corbin, 1990). There are many logical methods to connect things together, for example, cause and effect, procedure or steps of a process, or properties of something.

- Selective coding: is the third stage of qualitative data analysis which means selecting a core category and focus on it.

The following diagram explains K. Punch definitions of coding types

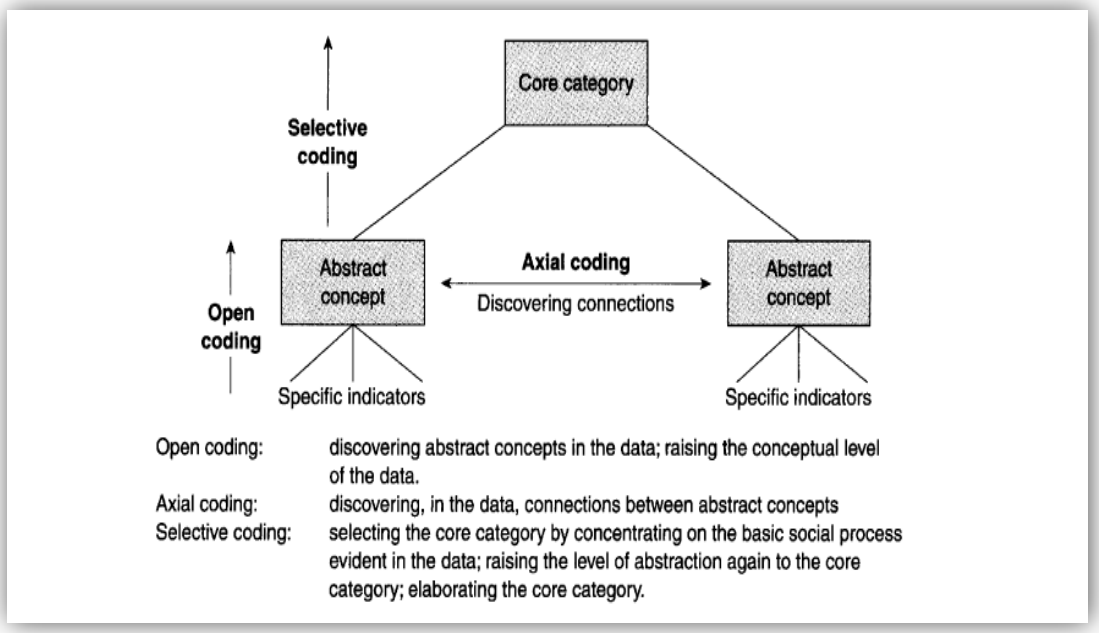

Figure 2.3: Representation of grounded theory analysis by K. Punch (2009)

2.5 Summary

This chapter provided an overview in literature about the main topics of this research. In the first section, a literature review has introduced about the challenges of construction industry and BIM. Where the second section clarified the projects delivery systems, the stages of design process and the definition of constructability. The third section discussed the documentation objectives and how to document construction project documents. Lastly, the fourth section was about the qualitative data analysis meaning and the grounded theory procedure.

Chapter Three

Methodology

This chapter provides a detailed description for the method that was used to collect and analyze the data in order to answer the research questions. In addition, it explains the research strategy, research tools, research sample and the source of data.

Qualitative data analysis was chosen as an approach to analyze the data by a computer software called QDA Miner. The research was conducted with engineers from the field of construction projects in KSA. Semi-structured interviews and questionnaires were performed to acquire data about the design process stages and its problems, and to find out what BIM can add to solve these problems

3.1 Research Strategy

As mentioned in chapter 2, qualitative data analysis follows two main approaches, the deductive approach, and the inductive approach. The difference between these two approaches is that the researcher has a theory or predetermined thoughts about the theory before he conducts the research or not.

In this research, the targeted area is Saudi Arabia where the adoption of BIM is not an industry fashion. According to a survey conducted by Sharif (2011) 75% of the construction industry personnel in Gulf region

and Jordan are not BIM adopter, and most of the other 25% are beginner with BIM –they use it only for visualization-. Hence, the amount of studies in literature about the BIM topic and its potentials in the Gulf region seems to be nonexistent. And this prohibit shaping a picture about the effects of adopting BIM in the construction industry.

However, Egan (2002) concluded that it is sufficient to have general understanding about the situation being investigated to initiate qualitative data research. Hence, because of the above mentioned reasons and to add more flexibility to the process of gathering data, the researcher decided to employ inductive qualitative data analysis following the procedure of grounded theory that was discussed in chapter 2 in order to discover more about the design process from the project's engineer's experiences in their daily lives (A. Saleh, 2013 and Mariapolski, 2001) and to assess the existing design process and its main problems from the real design environment of construction projects.

Furthermore, the research utilized this approach in order to answer the question of what BIM can add to enhance the design process and the whole construction industry.

3.2 Research Flow

The research has been started with performing a literature review about the main topics of this research like construction industry challenges, design process and BIM potential benefits. Then, two firms have been

considered as different case studies, the first case is not BIM-adopter firm and the second one is BIM-adopter.

Semi-structured interviews have been conducted with industry practitioners from not BIM-adopter firm in order to deeply understand the design process main stages and its main problems that negatively affect the whole project lifecycle. In addition to identify the perception and thoughts of employees about BIM. It is important to notice that not all the interviewees are employed in the case firm, some of them are consultant engineers that are working in projects executed by the case firm.

The next step came as following up to the results of case 1 because it make more sense to discover the role of BIM in overcoming the design process problems based on real business experience. Hence, data gathering from the second case, which is BIM-adopter, was through a questionnaire distributed to 9 engineers from the case firm technical office in order to further understand the design process and its problems, in addition, to identify if BIM can fix these problems.

Actually the firms in two cases are working in different fields of construction, the first one is in infrastructure projects and the second is in the field of steel structure buildings. However, it makes no difference what is the field of firm’s operation as the research concerns is the design process as flow of work not what is technically done in the process.

The following figure illustrates the research flow a9nd what is each stage about:

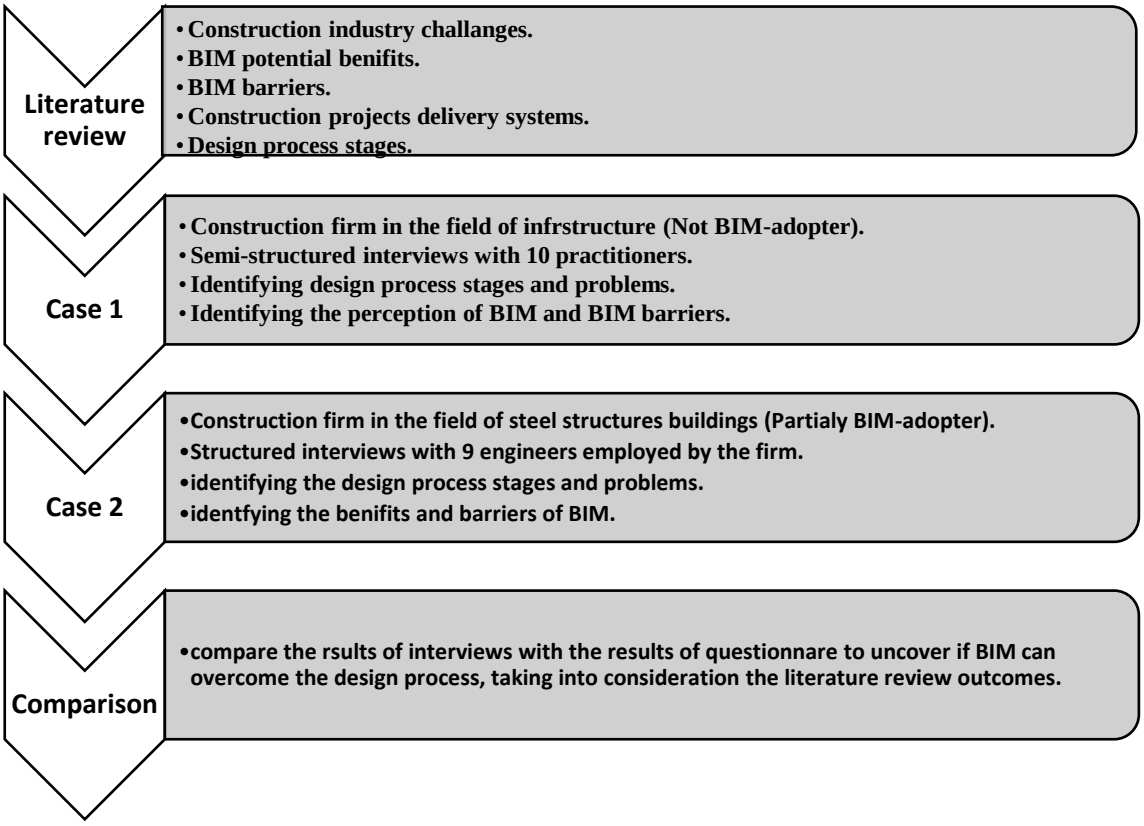

Figure 3.1: Research flow diagram

3.3 Research Tools

In order to gain a valuable results, the gathered data should be sufficient and clear which can be achieved through using the suitable research tool. One of the main goals of this research is to assess the design process and reveal its main problems, and the general situation in KSA is that the construction firms are not BIM-adopter. Hence, Semi-structured interviews were used to collect data in case 1 of this research since it's the case of not BIM-adopter firm. Semi-structured interview is the most used tool in qualitative research, also it gives the researcher more control and

flexibility to pursue the interviewees during the interviews. Moreover, audio recorded semi-structured interviews give a chance for further refine of transcript and gain a high level of details (Saleh, 2013) (D.L. Morgan & Guevara, 2008; Silverman, 2001).

On the other hand, structured interviews were used to collect data in case 2 since it came as a following up case in this research. Cohen and Crabtree (2006) stated that structured interviews best use is after using less structured interviewing methods that provide the researcher with adequate information about the topic. The following subsections explain how each approach was used in this research:

3.3.1 Semi-structured interviews in case 1

The questions of the interviews were open-ended questions in order to give more freedom to the interviewees in their answers and create a chance of acquiring more data (A. Saleh, 2013) and (Kadushin, 1990). The interviews were performed in Arabic language considering that some interviewees are not fluent with English. Then, the interviews transformed from audio recorded into written transcript in English language. These transcripts were used as input data to a computer software to analyze it and extract a meaningful information. The interviewing process has started on 7-Dec-2015 and ended by 22-Nov-2016, each interview took approximately 40 to 50 minutes to be conducted.

3.3.2 Structured interviews

The interviews in this case were paper-based self-administered questionnaires, this type of questionnaires are considered as structured interviews (Cohen and Crabtree, 2006). The questionnaire have been distributed on the engineers of second firm's technical office and they asked to answer the questions within two days. The questionnaires were distributed in 15-Oct-2017 and collected in 17-Oct-2017. Then, the answers of questionnaires were analyzed using the same computer software that is used in case 1.

Mckenson and Wille (1999) highlighted that computer systems allows the researcher to deal with huge amount of data and provides better coding techniques. Hence, the QDA Miner software was used in analyzing data as per grounded theory method. According to PROVALIS research website, QDA Miner software is a qualitative data analysis tool for coding, annotating, retrieving and analyzing documents and images that can be used to analyze different types of data like interviews, transcripts, speeches, journal articles and any type of text data. In addition, it allows for analyzing photographs, paintings and drawings.

3.4 Development of the Interview and Questionnaire

The interview questions in both cases were designed to collect the required data to answer the research questions. The following subsections clarify each interview's development process:

3.4.1 Development of case 1 interview's questions

There were two different forms of interview's questions (Refer to appendix 1 &2). The first one was used with engineers from the firm's technical office and the other was used with consultant engineers that are working in the same projects of the case 1 firm in order to gain data from different point of views. However, both two forms questions have the same goals.

Each interview contains 13-17 questions divided into 5 sections. The first section aimed to gather personal data about the interviewees, the interviewee name, position, years of experience, and contact information.

The second section contains introductory questions in order to identify the stages of design process which is answering the first research question, and its main problems to answer the second research question. Also there was a question about the technology tools that are used in design process, and the last question was about the current usage of BIM tools in the design process to assess the engineer's familiarity with BIM applications.

In order to gather more focused data, the interview's questions had considered the main industry challenges that was discussed in chapter 2. The fragmented nature and insufficient information, ineffective communication and coordination are the main difficulties that face the

industry practitioner. Therefore, the third and fourth sections concentrate on the documentation and communication problems.

The third section was to gather data about the documentation method of produced design and the problem that faces the practitioners in the current method of documentation. Moreover, this section aimed to determine the role of BIM to overcome the documentation problems from the interviewee point of view.

The fourth section was about the communication tools that are used by the project parties and the difficulties of communication process if it is exist. Furthermore, this section investigates the role of other engineering sections like Electrical and Mechanical Engineering in the design process to investigate about the coordination process.

The fifth part of interviews came to investigate more about BIM and its potentials. It aimed to define the proper use of BIM to enhance the design process and at what stage of the design process it is better to adopt BIM. In addition, this section gathered the interviewee's suggestions to improve the design process and their perception of BIM as a tool of design.

However, though the case firm is not BIM-adopter, the questions related to BIM were developed to gather data in case the respondent is familiar with BIM from his own previous experience. Besides that, the researcher added questions in some interviews through the discussion with interviewees or as a response to the interviewee's answers.

3.4.2 Development of the case 2 questionnaire

The questionnaire consisted of two parts (Refer to appendix 4), the first one was to gather personal data about the respondent like name, position and years of experience. Where, the second part contained five questions, the first question asked about the problems that the designer faces during the process of design, , and the second one was about the stages of design process followed by the case firm, so these two questions were to further investigate about the results of case 1. While the third question was about the technology tools that are adopted by the case firm, and the fourth question was about the benefits of using these tools against the traditional tools of design, so these two questions aimed to reveal what BIM can do to overcome the design problems. The last question was about the barriers of using such tools in the whole process of design and construction as the case firm is partial BIM-adopter.

It is important to notice that the questionnaire came more focused than the semi-structured interview for many reasons. First, the questionnaire was after the semi-structured interview, so it focused on the main research objectives which are design stages, design problems and role of BIM in enhancing the design process. Second, questionnaires should not be too long because long questionnaires are completed with less accuracy by the respondents (Adam and Cox, 2008). As a result the questionnaire did not asked about the communication and documentation topics, besides

that, the firm does not use BIM to communicate its designs, it uses the traditional 2D drawings.

3.5 Research Sample

3.5.1 Case one sample

Burnand and Gill (2008) clarified that qualitative data analysis requires intensive resources and time consuming. However, in this approach unlike the quantitative methods there is no equations to determine the required sample size. Egan (2002) mentioned that "*Data collection is not time discrete but is woven with data analysis until the researcher has determined a point of saturation*". Furthermore, (Dey, 1999) stated that the researcher should stop sampling when theoretical saturation achieved. Saturation occurs when the researcher cannot view new information (Simon, 2011).

Therefore, the researcher started sampling with no previous idea about the number of required interviews to reach the point of saturation. The process of data collection progressed with data analysis interview by interview. In other word, the researcher conducted the next interview after finishing the previous one coding. The point of saturation was achieved after conducting 10 interviews, out of them 7 were with contractor's employees, and the other with consultant engineers from different firms. The following table illustrates the interviewee's profiles:

Table 3.1: Case 1 interviewee's profiles

Serial	Interviewee Name	Position	Years of Experience	Employer
1	Hussen Mahmoud	Designer	6	Al-Rwabet
2	Amro Saleem	Draftsman	8	Al-Rwabet
3	Abdulmen'm Jamal	Project Manager	15	Al-Rwabet
4	Abdullatef Adam	Consultant Engineer	8	SATIC
5	Mostfa Othman	Designer	6 as designer, 5 as site engineer	Al-Rwabet
6	Ahmed Dahi	Project Manager	13	Al-Rwabet
7	Malek Alasyote	Designer	4	Al-Rwabet
8	Nour Al-din Ata	Designer	3 as site engineer	Al-Rwabet
9	Ala Bakkar	Consultant Engineer	7	Saudi Tech
10	Mohammed Abu Hashem	Former consultant, Designer	7	Bayt Alkhebra

3.5.2 Case two sample

As mentioned before, the used approach in this case was distributing questionnaire as a type of structured interview. The case firm technical office contains 13 detailing engineers and 5 design engineers, the respondents were 7 detailing engineers out of 13 and the designers were 3 out of 5, so the respondent's percent were 54% and 60% in arrow. The following table explains the respondent's profiles:

Table 3.2: Case 2 respondent's profiles

Serial	Interviewee Name	Position	Years of Experience	Employer
1	Ezat Abu-Farha	Manager	10	IBSF
2	Omnyia Yassin	Design Engineer	6	IBSF
3	Samar Bishawi	Design Engineer	6	IBSF
4	Riham Abu-Shmais	Design-Detailing Engineer	6	IBSF
5	Sama Sha’ar	Detailing Engineer	5	IBSF
6	Ramz Bustami	Detailing Engineer	4	IBSF
7	Amal Alsafadi	Detailing Engineer	2	IBSF
8	Lubna Waleed	Detailing Engineer	2	IBSF
9	Safaa Suliman	Detailing Engineer	2	IBSF

3.6 Data Analysis Procedure

The data analysis has started after conducting the first interview according to the process that was stated in section 2.4.4 starting with open coding of data, then finding relations between codes as axial coding, and finally select the core category as selective coding.

Though, the procedure of grounded theory explains that defining the core category is the third stage in analysis. K. Punch (2009) mentioned that “*potential core categories are noted right from the start of the analysis, though final decision about the core category should not be made too early*”.

The following example explains how the researcher has adopted the grounded theory method in analyzing the gathered data through the interviews and questionnaires.

Consider the question No1 in the second section of contractor's employee's form of case 1 interviews. The question was:

Do you think that the design process has any problems? If yes, what are the main problems that you are facing during the process?

The respondent answers were as follows:

Interviewee No 1

> *Yes, we face many problems during the design which occurs due to poor planning from the beginning of the project. For example, our designs depends on data that have been gathered from site by surveying tools. In many cases this data may be fault. Then, the error discovered at the late stages of the design in such time doing modifications will be disastrous.*

Interviewee No 2

> *Yes, the main problem that the work does not organized well. I have to deal with each engineer or surveyor separately. In some cases there are a lot of jobs that I should finished immediately. This make me confused and affect my productivity.*

Interviewee No 3

> *Yes, one of the most important problems is that the designers almost do not have executive experience. Therefore, they may ignore some executive limitations when they put the design criteria. As a result of this, the contractor has to make modifications on these designs to*

consider such limitations. Moreover, as in case of municipality projects, the executives work in site started before the designs completely finished. As a result, doing modifications become harder with the project progress in site.

Interviewee No 5

Yes. I think the process of design approval after modification of the design is very time consuming. The designer should make the suggested modification then send it to the consultant. The consultant may approve the design and then send it to the client to review it or he may suggest another modification. This process is not integrated and very time consuming.

Interviewee No 6

Yes. We face a problem with the technical office. The shop drawings of structural elements which produced by the designers may cause a large quantity of wasted steel. The designer should consider the length of bar in a manner that reduce the wasted steel to the minimum.

Interviewee No 7

Yes, we face many problems during the design phases. For example, most of ministry of transportation projects the designs are produced by a design office hired by the ministry. When the contractor and consultant of the project defined they will make modifications. This process consume time and effort. Also, in some cases the surveyor that collect data from site may be unprofessional I think there is a problem with the employee recruiting.

Interviewee No 8

> *Yes. The main problem here is the repeated work that comes as a result of lack of coordination between project parties. In such cases, the client and the consultant may suggest different solutions to solve a problem or perform action. Especially in preparing shop drawing, you work for days on preparing it according to consultant instructions, then before the approval, the client may suggest different instructions, as a result you have to repeat the work. Moreover, preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office, here we deal with more than one project and every project engineer want his job done in short time even he asks for it. This puts you under continuous pressure and causes lack of concentration to designer.*

The analysis was started with open coding, all sentences underlined with red color are coded as "**Design Problems**". Likewise, sentences underlined with green coded as "**Causes**" and the Pink-underlined considered as "**Effects**".

The next step was axial coding, at this stage the researcher was trying to find connections between the open-coded data. Let's take a look on data of the code "Design problems":

1. *Error discovered at the late stages of the design.*
2. *The work does not organized well.*
3. *The designers almost do not have executive experience.*

4. *The executives work in site started before the designs completely finished.*

5. *The process of design approval after modification of the design is very time consuming.*

6. *We face a problem with the technical office. The shop drawings of structural elements which produced by the designers may cause a large quantity of wasted steel.*

7. *Most of ministry of transportation projects the designs are produced by a design office hired by the ministry. When the contractor and consultant of the project defined they will make modifications.*

8. *The surveyor that collect data from site may be unprofessional.*

9. *The repeated work.*

10. *Preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office.*

It is clear that there is a relation among some of these problems. Some are related to technical issues such as problem No 6 and problem No 8, and the others related to managerial and organizational issues. Therefore, the code “Design problems” can be recoded as “Managerial design problems” and “Technical design problems”. However, it is possible to code the same problem in both new codes, for example, sentence No 8 can

be coded in both codes. It can be technical if the high risk of collecting fault data is considered. On the other hand, it is coded as managerial if the problem seen as problem in recruiting the right people or as problem in training of employees.

The same happened with the code “effects”

1. *This make me confused and affect my productivity.*
2. *Very time consuming.*
3. *This process consume time and effort.*
4. *This put you under continuous pressure and cause lack of concentration to designer.*

By taking a look into these effects, it is noted that a connection can be identified among them. Some affect the employees themselves like making the employee confused, and the other affect the work such as consuming time and effort. Therefore, the code “effects” can be divided into two codes “Effect on personnel” and “Direct effect on the work”.

The third step in coding process is selective coding, at this stage the researcher should concentrate on the core category by further scanning and skimming of data. For this example, the code “Causes” was produced by open coding contains:

1. *Occurs due to poor planning from the beginning of the project.*

2. *In many cases this data may be fault.*

3. *Lack of coordination between project parties.*

The above are reasons for problems arising in design process. However, the first one claims that poor planning from the beginning of project is a cause for arising problems and that is true, considering another point of view, poor planning can be considered as managerial problem. Therefore, this sentence was recoded with "Managerial design problems" as selective coding process. Likewise, the other two causes, the second one was recoded with "Technical design problems" and the third was recoded with "Managerial design problems".

The researcher emphasizes that it is possible to find data that should be coded in a category that isn't related to the question's goal. On other words, if question No 1 in the interview aims to gather data about design problems, it is not obligatory to code only from this question's answers only. For example, the thick-red underlined sentence "*shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office*" was coded as "Managerial design problem" and as "Suggestion to enhance the design process" though gathering suggestions to enhance the design process was the aim of the last section of the interview.

3.7 Summary

The methodology chapter introduced a detailed information about the methodology of acquiring and analyzing the data. The first section of the chapter explained why qualitative data analysis and the grounded theory was chosen as a research strategy. The second section clarified the research flow as steps. While the third section discussed the research tools and the data gathering process. Where the fourth section illustrated how the interview and questionnaire's questions were developed. And the research sample section discussed the process of sampling and the sample size of both cases of the research. And the last section explained the research procedure of analyzing data by providing a detailed example.

Chapter Four

Data Analysis

4.1 Introduction

After discussing the methodology of data collecting and data analysis in the previous chapter, this chapter will explain in details the findings from the conducted interviews and questionnaires. These findings should asses the current conditions of design process in construction projects in Saudi region and reveal the role of BIM in this process enhancement.

At the beginning of the analysis it is important to present the coding process as per discussed in chapter 2, the process starts with open coding such that the researcher puts labels on the text. Then, finding relations among these labels as axial coding. And finally revealing the core category in the process of selective coding. However, Glaser (1992) mentioned that "*literature can be used as data and constantly compared with the emerging categories to be integrated in the theory*".

4.2 Design Process

The assessment of design process that is currently used in Saudi region concludes assessment of the stages of design process in order to shape understandable conception for the process. In addition, the assessment identifies the main problems of the design process that affect the process itself and the whole lifecycle of the facility.

4.2.1 Design Stages

4.2.1.1 Case 1 design stages

The first step in data analysis of case 1 interviews is to identify the design process of roads projects and the stages that the design being developed through it. From the interviews answers, it has been noted that the road design passes through two main stages. The first one is called "Tendering design" at this stage the client hired a design office to transform the project from idea into a real design. The second stage is "Design modification stage", this stage occurs after identifying the contractor that will execute the project. The following subsections will explain each stage in details as per respondent answers

Tendering Design

As mentioned above, this stage comes first to transform the project from idea into a real design such that the client hired an external design office to perform the design activities and produce the project drawings that would be part of tender documents.

The interviewees stated that this process consists of five stages as follow:

1- Topography study: At this stage the designer study the region's topography such that many road paths are generated as design alternatives to choose the proper one among them.

2- Identifying the proposed road path: this stage comes as a result of the previous stage after studying all design alternatives and the proper road path is chosen. Demographical and economical factors are considered in the process of identifying the road path.

3- Surveying data collection: the surveyors of the design office start collecting surveying data along the chosen path, the coordinates and level of centerline are collected. Also, every obstacle in the way of road like buildings, electric poles and civilian's lands should be surveyed.

4- Geometric design of the road: based on the collected surveying data, the designer starts to design the road geometrically such that the horizontal alignment and the profile of road are designed. At this stage the coordination with other engineers like electrical and mechanical is very important in terms of removing the obstacles and design the electrical and mechanical elements if it exist. Further, all the structural elements like retaining walls, bridges and culverts should be designed at this stage.

5- Final delivery of drawings: the designer submits his designs from the previous stage to the client as drawings to be a part of tender's documents.

The following table shows some of interviewee's descriptions for this stage:

Table 4.1: "Tendering Design" stage in Case1

Design Stages			
Interviewee's No	**Quote**	**Open coding**	**Axial Coding**
6	Studying the topography of the region. After determining the road path a surveying data need to be collected. Starts the design process where the roads geometry is designed and any needed structural elements also is designed in this process. Structural element like culverts, bridges, retaining walls. The final design transformed into drawings which is included in the bid documents.	1- Topography study of the region. 2- Evaluate Alternatives. 3- Surveying data collection. 4- Geometric design and structural elements design 5- Design approval and shop drawings delivery.	Tendering Design
7	Topography study for the region of the two point that will be connected. Propose road path alternatives. The suitable alternative chosen based on economical, demographical, topographical criteria. Collecting surveying data from the site. All obstacles, electric poles, manholes, houses that the path passed through it or beside it should be surveyed. Start the design process itself based on AASHTO specifications or any other specifications defined by the client or consultant. This stage also includes the design of any needed structural elements, like bridges, retaining walls and culverts. If the designs performed by external design office the design approvals done with the client -–ministry of transportation- while if it performed by the contractor the designs approved by the consultant. Preparing of the final drawings.	1- Topography study of the region. 2- Evaluate Alternatives. 3- Surveying data collection. 4- Geometric design and structural elements design 5- Design approval and shop drawings delivery.	Tendering Design

Design Modification Stage

After performing the tendering process (Bidding) in order to select the contractor, the construction stage would start. Thus, the design modification stage occurs at construction stage where the execution of the project has to be start, this process has been discussed by respondent as follow:

1- Surveying data collection: the contractor's surveyors repeats the collecting of surveying data as in stage 2 of tendering design such that the coordinates and level of the centerline are gathered, in addition, every obstacle in the right of way of the road should be collected.

2- Geometric design: based on the new surveying data, the contractor's designer repeats the geometric design of the road. Further, the contractor may suggests changes on the designs from tendering stage according to many factors that will be clarified later.

3- Final delivery of drawings: all the designs that produced from the previous stage should be approved by the consultant in order to be constructed in site. However, there would be many revisions for the same design before the approval of the consultant.

The following table explains some of the interviewee's descriptions of this stage:

Table 4.2: "Design Modification" stages on case 1

Design Stages			
Interviewee's No	**Quote**	**Open coding**	**Axial Coding**
5	However, in most cases when the contractor is identified. The contractor team repeat the surveying data collection process. If any obstacles or mistakes are discovered, the contractor design team perform the required modifications with the coordination of the consultant. For example, if the contractor discovered that the road path crosses a land owned by a citizen, the contractor may suggest to transfer the road centreline to avoid problems with this citizen because the procedure of transfer the ownership of such land from a citizen to the government takes a very long time.	1- Surveying data collection 2- Design modification	Design Modification Process
8	… Most of our works is to modify the designs that comes with tender documents. The surveyors start with checking the centreline coordinates in project site, in most cases they found difference between the designs and reality, here our job starts. We took the new surveying data and modify the designs according to it, we may add retaining wall or culvert or shift the centreline of the road and then change the road geometric design.	1- surveying data collection2- Design modification	Design Modification Process

In the light of the previous descriptions, it can be concluded that the current process of road design passes through two stages. The first stage called “Tendering Design” comes before the bidding process such that the owner hires a design office to do the job and the final drawings considered as tendering documents. The second stage called “Modification stage” begins after bidding process, which identifies the contractor and consultant, such that the contractor modifies the tendering design simultaneously with the start of construction activities. Figure 5 provides a summarized representation for the stages of design

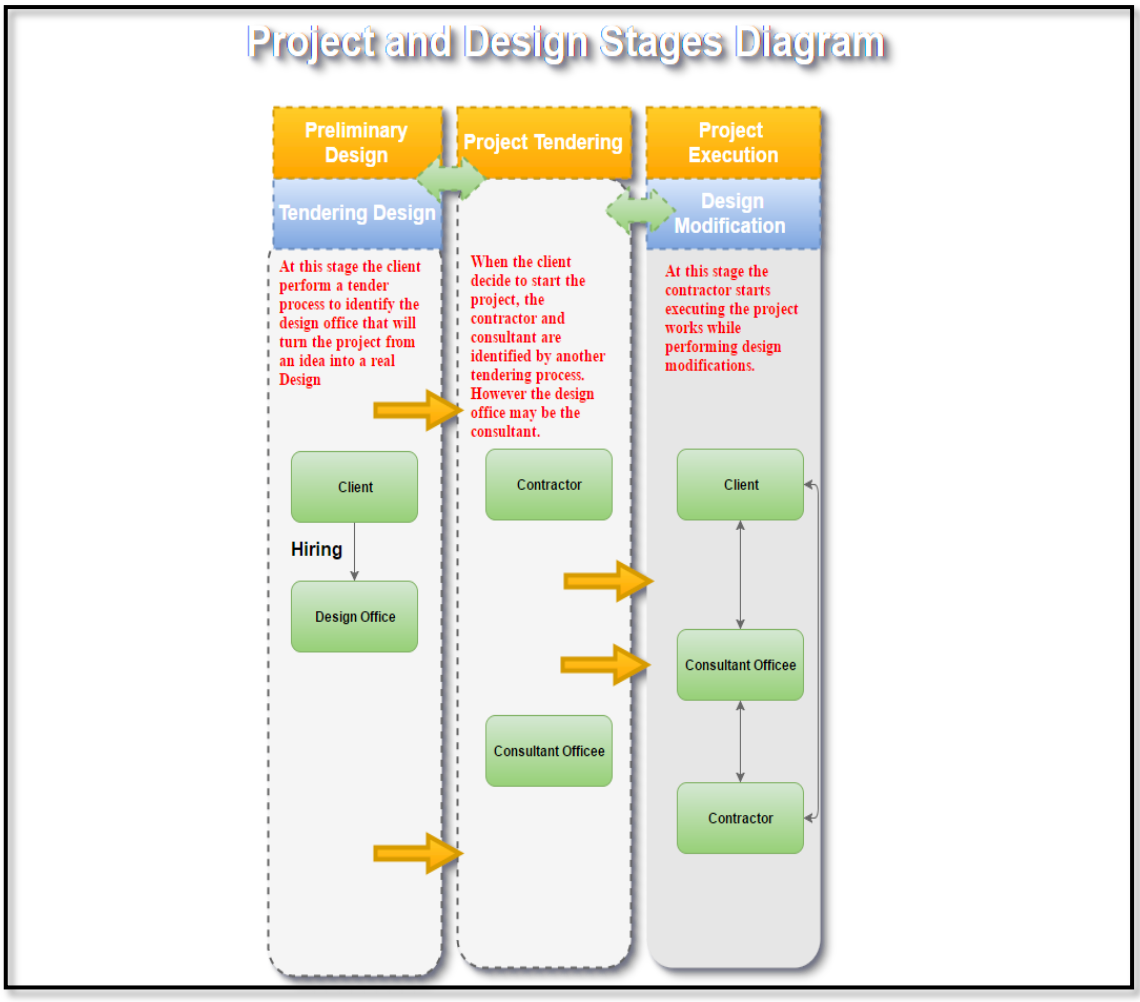

Figure 4.1: Design Stages Diagram

4.2.1.2 Case 2 design stages

In case 2 firm the respondents explained the stages of design as the following points explain, also figure 4.2 illustrates the process.

1- **Get information from the client**: The process starts with this stage such that the client announce his project to the public seeking a firm to construct his project. It is sales engineer responsibility to get this information about the project and transform it into a written description. This information includes the area of the building, function of the building, material, dimensions of the building and 2D architectural drawing for the location of the project (site plan).

2- **Preliminary Design**: After the sales engineer got the information, the firm's designer job is to take these information and transform it into a real preliminary design using MBS (Metal Building Structure).

3- **Bidding Stage**: at this stage the client chooses one proposal among the competing firm's proposals considering many aspects that are defined by him.

4- **Final Design**: once the IBSF proposal has been chosen, the designer should finalize his design with more accuracy in calculations.

5- **3D Model:** using Tekla Structures software, the detailing engineer creates a 3D model for the building according to the designer sketches.

6- **Preparing of Approval Drawings:** after the creation and check of the 3D model, the detailing engineer directly generates 2D drawings from the 3D model.

7- **Preparing of Shop Drawings:** once the client has approved the Approval Drawings, the detailing engineer can directly generate the Shop Drawings from the 3D model.

8- **Preparing of Construction Drawings:** once the fabrication process has finished, the construction stage should starts according to the Construction Drawings which are generated directly from the 3D model also.

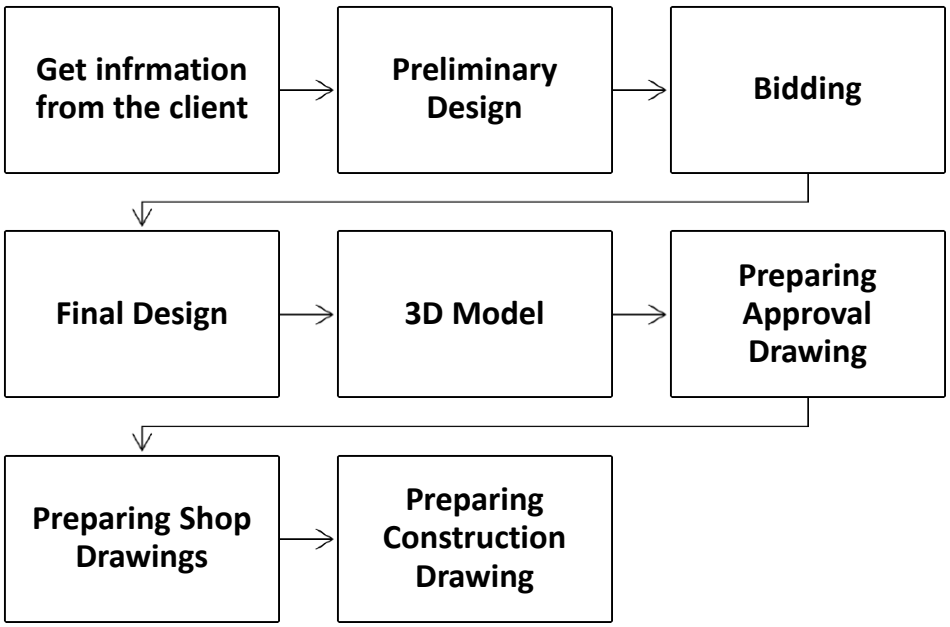

Figure 4.2: Stages of design in case 2

Table 4.3: Design stages in case 2

Case	Quote	Code
Ramz Bustami	Company takes information from the customer in order to give a suggested design properties	Get information
Riham Abu-Shmais	Preliminary design according to the client architectural drawings using MBS or STAAD in order to estimate the bulk weight of the building, section's profiles and column's dimensions	Preliminary design
Ezat Abu-Farha	……Then after bidding stage,……	Bidding
Riham Abu-Shmais	After the bidding stage and signing contract a detailed precise design is done according to the preliminary design.	Final Design (Precise Design)
Safaa Suliman	The design is approved and the detailing stage starts to 3D model the project to export all the needed drawings to construct it.	Detailing Process
Riham Abu-Shmais	After the approval of approval drawings, shop drawings are prepared in order to use it the fabrication process. Then construction drawing are prepared to use it in site.	Preparing of Drawings

4.2.2 Main Design Problems

The next step of this research is to discover the main problems of the design process in both cases of this research in order to answer the second research question. The following subsections explain the design problems in case 1 and case 2.

4.2.2.1 Design problems in case 1

According to the interviews results, the design problems can be considered in two aspects. The first one related to managerial issues and the second one related to technical issues, the analysis revealed that most of problems in the current design process are related to managerial issues.

Managerial Issues

Managerial issues are related to problems in the process of design itself. The interviews results reveal that there are problems in the process as the following:

1- Poor planning and organizing of the process: the interviewees stated that the process is not planned from the beginning such that the work is done randomly and in some cases the execution in site begins before finishing the design.

2- Unavailability of time schedule: the analysis shows that the process of design is performed without a time schedule to organize the work.

3- Problems in coordination: the interviewees uncovered that in some cases some elements are modified without considering other elements that related to this one, and this causes inconsistency and clashes in design.

4- Repeated work: the interviewees stated that they suffer from the repeated work due to incoordination between project parties which make the process of design very time consuming.

5- Time consuming: the process of design approval by the consultant is time consuming due to the way of communicating designs with him. The designer finish his work and send it to the consultant for approval, then the designer should wait for the consultant comments to modify the design and so on, and in some times the client has his own comments that may differ from the consultant comments which make the designer confused and wastes more time in doing modifications.

6- Undefined communication: the communication tools should be defined in contract documents in order to avoid conflict during construction. Moreover, defining the communication tools will define which one can be considered as formal documentation. For example, if email is considered as formal communication tool, each project party would be responsible on anything he communicated using this tool like drawing, schedules, quantities..etc.

7- Human resources activities: the analysis stated that there is problems in hiring qualified people and performing training programs to develop the employees in design aspects and using developed software in design.

Technical Issues

Technical issues are problems in the inputs of the design process like surveying data and people who perform the design. The following explains these problems:

1- Fault data: the interviewees stated that in some cases the surveying data that collected from the site is not precise and this may causes very costly loses if it discovered lately in construction activities..

2- Lack of experience of designers in execution aspect: like in case of designing the retaining walls, if the designer does not has an enough executive experience he will not consider the length of reinforcement bar in a manner that minimize the wasted material.

Actually, both problems can be related to the problem of inexperienced employees and designers in field operations and in design itself, and this make the technical errors occurrence high.

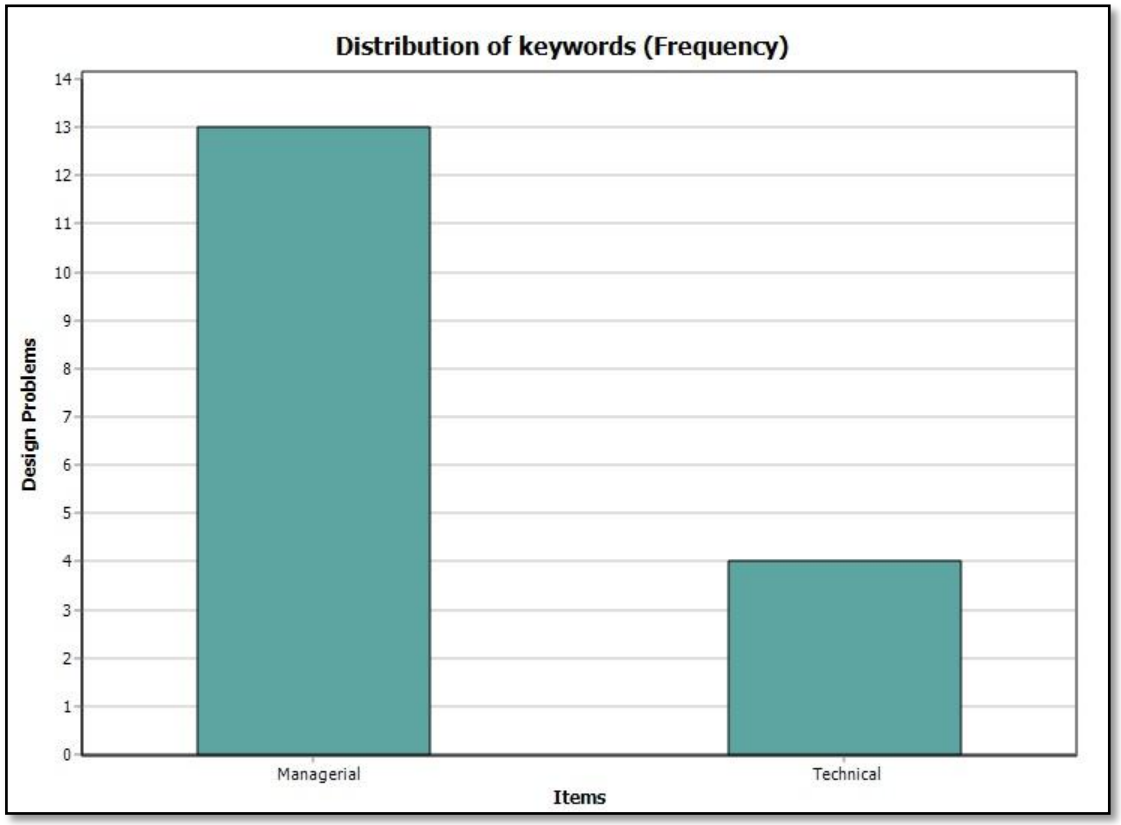

Figure 4.3: Design problems coding frequency

Table 4.4: Main design problems in case 1

Design Problems			
Interviewee No	**Quote**	**Open coding**	**Axial Coding**
1	For example, our designs depends on data that have been gathered from site by surveying tools. In many cases this data may be fault. Then, the error discovered at the late stages of the design in such time doing modifications will be disastrous.	fault data	Technical design problem, cause
7	In some cases the surveyor that collect data from site may be unprofessional	lack of experience	Technical design problem
1	poor planning from the beginning of the project	Poor planning	Managerial design problem
8	Moreover, preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office,	availability of time schedule	Managerial design problem
10	if the process of communication organized well and identified clearly in contract, the conflict can be avoided	Undefined communication	Managerial design problem
8	Yes. The main problem here is the repeated work that comes as a result of lack of coordination between project parties.	Repeated work, Uncoordinated work	Managerial design problem

4.2.2.2 Design problems in case 2

The respondent's answers revealed that the process of design in case 2 firm does not flow smoothly such that a lot of problems, limitations and design changes control the flow of the process. According to the respondent answers, the most frequent problems they face are:

1- **Change orders**: the respondents clarified many reasons that could lead to change the design by the customer like changing the project's vision and inadequate information from the customer about his idea. However, regardless the reasons of change orders, approximately all the respondent assures that too many changes orders occur during the design which cause confusion for the designer and too many repeated work especially if it comes at late stage of design process.

2- **Inadequate information and Mistakes in building description**: another problem that faces the designers is that at early stages of the design the designer has not a clear idea about the project as a result of inadequate information provided by the customer, also the project description, which is essential for the designer, is written by the sales engineer who could not get the customer idea well. Hence, the produced design may not fulfil the customer needs leading to increase the rate of changes order.

3- **Weak communication with customer**: the produced designs need to be approved by the client or his representative, therefore a

communication should occur between the designer and the client. Meanwhile, this communication has been described as a slow process which in turns causes delay in design approval.

4- **Market Conditions:** the respondents stated that in some cases the design alternatives could be limited due to unavailability of material in market, or due to material shipment constraints, for example, the designers are not allowed to use member with a length exceeds 12 meter because such members cannot be shipped to the project site.

5- **Time limitations**: the time of finishing the project is one of the contractual issues that controlled by the contract with the customer, the respondents clarified that in some cases they find the time illogical such that the designs are accomplished with rashness which leads to increase mistakes in design.

6- **Coordination of drawings**: this issue does not take the respondent attention except the manager of the technical office, he assured the importance of coordinating different engineering parties work like (Civil, MEP, Arch), else a lot of revisions and modifications could occurred during the design process and that will increase the cost and decrease the quality of design.

The following table shows some of the respondent’s answers:

Table 4.5: Design problems in case 2

Case	Quote	Code
Lubna Waleed	Change orders by the client which could be after finishing the design or at late stage of design	Change Orders
Ramz Bustami, Omnyia Yassin	"unclear data received from the customer or inadequate given information" "mistakes could occur due to mistakes in the building description"	Inadequate Information, Mistakes in description
Riham Abu-Shmais	The communication between the designer and the customer is a slow process	Weak communication
Sama Shaar	Substitution of material due to lack in market	Market conditions
Omnyia Yassin	some mistakes in design occur due to time limitations	Time limitations
Ezat Abu-Farha	….is the coordination between all parties (Arch, Civil, & MEP)……	Coordination of drawings

4.2.3 Suggestions to enhance the design process

In the view of design problems section, this section will detect the respondent's in case 1 point of view to make the design process much better, the data gathered from case 1 only because the questionnaire in case 2 has to be short. The responses of the interviewees have been found related to managerial and technical enhancement. Since the managerial issues were the most concerned by the respondent, the suggestions also were focused on managerial enhancement of the process. Figure 4.4 illustrates the frequency of each category in the interviewee's responses.

Technical Enhancement

This issue was discussed by interviewees in order to overcome the technical design problems and they suggested the following:

1- Experience in site operations: interviewee 3 stated that the designer must have experience in execution the work in site before he works as designer.

2- The designer should visit the site of construction: interviewee 8 mentioned that it is better for the designer to visit the site at construction stage in order to avoid deign errors.

Managerial Enhancement

This issue was the focus of the respondent in their answers to overcome the managerial problems of the design process and they suggested the following:

1- Organizing the work: the work of design should be organized in a manner that prevent the distraction of designer. This can be achieved through setting a time schedule to organize the technical office work, also a supervisor should organize the work of each engineer.

2- Enhance the communication: the interviewees suggested that the process of design modification should be more integrated to save time, and this can be achieved by enhancing the communication between the project parties during the design approvals.

3- Training of designers: the firm should perform training programs in order to develop the firm's designer abilities to use modern softwares.

4- Coordination of designs: the produced designs should be reviewed before sending it for construction in order to avoid costly errors especially the structural and MEP designs.

Table 4.6 clarifies some of the interviewee's answers.

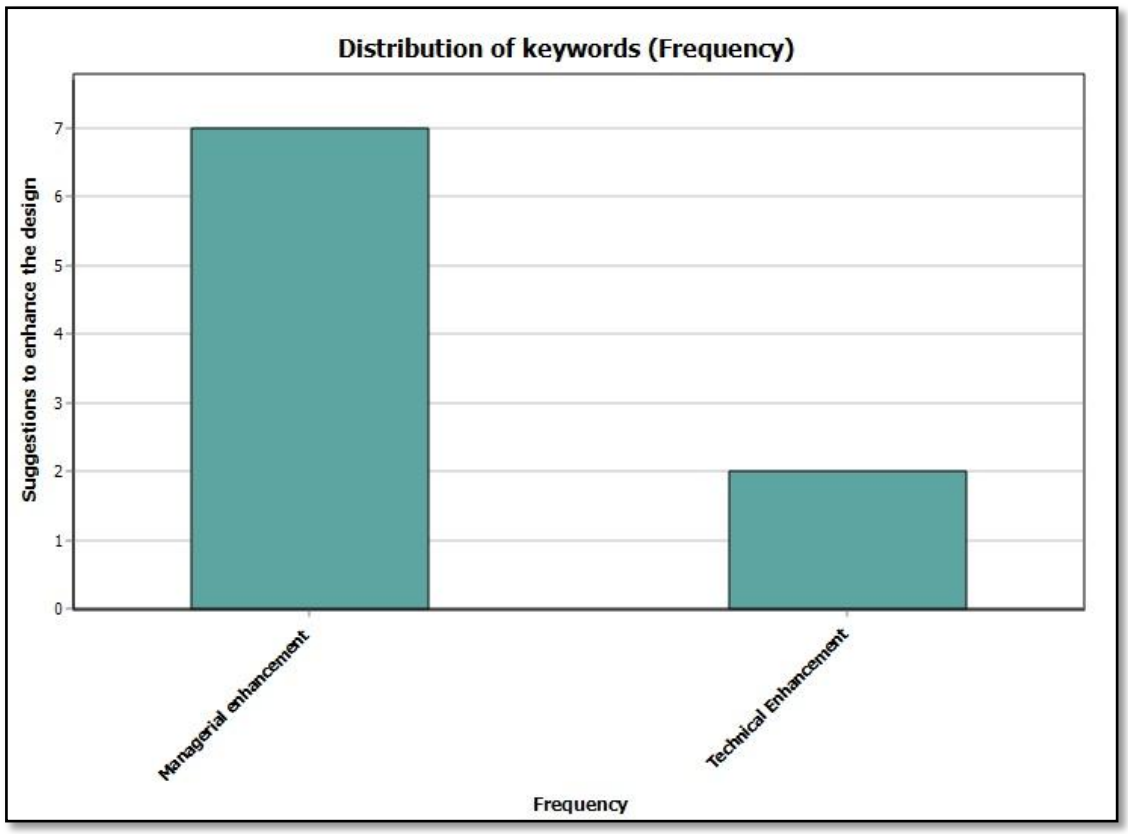

Figure 4.4: Suggestions to enhance the design process

Table 4.6: Suggestions to enhance the deign

Suggestions to enhance the design			
Interviewee No	**Quote**	**Open coding**	**Axial Coding**
3	Yes. I think that designer should has executive experience at least 5 years before he performs any design.	Technical experience	Technical Enhancement
8	I think that the design engineer should visit the site from time to time, this will give him a better imagination about the work and enhance the sense for discovering design errors.	Design office in site	Technical Enhancement
1	I prefer to reorganize the design approval process by making the designer directly communicate the consultant engineer to avoid the misunderstanding of the designer point of view.	Enhance the communication	Managerial Enhancement
6	Yes. I think that our company is responsible on training for the technical office engineers	Training the designers	Managerial Enhancement

4.3 Documentation

As discussed before, this research will focus on the documentation process because it is one of the main challenges of the industry. Therefore, the interview asked questions about the documentation method that is used

by the interviewee and the problems of it. However, all data about the documentation issue was gathered only from the interviews.

4.3.1 Documentation method

Documentation method is the way that is used by the designers to save their produced designs in a way that it will be easy to find it again. The analysis of respondent's answers reveals that most of the interviewees used to document their designs personally. Figure 4.5 illustrates that 8 respondent out of 10 use personal method, where only 1 use a systematic method defined by their firm, and the last interviewee uses his own method to document the soft copies of designs and the firm systematic method to document the hardcopies of design.

1- Systematic methods of documentation means that the designer uses a method defined by his firm-as policy- to document his designs. Interviewees 9 and 10 stated that in their firms, there is a specialized position called "Document controller" his job is to document all the design's submittals, meeting records and memos.

2- Personal method means that the designer documents his designs by his own method. All interviewees except 10 use this method of documentation with a little differences among them such that the designer save softcopy from the design in his own Pc with a specified name, and keep a hardcopy in a file, refer to table 4.7.

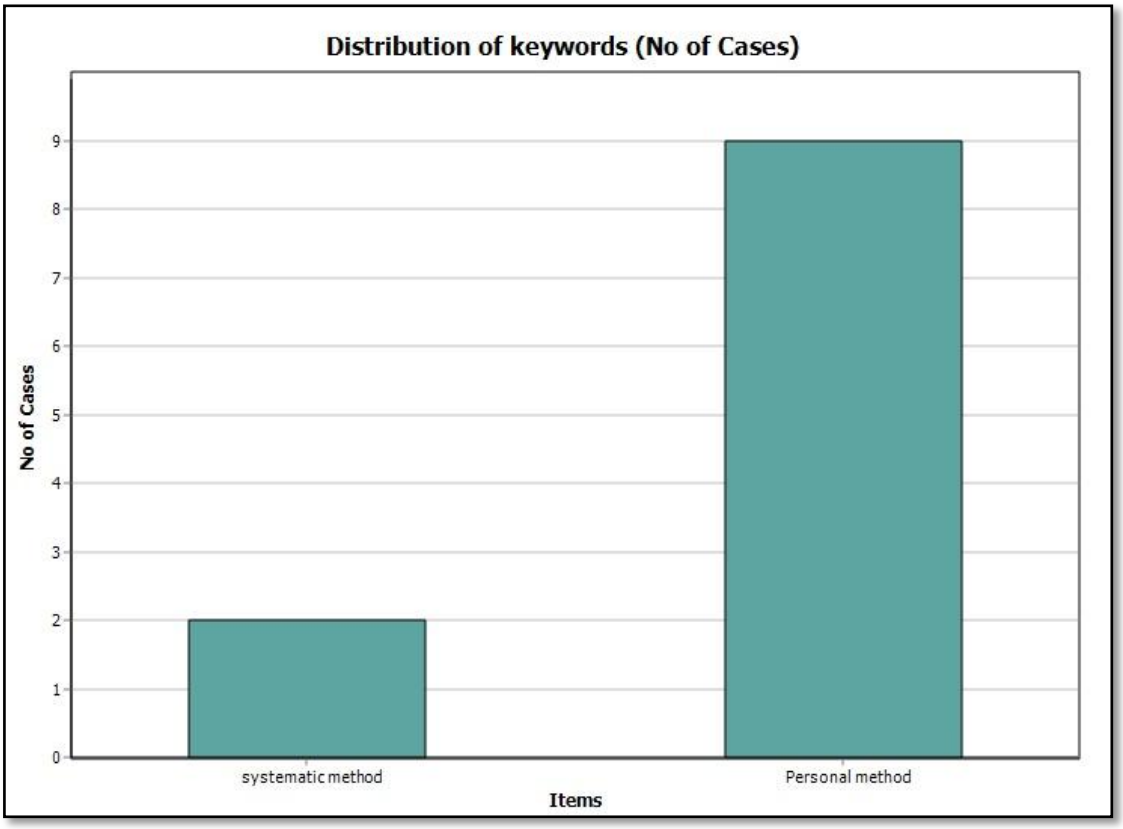

Figure 4.5: Documentation methods

Table 4.7: Documentation method

Documentation Method			
Interviewee No	**Quote**	**Open coding**	**Axial Coding**
10	Each drawings out from the design office to the consultant office has a unique code with an indication to the number of times that this drawing has been submitted for approval.	Coding system, Revisions	systematic method
9	Our office has a document controller position, his job is to organize and document all important documents and memos and drawings	Specialized employee	systematic method
7	The approved designs are saved as soft copy in engineers desktop and as hard copy in the project files.	traditional documentation	Personal method
6	I use a system for documentation by naming the folders on my laptop. Each part in the project has its own folder like (bridges, culverts, retaining walls, time plan ... etc). Also, I keep a hard copy of the approved design only in a special folder. In addition, the technical office has its own copies of designs	naming system, traditional documentation	Personal method

4.3.2 Problems of documentation

The second step in the documentation process assessment is to identify its problems, the analysis revealed the following:

1- The analysis uncovered that 8 interviewees have organizational documentation problems due to unavailability of documentation system in their firms.

2- Five of the interviewees stated that they are satisfied with the current method of documentation.

3- The other five interviewees clarified that they face problems with current documentation method like:

   a- It is hard to get the design again: with passing of time the number of designs increases and finding a specified one become harder.

   b- Existence of obsolete designs: this may happen due to using a personal method that does not contain a system for disposal of unneeded files.

   c- High possibility of losing files: the designs are saved in the designer's pc which make the possibility of losing important files very high in case of pc's breakdown.

   d- Possibility of sharing obsolete designs.

The following table summarizes some of the respondent's answers regarding the documentation problems:

Table 4.8: "Problems of documentation" category interviewee answers

Problems of Documentation			
Interviewee No	**Quote**	**Open coding**	**Axial Coding**
6	No. I think this method is suitable for me.	Find it suitable	No problem
4	No, I do not have problems with this method.	No problem	No problem
7	When the designs becomes so many, it becomes harder to gets it again especially if that happened after long period of time.	hard to get the design again	Facing Problems
1	Existence of several copy of the same design.	unneeded copy of the same design	Facing Problems
9	With soft copies documentation yes, I am always worried about losing my files, I think a recovery server or data base should be available for the purpose of soft copies documentation.	losing files	Facing Problems

4.4 Communication

Also for the communication issue the data was gathered from case 1 only, since case 2 focused on the design process problems and the benefits of BIM.

4.4.1 Communication method

Communication method means the mean that being used among the project parties to communicate each other during the design process or construction of the project. Interviewee 10 stated that the mean of communication should be identified in the term of contract:

> "The authorized method of communication should be identified in the term of contract. Therefore, anything will being sent using an authorized communication method will be considered as approved documentation".

However, the analysis reveals that 8 interviewees out of 10 use face to face meetings as primary mean to communicate with the others. Where the other means like mobile, emails and memos come as secondary means.

4.4.2 Goals of communication

The interviewees explain why they communicate each other. And the answers were as the following, refer to table 4.9:

1- Explain about design details: the communication with others occurs to ask for explanation about some design details.

2- Design approval: the consultant and the designer communicate in order to discuss the designs and approve it.

3- Coordination of work: interviewees stated that they communicate with others to coordinate the works with them.

4- Inform the client about the status of the project: the consultant organize meetings with client to gain his point of view about the project and monitoring the progress of the project.

5- Problem solving: in case of problems occurrence in projects, the project parties communicate each other to solve the problems.

Table 4.9: Goals of communication

Goals of communication			
Interviewee No	**Quote**	**Open coding**	**Axial Coding**
4	The communication occurs with contractor in all stages of design in order to approve the designs and make the needed modifications	Design Approval, Ask for modifications	Goals of Communication
4	In order to let the client know where we are now.	inform the client with updates	Goals of Communication
2	In some cases I have to explain about some details at design drafting phase	Ask for Explanation	Goals of Communication
7	With the consultant I use face to face meetings to discuss the design details and the email to transfer the files	Discuss the design, Transfer the files	Goals of Communication
7	The communication with the client is rare in the design unless there is a special case such as problems with citizens.	Problem solving	Goals of Communication
6	If there is electrical work in the project, an electrical engineer coordinate with site engineer and the project manager about the time of performing the electrical work.	Coordination of work	Goals of Communication
9	Yes, during the execution of the project we should be always in touch with client, every day we have to submit a report of daily progress, also there is a weekly face to face meeting with client the progress of the project and its problems are discussed. and contractor, in this meeting	inform the client with updates, Problem solving, Monitoring project progress	Goals of Communication
10	with client face to face meetings is better because you can gain the other point of view in a better way	Collaborative thinking	Goals of Communication

4.5 BIM Adoption

After analyzing the data of design process assessment, this section will include the data analysis of BIM adoption. The data has been gathered from the interviews and questionnaires was focused on many issues regarding BIM adoption. First, the data uncovers the technology tools being used in design production process in both cases to assess the current level of technology advancement and explains the experience of the interviewees with BIM technology. Second, the data from case 2 investigates the benefits of BIM implementation in design process, though BIM as adopted at detailing stage only. Finally, defining the factors that affect BIM implementation in Saudi region by pointing out what will motivate or prohibit the implementation of BIM.

4.5.1 Technology tools

This section aims to explain about the technology tools that are used by the designers to produce their designs. The results showed that all of the respondent in case 1 are using not-BIM tools in producing their designs, except interviewee 1 that just started learning INFRAWORK. The most used software by the respondents in case 1 were AUTOCAD, CIVIL 3D and MICROSOFT EXCEL.

Meanwhile, the answers of respondents in case 2 stated that they use Tekla Structures, which is a BIM software, at detailing stage after finishing

the design. Also, they use MBS and STAD Pro, which are not BIM software, for doing the Preliminary design and the final design. So, the firm in case two has considered as partially BIM-Adopter.

4.5.2 Experience with BIM

The data explains that no one of the interviewees in case 1 has a real practical experience with BIM. Interviewee 1 is the only one who deals with a BIM software, which is Infrawork, as a self-training. While, all of the respondents in case 2 have experience with Tekla Structures software, so they can be considered as experienced with BIM.

4.5.3 Benefits of BIM

Benefits of BIM is what BIM can do or what makes BIM more efficient in design. Since the respondents in case 2 are experienced with BIM and the interviewees in case 1 are not, the data has been gathered only from the questionnaire answers in case 2.

The respondents have mentioned some of BIM benefits in their answers as follows:

1- **Saving time**: saving time was the most interesting privilege of BIM according to the respondents answers, the time saving in design process can be as a result of different things like easiness of constructing the model, making modifications with no need to repeat too many steps and generating the 2D drawings easily noticing that

one steel building could need a thousand of drawings to be fabricated and erected.

2- **Visualization and clash detection**: the clash detection also was an interesting property of using BIM according to the respondents, the Tekla software can detect any clash in the model; so the detailer can inform the designer about the clash in order to fix it. In addition, the detailer can check the model by his eyes because of building visualizing. As a result the generated drawings for fabrication purposes will not contain costly mistakes.

3- **User friendly**: the respondent's clarified that the software is easy to use in term of learning and dealing with it. Also, the software has tools that make creating 3D models easy and fast process due to availability of ready patterns for a wide range of members and connections.

4- **Improve quality**: the BIM software improves the quality of design process final products, which are the drawings, through getting information about the building from the user to use it in the model to produce more precise and cost effective designs. Moreover, avoiding the clashes from the model improves the quality of generated drawings.

5- **Better coordination**: the Tekla software allows for better coordination through providing the ability to model the all parts of

the building in one model, also the software allows sharing the model with other BIM software.

The following table shows some of respondent's answers:

Table 4.10: Benefits of BIM

Case	Quote	Code
Lubna Waleed Ramz Bustami	…Speed in achieving the required job…. different sections can be used and modelled at any location in short time	Saving time
Safaa Suliman	the ability to see how the project will be constructed in real and	Visualization
Ezat Abu-Farha	you can identify any clash to avoid any problem in construction	Clash detection
Riham Abu-Shmais	This software is not hard to be learned because it user-friendly and anyone can learn how to use it.	User Friendly
Sama Shaar	Precision and control: 3D modelling software collect accurate data to develop a precise model.	Improve quality
Ezat Abu-Farha	I believed that using BIM tools for modelling each type of building and inserting all building items in one model will be very good coordination for all parties	Better coordination

4.5.4 Factors that affect BIM implementation

The aim of this section is to realize the factors that influence the BIM adoption in Saudi firms from the interviewees and respondent's point of view. The data analysis uncovered many factors that related to the firm itself and the whole market of construction in KSA. These factors have

been categorized into two main categories which are motivators and barriers of BIM implementation

4.5.4.1 Motivators

The motivators of BIM are the things that encourage BIM adoption in the firm. This issue has been discussed by interviewees 1, 2, 3, 5 and 7 from case 1and the results were as follows:

1- **Availability of success case**: interviewee 1 stated that availability of real success case in BIM adoption among the construction firm will motivate his firm to move towards BIM.

2- **Role of the government**: the interviewees stated that the government as it is the client in infrastructural projects in Saudi region has a massive role to encourage BIM adoption.

3- **Multi-national competitors**: the nature of KSA market and the existence of multi-national companies will raise the competition and motivates the firms to improve their performance.

4.4.4.2 Barriers

Barriers of BIM are the reasons that will move the firms away from BIM. The results of interviews in case 1 uncovered many barriers for BIM adoption like:

1- **Organizational structure of the firm**: interviewee 1 and 10 stated that the organizational structure of their firm will not support this

change because there is no coordination between functional departments of the firm.

2- **Unavailability of skillful people**: interviewee 3 said that his firm doesn't has skillful and familiar people with BIM and this prohibit the implementation.

3- **Implementation of BIM by one party**: the BIM implementation should be by all project parties to be effective.

4- **Top management role**: interviewee 8 emphasized that top management of the firm should be convinced with efficiency of BIM adoption.

5- **Industry style**: changing the industry style and traditions will make the mission more complicated.

Table 4.11: Barriers of BIM according to case 1

Factors that affect BIM implementation			
Interviewee No	**Quote**	**Open Coding**	**Axial Coding**
3	Because our firm does not have the skilful and experienced people in this technology.	unavailability of skilful people	Barriers
1	Also there is no actual success case of BIM implementation in the market or among the firm competitors.	unavailability of real success case	Barriers
8	In our company the management should be convinced with the efficiency of such technology. Moreover, the other parties should also adopt BIM.	Top management commitment	Barriers

While the respondents answers in case 2 revealed the following:

1- **High cost of implementation**: the main barrier of BIM according to the respondents is the high cost of software licenses, for example, the license for single Pc for one year of Tekla Structure software costs approximately 20000 $ (Twenty Thousand Dollars). While, two of the respondents assured that the saving in money that BIM allows in much larger than the cost of implementation.

2- **Lack of Experience:** another important reason that limits BIM spreading out to the market, is the lack of experience in such technology among the engineers especially the experienced ones. As a result, the firms should train the employees and that can be considered as risky investment.

3- **Cultural issues:** this barrier has mentioned by one respondent, he claimed that in the culture of people in some areas prevent them from paying money to get a license of software.

Table 4.12: Barriers of BIM according to case 2

Case	Quote	Code
Safaa Suliman	The high cost of these software makes it harder to depend on them	High cost
Lubna Waleed	Lack of experience and skills of using these software especially among the experienced engineers	Lack of experience
Ezat Abu-Farha	just the culture of some areas by paying money for getting license version of these tools	Cultural issues

4.6 Summary

This chapter introduced the results of data analysis that has been done using QDA Miner software. The first section was an introduction to data analysis chapter. The second section discussed the current design process stages and its main problems in both cases of reseach, also it derived the interviewee of case 1 suggestion to enhance the process of design.

The third section was about the documentation process and its main problems. Where the fourth section was about the communication process and goals of communication among the project parties.

Further, in the fifth section, BIM adoption has been analyzed in terms of the current technology tools that are used by each firm in design, factors that affect the implementation of BIM and the benefits of BIM from the respondent' perspective.

Chapter Five

Discussion of Results

5.1 Introduction

In the previous chapter, the first step was analyzing the data in order to assess the current conditions of the design process in Saudi region considering two different cases. The first one was not BIM-adopter firm, and this case mainly focuses on the design process stages and problems regarding the communication and documentation processes. The second case was partially BIM-adopter firm that implement BIM in one stage of the design process which is the detailing stage, this case focuses on design process stages and problems in addition to what BIM can add to the design process.

In the view of the above, this chapter will discuss deeply the results of data analysis in view of literature in order to shape the full image of current used design process. Then, BIM will be investigated if it is the proper solution to overcome the problems and weaknesses of the current process to produce more efficient design process considering the challenges and limitations that were mentioned by the interviewees and respondents.

5.2 Discussion of Results

5.2.1 Design Process Stages

5.2.1.1 Case 1 firm

The interviewees in their answers have described two different design processes that occur at two different stages of highway lifecycle. The first one was “Tendering design” which is occurs at early stage of highway development and the other was “Design modification” which is starts during the construction of the road.

Tendering Design

The interviewees said that this stage starts with client “Government”. They mentioned that the client hire a design office to perform the design, but they did not provide any details neither about how the client identify the need for the project nor about how the client has formed the concept and budget of the project. However, the U.S. Department of Transportation stated that the detailed design of highway occurs in the middle of highway development process and acts as link between the predecessor phases of planning and development with the successor phases of construction and maintenance. Moreover, the Queensland government explains two stages comes before the design development stage in building of a road and these stages may take several years to be finished depending on the project scale.

Anyway, the respondents have described the design development stage in a step form as the following:

1- Topography study: At this step the region between the two connected points is studied in order to develop design alternatives by suggesting many roads' paths.

2- Identify the proposed path of the highway: This step is connected to the previous one; interviewee 5 mentioned that the selection of the proposed path done based on demographical and economical factors. Demographical factor includes the people that the highway should serve and how they distributed on the ground. Economic factors include the cost of each design alternative; the selected path should be economically feasible. However, the British Columbia government stated through its manual of highway design that these two steps have to be done in the planning stage through the analysis of needs and many exploring studies to identify the feasible corridor of highway. Moreover, AASHTO, which is the certified transportation specification in KSA, defines more aspects that should be considered when choosing the road path such as road classification, traffic volume and the design speed. This step requires to communicate effectively with client in order to match his needs and requires efficient documentation of client coordination and instructions because the whole design will affected by it at later

stages. This process is very time consuming and very costly (Kim et al, 2016).

3- Surveying data collection: After identifying the road path, a detailed surveying study should be done along with the path. All obstacles, houses, electric poles should be surveyed. Nevertheless, the interviewees did not explain the boundary that should be covered in collecting surveying data. The surveyors should be professionals and gather data with high accuracy in order to avoid design mistakes that could be extremely costly at construction stage.

4- Geometric and road profile design: This step includes identifying the horizontal cross-section of the road with detailed dimensions in addition to determine the design elevation. All structural elements like culverts, retaining walls and bridges are designed at this step. The respondents stated that the designer at this step can move the centerline slightly to avoid obstacles as much as possible, also the designer should consider the cost of construction, for example, minimizing the cut and fill operations. Moreover, as interviewee 2 stated, coordination with mechanical and electrical engineers is required at this step in case of the project includes electrical or mechanical works. This need for coordination emphasizing the need for effective communication and representation tool to assure mistakes and clashes avoidance in design.

5- Final delivery of drawings to the client: At this stage the final detailed design drawings are delivered to the client. These drawings will be part of the tender's documents and it will be delivered to the contractor. Therefore, this document should be clear, coordinated and does not contain inconsistent information.

Design Modification Process

After finishing the tendering design process, the client performs a bidding process in order to select the contractor to start the construction stage. However, it may take several years between the tendering design and construction stage. As interviewee 8 has mentioned, the contractor do not design the road from zero but he modifies it. The process of design modification was described by the respondents and they stated many factors that could lead to modify the design. The following illustrates the steps of design modification process in addition to the factors according to interviewee's answers:

1- Repeat the collection of surveying data: The first step that the contractor should do is to collect surveying data in order to be sure that nothing has changed on field. Everything in the right-of-way of the highway should be surveyed. This step is necessary in all cases especially when there is a long period of time between tendering design production and the start of construction stage. The Queensland government stated that the design process could take one to two years to be finished for major and complex projects. However,

interviewee 3 said that the client may hire an external third-party office to do this job.

2- Modify the geometric design: This step comes as a result of many factors according to interviewees:

a- According to the new surveying data: Updating the surveying data could reveals new obstacles that may prevent the construction processes like electric poles, civilian lands and houses. Such obstacles should be removed, but the contractor may modify the design by moving the centerline of the road in order to save time as interviewee 6 has explained.

b- According to change order: This factor depends mainly on the client and changes in his needs. However, these changes should not change the project scope; it should be within the range of flexibility of tendering design, because any changes at this stage will require additional cost and time (Stamatiadis et al, 2012). Else, there were problems in the planning and project development phases or the tendering design did not satisfy the client needs and goals.

c- According to execution aspects: As interviewee 6 has clarified, the contractor may suggest to modify the design of some elements in order to save the time of execution of that element, or because the contractor founds that construction according to

tendering design will cause a huge amount of waste. This issue indicates that the tendering designs have problems in terms of constructability.

d- According to contractor suggestions to minimize the costs: The contractor always seeks to get his job done with minimum time and cost. Therefore, the contractor may suggest modifying the design in order to get an easy to execute and less cost design. As in the case explained by interviewee 5, the contractor may replace bridge with culvert because the culvert execution requires less time and money.

3- Final delivery of drawings to the consultant: As in case of tendering design, the drawings should be coordinated, clear and without mistakes in order to avoid repeated work and costly changes. However, interviewee 5 stated that the process of design approval is very time consuming because of inconsistent of orders from client and consultant, this kind of conflict happened due to ineffective communication and collaboration among project parties.

Briefly, the project delivery system in this case can be represented as figure 5.1 shows:

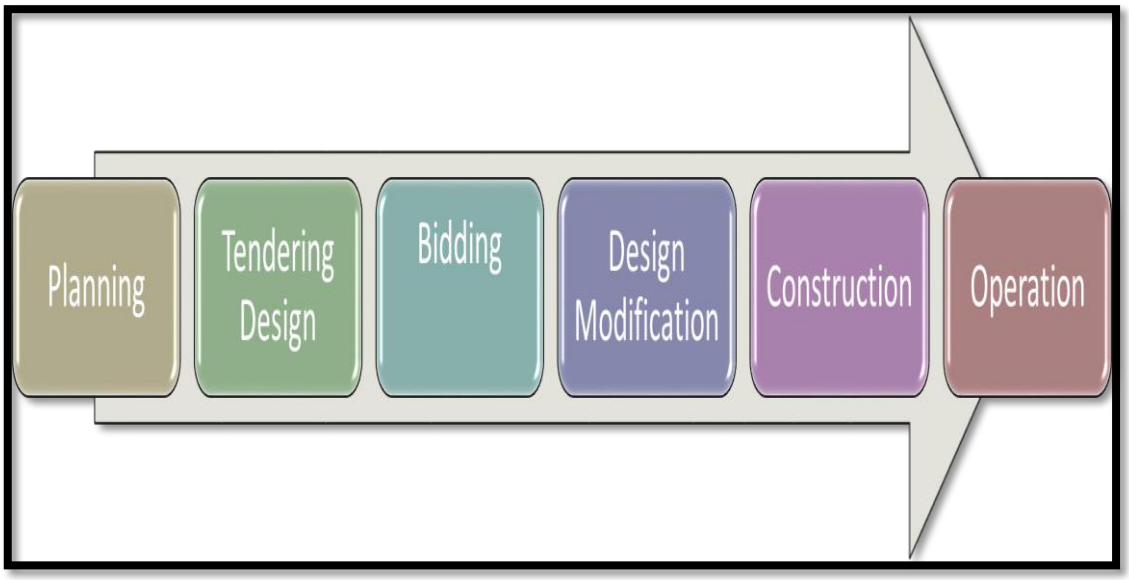

Figure 5.1: Project delivery system in case 1

Since the client hires an office to do the design job before the bidding and then performs bidding process to choose the contractor to do the construction works, the project's delivery system in this case can be described as design-bid-build system.

5.2.1.2 Case 2 firm

In case 2 firm the design process flows as the following:

1- **Get information from the client**: The process starts with this stage such that the client announce his project to the public seeking a firm to construct his project. It is sales engineer responsibility to get this information about the project and transform it into a written description. This information includes the area of the building, function of the building, material, dimensions of the building and 2D architectural drawing for the location of the project (site plan).

2- **Preliminary Design**: After the sales engineer got the information, the designer job is to take these information and transform it into a real preliminary design using MBS (Metal Building Structure) software in order to estimate the quantities and time required to accomplish the project. The products of this stage are 2D drawings, quantities estimate and time plan, all of these documents shape a priced proposal to compete other firms in the bidding process.

3- **Bidding Stage**: at this stage the client chooses one proposal among the competing firm's proposals considering many aspects that are defined by him.

4- **Final Design**: once the IBSF proposal has been chosen, the designer should finalize his design with more accuracy in calculations. All the member's sections, connections and roofing system are identified and designed, then a communication with the client occurs in order to get approval on the final design. The outputs of this stage are a clear sketches for the whole project in a form of 2D drawings, these sketches should be used by the detailing engineer to create the 3D model for the building.

5- **3D Model:** using Tekla Structures software, the detailing engineer creates a 3D model for the building according to the designer sketches, the software has a wide range of patterns for different types of members and connections which in turns make the process of modelling so easy and fast. Moreover, the detailer should use the

clash detection property to be sure that the building will be constructed without any problem. If any clash is detected, the detailer should notify the designer in order to fix the problem.

6- **Preparing of Approval Drawings:** after the creation and check of the 3D model, the detailing engineer directly generates 2D drawings from the 3D model which contain plans, elevations and miscellaneous drawings in order to get the client approval on these drawings.

7- **Preparing of Shop Drawings:** once the client has approved the Approval Drawings, the detailing engineer can directly generate the Shop Drawings from the 3D model, the shop drawings include two types which are part drawings and assembly drawings. These two types of drawings in addition to some lists like material list, part list, bolts list ….etc, are necessary to the fabrication process of building's members.

8- **Preparing of Construction Drawings:** once the fabrication process has finished, the construction stage should starts according to the Construction Drawings which are generated directly from the 3D model also.

Since the client choses one firm to do the design and construction works, the project's delivery system in this case is design-build approach.

5.2.2 Design Problems

In both cases of this research, the respondents assured that the design process suffers from many problems. The following sub-sections explain in details the design problems in each case:

5.2.2.1 Design problems in case 1

The results of interviews reveal that the design process has many problems regarding managerial and technical aspects. Regardless the process of design is at early stage "Tendering design" or at construction stage "Design Modification stage" both processes have problems according to the interviewee's answers:

Managerial Problems

1- Lack of coordination between the project parties: The current status of communication between the project parties does not support collaborative working. The design is performed by a design office as tender document with coordination of client and consultant. Then, at construction stage different designer and field engineer and may be different consultant will deal with the design. Thus, the connection between the designer who did the original design and the filed engineer is missing, also the connection with consultant at construction stage is missing. As a result, the rate of modifications and repeated work will increase at construction stage. Moreover, the involvement of consultant and client in design modification process

is weak, the consultant getting involved the process when it at late stage. Hergunsel (2011) stated that the traditional design-bid-build approach of project delivery prevent the collaboration with contractor at design phase. Moreover, According to the study of Almohammadi et al (2013) which is previously mentioned in chapter 2, poor design integration was a significant drivers for the challenges of Qatari construction industry.

2- Unorganized work and unavailability of time schedule: The work starts before finishing the design of all project elements; as a result the process of modifying the designs becomes harder with the project's progress, the designs become less capable to change at construction stage (Kentucky Transportation center, 2012). Moreover, doing job without plan is the same as blind man without a stick. Nima (2001) and Hassan (2005) uncovered that the design should be construction-driven activity. In other word, the design processes should be in the same sequence of construction processes. Hence, construction schedule must be developed before the design schedule.

3- Lack of design competency in some structural elements such as bridges design: The firm should have professional employees and capabilities commensurate with the size of work that should performed. Thus the human resource activities in hiring proficient people should fulfill these requirement.

4- The high rate of design modifications that required by the client: Most of highway projects are governmental projects that planned by collaborative efforts among governmental authorities and planning agencies at concept and planning phases (Queensland Government, 2010). Hence, the client should identify his needs at early stages of the project in order to minimize changes at construction stage. The U.S department of transportation assures that the quality of final project depends mainly on planning and design stages.

5- Lack of execution experience of design engineers: The designer should has execution experience in site before he works as designer in order to be able to evaluate design alternatives and choose the proper material. Roddis (1998) explained that the designer needs the advice of the constructor to decide that the design is constructible. In addition, in Anderson et al (1999) study the lack of experience issue has mentioned in design firms observations and construction firms observations as a main reason for weak constructability of highway projects. Also, insufficient experience and imagination of the designers will limits the applicability of software outputs that are produced by them, and it could be costly if they want to visit the construction site when they are far from it (Alaghbandrad, 2012). And this explains why interviewee 8 has suggested that the designer should visit the construction site from time to time to enhance his imagination.

6- The process is time consuming: The wasted time comes as a result of all other problems of poor communication, working without schedules, change orders and lack of experience. Any extra activity will transform into consuming more time and money.

7- Undefined communication: The interviewees have illustrated in their answers that they mainly use face to face meetings to communicate with other project parties. However, face to face communication requires the communicated persons to be in the same place which makes the process not efficient especially for parties that are separated geographically. Moreover, unavailability of defined communication policy in the firm to organize the communication process and the tools that the employees should use. The deployment of communication technology is the way to achieve effective and real time communication (Ahuja et al, 2009). Also, it provides better control, more effective documentation, and more organized flow of work (El-saboni et al, 2009).

Technical Problems

1- The high risk of error and fault data in the surveying processes that are collected from site. This problem, related to other managerial problem of recruiting unprofessional employees.

2- Do not consider executive aspects: This issue can be related to the lack of experience and knowledge issue. As mentioned before the

designers should have experience in site operations to be able to choose the proper design alternative. However, even the designer has sufficient experience; he may not consider the problems that the contractor will face during construction (Madelsohn, 1997 and Hassan, 2005).

3- Uncoordinated design: The design process requires coordination between multidisciplinary teams like civil, electrical and mechanical engineering in order to avoid clashes and errors in the design process production "Drawings". Roddis (1998) stated that collaborative process needs exchange of information between the multidisciplinary teams with different times and locations at all stages of design process. This can be referred to ineffective communication tools that are used by the designers to share their knowledge and information. Moreover, the reliance on traditional method to coordinate the drawings like CAD layers make the process more complicated and requires more effort. Ghanah et al (2000) and Hassan (2005) stated that using of visualizing tools enhance the ability of discovering construction difficulties before it occur at site, else, high attention should be given to the traditional communication tools like drawings and papers.

As it noticed from the previous observations, it is clear that the problem is not only in the preliminary design stage; approximately the same problems are existing at construction stage. However, if the

preliminary design has problems, the construction stage will not be perfect; Madelsohn (1997) stated that 75% of construction stage problems are generated in the design stage. Hence, all those problems and mistakes will be translated into delay, money loss, repeated work, and high rate of design modifications.

5.2.2.2 Design problems in case 2

As mentioned earlier, the project's delivery system in this case was design-build approach, and according to the questionnaire's results the design process has problems. Though the DB approach aims to create integrated design process rather than the traditional DBB approach, and according to CII (2002) it has better performance in terms of cost performance, schedule control, number of change orders and quality of end products. The problems that are clarified by the respondents seem to be the same problems that have been discussed in case 1 like: change orders, weak communication with client and coordination of drawings.

However, the respondents pointed out a problem of inadequate information especially at early stage of design, this problem arises in DB approach and may not occur in DBB as a result of early coordination and transfer of project information among the project parties in DB approach with less definition than in DBB approach (Chang et al, 2010). The same researchers also stated that this problem may occurs due to design and construction concurrency.

5.2.3 Documentation Process

Document control and information management system is very important process that should be performed well to avoid negative implications on the final project (http://www.qualityinconstruction.com). The results of the interviewee's answers in case1 revealed that not all of them have a documentation system in their firms. According to interviewees 1, 2, 3, 5, 6, 7 and 8, who are contractor engineers, all of them use a traditional method of documentation such that they keep a soft copy for each drawing on their own PCs and a hard approved copy in the project files. Moreover, among them interviewees 1, 5, and 7, who are contractor's design engineers, stated that they submit a hard copy to the consultant for design approval process and they keep a soft copy in their own PCs even after the drawing considered obsolete. While interviewee 4, who is a consultant engineer, stated that he documents soft and hard approved copies only. And, interviewee 3 said that the client also documents soft and hard approved copies. Interviewees 9 and 10, who are consultant engineers, clarified that the design office should have a document controller, his responsibility to organize the documentation process of all drawings, memos and other project's documents. Further, in case of design approval process, the drawing should have a unique code with indication to the number of revisions that performed on the drawing.

However, most of the interviewed engineers follow a method of documentation has many problems comparing with the minimum

requirement of document controlling that explained by "Quality in construction" website in chapter two. The following discuss the interviewee's behavior against the recommended issues by "Quality in Construction" website that should be considered in each construction firm:

1- Changes on documents and quick inform of changes: the approved drawings are separated on the construction team, design and site engineers; once a change on any drawings happened the person who did the change should distribute the new information on all the team. This will require additional effort from the designer. In addition, there is a risk to use an obsolete drawing in construction processes.

2- Coding system: each engineer uses his own system to name the drawings and this will cause conflict in sharing information. Each drawing should have a unique code to facilitate tracking of documents. OREGON Department of Transportation stated that project records should be organized in a way that makes it easy to find.

3- Previous revisions: interviewees 1 and 5 stated that they keep the obsolete designs on their PCs and this condition will be risky in case of sharing these designs to be used in field. Effective documentation system should be effective in obsolete files disposal, Yalcinkaya and Arditi (2013) define information management as "*the collection, documentation, dissemination, safe keeping, and disposal of verbal and graphic project-related information*".

4- Source of information: There is no one source of information, each designer and engineer has his own files. Haltenhoff (1998) stated that the huge amount of information generated for each project required efficient information system in terms of storage and retrieval.

In the view of the above, it is clear that the requirement of document controlling is not available in the current system of work of the firm in case 1. Some interviewees find the current system of documentation suitable for them. In contrast, the other interviewees emphasized in their answers that they have problems due to inappropriate documentation of their designs. It can be concluded that the documentation process suffers from this:

1- The firm does not have a documentation system. Every employee is responsible on documenting his files and designs. Where, in practice, it is very important for construction companies to have a project documentation system because it’s the only record of what actually done on the project (Sutton, 2014).

2- High chance of losing files due to inappropriate documentation.

3- With the progress of project time, the number of drawings and designs becomes large and all of these designs should be submitted as “As Built Drawings” at the end of the project. However, the good documentation the easy delivery of As Built Drawings.

4- The probability of sending fault designs to be executed in site becomes high with unavailability of documentation system, and such error may cost the firm a lot of money.

5.2.4 Communication Process

Goh et al and Littlehohn and Foss (2007) defined communication as "*The activity of conveyance, exchange, and transmission of information (ideas and facts, from simple social or emotional concepts to sets of highly complex instructions)*".Since overcoming the design problems is a main goal in this research and the communication problems were mentioned by the respondents in both cases, effective coordinated communication process becomes highly needed. Charalambous et al (2013) stated that coordinated communication and communicated coordination is required for effective collaboration. In practice, when actors are able to work in their own methods and practical ways and being able to communicate with others simultaneously, it can be concluded that effective collaboration can be achieved only by effective communication and coordination (Isikdag and Underwood, 2011). However, the analysis of data uncovered that the interviewees use different method of communication and mainly they used face to face meetings which is considered as traditional way of communicating in addition to its high dependency on paper document. The following explains the methods of communication that are used by the interviewees:

1- Primary tool: most of interviewee use mainly face to face meetings to communicate with the others. However, all of them use other communication model than face to face meetings.

2- Secondary: other tools of communication which are e-mails, mobiles, memos and social media like WhatsApp.

However, the interviewees stated that there is no interaction between the project parties by giving example on the design approval process such that the contractor's designer should wait for the consultant comments to know if he design is approved or not, and in some cases he should wait for the client comment which may different from the consultant opinion.

It is noticed that the communication channel can be described as one-way channel, such communication requires more time and increases the rate of repeated work in addition to the harmful effect on the construction processes progress.

Contractor should be able to communicate with all project parties in a clear channel (Tessema, 2008). Goh et al stated that conventional methods that don't support visualizing understanding provide limited design communication. Furthermore, they stated that conventional methods of construction leads to poor communication between the contractor and the clients and that will cause project's delay. However, in case of firms that have technical office geographically separated from the projects locations, effective communication is required among the firm's designers

and field engineers also. While, designs produces by CAD can be misunderstood according to (Tessema, 2008) and what interviewee 1 has stated. Hence, the need for better communication method is obviously clear.

5.2.5 Interviewee's Suggestions to enhance the design process

This research aims to enhance the design process through assessing the problems of the current work system and providing a solution for it. However, the interviews of case 1 gathered the respondent's suggestions to enhance the design process in order to capture their point of view through their knowledge and practical experience. The following is what the interviewees have suggested:

Technical Enhancement

1- Experience: interviewee 3 has suggested that the designer should have at least five years of experience in field's operations before he starts practicing design.

2- Design office in site: interviewee 8 suggested that the contractor's designer should visit the site of construction from time to time to enhance his imagination and sense to discover design errors and clashes.

Managerial Enhancement

1- Communication process: Interviewee 1 suggested that the designer should directly communicate the consultant engineer to approve his designs in order to avoid misunderstanding of the designer point of view.

2- Training: Interviewee 6 suggested that the firm should deploy the designers in training programs in order to be up to date with the design technologies and produce designs with less time and higher quality.

3- Schedule the work: Interviewee 2 and 8 suggested that the work of technical office should be done according to time schedule not in arbitrary way.

4- Coordination and design revisions: Interviewee 8 and 10 suggested that the design process needs better coordination especially with other disciplines like MEP. Moreover, all designs should be revised before it move to construction stage.

5- Integrated Process: Interviewee 5 claimed that the design approval process is very time consuming, he suggested that the consultant should be involved in the process at the beginning not to wait finishing of design and then involve and ask for modifications.

5.2.6 Building Information Modeling

In the view of the previous sections, it is noted that no one of the interviewees in case 1 has suggested adoption of BIM as a solution for the problems of design process. Therefore, This section investigates the BIM implementation benefits on the design process by considering a firm that already has adopted BIM in design processes. In addition, this secion identifies the barrieres of BIM implementation according to the respondents in both cases of this research.

5.2.6.1 Benefits and Potential Benefits of BIM

The benefits of BIM implementation were gathered from case 2 respondent's answers based on their practical experience with BIM software, which is Tekla Structures. Further, since the case 2 firm is considered partially BIM-adopter; the potential benefits of BIM implementation in case of full adoption of this technology will be discussed here according to the literature.

The following table explains benefits of BIM according to the respondent's answers and the potential benefits as it were discussed in previous studies in literature:

Table 5.1: Investigating the benefits of BIM

Benefits	Potential of BIM regarding the issue	Case 2 respondent's answers regarding the issue	Problems that can be solved by BIM regarding the issue
Higher profits	- 67 % of BIM adopted infrastructure firms in America achieved positive ROI (McGraw-Hill Construction, 2012). - The Australian government introduce BIM as recommendation to be used for complex projects at early design stage in order to achieve cost savings. - Autodesk (2015) concludes that cost savings are achieved through enhanced project management.	The respondents stated that cost saving can be achieved through avoiding costly clashes and saving of time in doing the required work.	Wasting of money.
Saving time	- Sanchez et al (2014) stated that BIM has potential to save cost through providing better planning and higher productivity, higher productivity means achieving work with less time. - Clevenger et al (2014) declared that BIM can save cost and time through decreasing the decisions in field. - BIM is a brilliant tool to optimize the efforts of the quantity surveyors (Hergunsel, 2011)	Saving time was the most interesting privilege of BIM according to the respondents, the time saving in design process can be as a result of different things like easiness of constructing the model, making modifications with no need to repeat too many steps and generating the 2D drawings easily	Wasting of time in doing modifications that caused design errors and change orders.
Documentation	- Yusuf (2014) said that "*BIM supports the storage, exchange and sharing of data between the different designers and disciplines in a project*".	The respondents did not mention the problem of documentation, but they mentioned that it is easy	-Obsolete drawings. - Fragmentation of information.

	- Yalcinkaya and Arditi (2013) stated that BIM is a huge database contains vital information like scheduling, estimations and change orders which are significant for construction management practices. - models generated by BIM are intelligent models, any change on any element in the model will be automatically coordinated with the corresponding information that are linked to that element like quantities and schedules, and this will reduce the documentation practices efforts and enhance the accuracy of documentation (Autodesk, 2011). - Benefits of BIM are not only at design stage, it go beyond to operation and facility management stage. BIM provide better facility management of infrastructures assets through the possibility of recording every maintenance details for each component (Marzouk and Abdel Aty, 2012) and (Clevenger et al 2014).	to do the modifications on the model and regenerate the required drawings, so it can be concluded that the problem of obsolete drawings is solved. In addition, other information like material list, bolt list…etc are updated automatically after doing any modifications.	- One source of information, since the model is the only source. - As built drawings that are necessary for operation and maintenance.
Communication	- BIM allows the project team to evaluate important decisions on computer instead of the field where doing changes is easier and more cost effective (Clevenger et al, 2014). Thus, shared understanding of the project and disciplinary collaboration are developed to reduce the design mistakes and miscommunication (Bennett, 2012). - Autodesk (2015) stated that BIM and visualizing facilitate communicating technical aspects of designs with client and as a result the client better	The respondents in case 2 did not directly clarify how BIM enhance the communication with the client. Meanwhile, they stated that with BIM doing modifications according to the client comments is faster, also BIM software produces high quality drawings rather than traditional tools. So, it can be	- The problem of integrating the client in design especially at early stages of design which was one of the design problems in case 2. - The problem of repeated work due to inconsistency in client

	understand such designs. Goh et al (2014) discusses the difference between the traditional ways of communicating designs with client and the case of using BIM in communication, they stated that the communication using 2D drawing is one way communication and this make the integration of information impossible. Where, using visualizing will integrate the client experience and concept into the model (Tessema, 2008). See Fig 5.2	concluded that BIM enhance communication through making the designer response to the client's comment more fast which leads to a faster communication process and enhancing communication with client. - Also, the respondent's clarified that BIM allows sharing of model with other software which in turn enhance the communication and coordination with other engineering disciplines.	and consultant comments, and the time that it takes to approve the design. - The problem of reliance on paper-based communication, since BIM provides sharing information with other media like images and 3D models. - The problem of continuous change orders.
Less fragmentation	- The integration that BIM allows leads to minimization of documentation and records (Botta et al, 2013) and (Sanchez et al, 2014). - Cetiner (2010) and Yusuf (2011) stated that BIM model is a single source database for all information of the facility that contains valid and consistent data about the facility from the design to demolition.	- The respondent's stated that they generate all drawings and tables that are required for building fabrication and erection from the 3D model, so there is one consistent source of information.	- The problem of paper-based fragmented information.
Clash detection	- Becerik-Gerber and Rice (2010) found that BIM mostly used by contractors in visualizing and clash detection. - Sacks and Barak (2007) concluded that BIM indirectly increase the profitability of engineering firms through error reduction.	The clash detection also was an interesting property of using BIM according to the respondents, Tekla software can detect any clash in the model; so the detailer can inform the	- The problem of clashes in design that may have costly effect especially if the design already has been constructed.

	- BIM eliminate the errors in designs that result from inconsistent information (Yusuf, 2014). -Autodesk (2011) stated the power of BIM in keeping consistent data regardless how many changes done on the design, the intelligent connection between the model and the information stored in the model keep the output without errors.	designer about the clash in order to fix it. In addition, the detailer can check the model by his eyes because of building visualizing. As a result the generated drawings for fabrication purposes will not contain costly mistakes.	- The problem of inconsistent information among the project's documents like drawings and bill of quantities (BOQ).
Improves quality	- Clevenger et al (2014) discussed the technical benefits of BIM in producing high quality construction documents, plans and estimates through making reliable representation of infrastructure to aid the decision making and design processes. - Hergunsel (2011) assured the value of BIM in producing powerful 3D rendering with real and consistent data which make understanding and communicating the designs much easier. - Strafaci (2008) mentioned that through using BIM simulations, visualization and analysis, the designer can produce optimized designs for roadways.	The respondents stated that the software takes information from the user in order to use it in producing optimized design, also they mentioned that BIM software produce high quality drawings through erasing the clashes from it.	- The problem of incomplete and inconsistent drawings. - The problem of communicating the design with the client through aiding decision making process with reliable representations.
Better design coordination	BIM is very useful tool to perform design reviews, constructability reviews, at design stage. Also it's effective in 3D coordination in both design and construction stages. Refer to Fig 1.1 by Messener (2009)	The respondents assured that Tekla software allows for better coordination through providing the ability to model all parts of the building in one model, also the software allows sharing the model with other BIM software.	- The problem of uncoordinated designs and drawings.

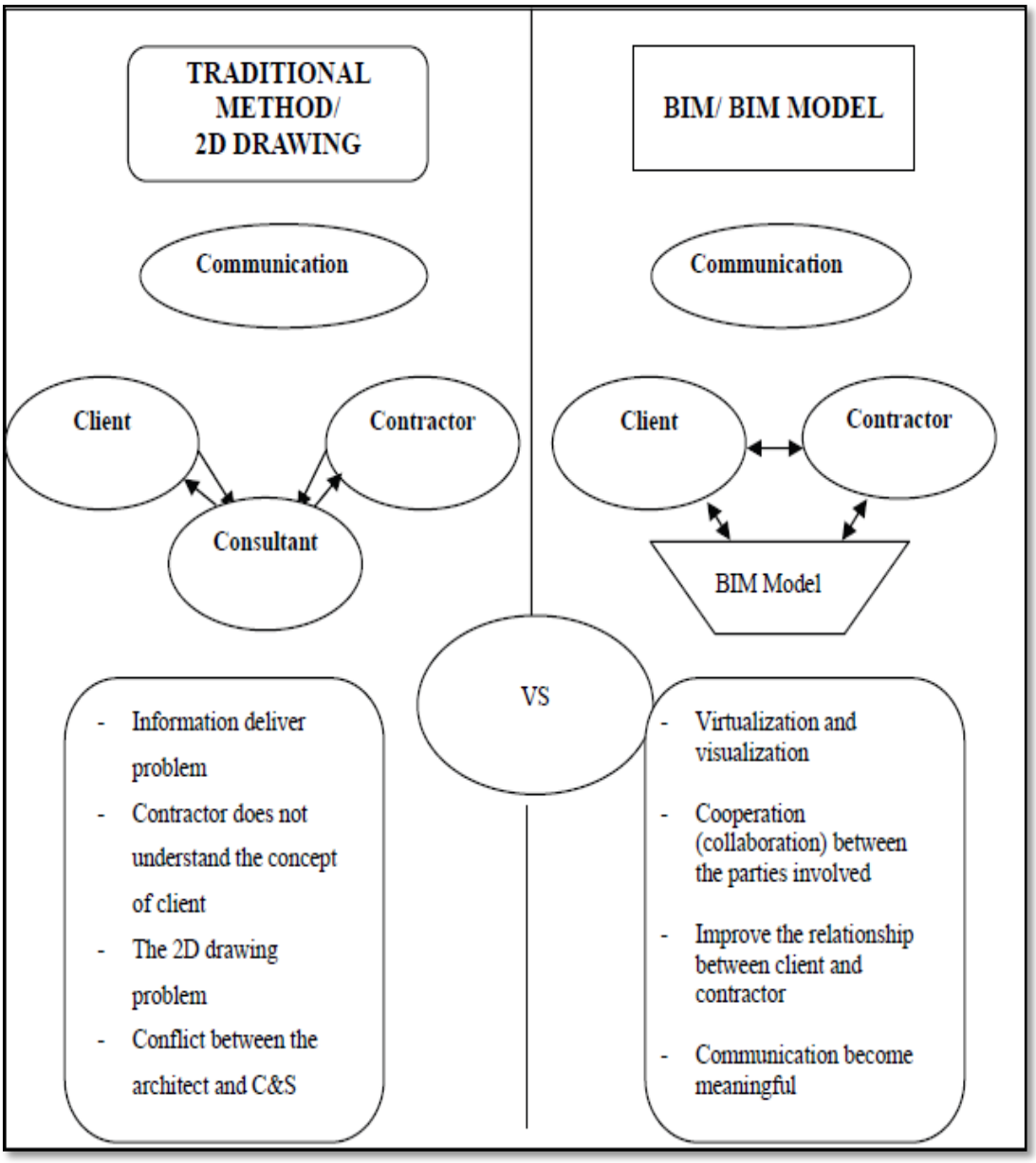

Figure 5.2: Comparison of communication between the client and contractor, Source: Goh et al (2014)

5.2.6.2 Barriers of BIM

As in case of any emerging technology, BIM would face some barriers that limit its expansion in the firm or in the whole market. The following table explains the main barriers of BIM implementation according to both cases respondent's answers:

Table 5.2: Barriers of BIM implementation

Issue	Literature	Case 1	Case 2
Lack of Experienced People	- Almohammadi and Richardson (2013) found that "Not having the appropriate people" is one of the main challenges of BIM in the Qatari market. - Sacks and Barak (2007) and Kaner et al (2008) stated that shortage of skilled personnel in BIM is one of the main obstacles that concern structural engineering firm in their plans to adopt BIM. - Another concerns related to this issue are the required training of employees to transform into professionals one in BIM technology and how much time this transform will take (Luthara, 2010).	The firm does not have the skilful and experienced people in BIM and that will prevent the firm from BIM adoption.	Lack of experience in such technology among the engineers especially the experienced ones. As a result, the firms should train the employees and that can be considered as risky investment
Cost of implementation	- Sanchez et al (2014) uncovered that the initial cost of adopting BIM and it's applicability to small and medium infrastructure project is big disquiet for the new adopter of BIM. -For infrastructure projects, the operation and maintenance cost is considered heavily much more the	This issue was not considered from case 1 interviewees.	The main barrier of BIM according to the respondents is the high cost of software licences, for example, the licence for single Pc for one year of Tekla Structure software costs approximately 20000 $ (Twenty Thousand Dollars). While, two of the respondents assured that the saving in

	first construction cost (Clevenger et al, 2014). - Yan and Damian (2008) stated that the largest BIM barrier is that the companies believe that the cost of employee training on BIM in term of human resources and time is very high.		money that BIM allows in much larger than the cost of implementation. - Also the respondents mentioned the cost of training that could be risky investment.
Cultural Issues	- Yan and Damian (2013) concluded that people refusing to change is a major challenge to BIM implementation. - Yusuf (2014) and Gu and London (2010) argued that the understanding of adopting BIM requires changing the entire work practice is a common misconception that blocks BIM adoption. - The culture of the organization have to be ready to implement BIM in order to achieve successful adoption (Bew and Underwood, 2010). - It can take too long time for BIM to be integrated as part of project culture (Clevenger et al, 2014).	- The traditions of the construction market in a challenge for BIM implementation.	The respondents stated that the culture of people in some areas prevent them from paying money to get a licence of software.
Availability of success case	- Yan and Damian (2008) concluded that the AEC industry will be convinced with investing in BIM	There is no one implement BIM technology. Therefore, the firm management do not	Not mentioned by the respondents

	when case studies evidence is provided to assure the profitability of BIM.	feel the risk of competitors surpass.	
Top management commitment	- Autodesk (2011) stated that BIM is a strategic change that requires top-down support to achieve its goals. They discussed that the top management should be aware about the strategic value of BIM, its benefits, and the changes it requires in terms of processes and structure of the firm. - Singhal (2013) concluded that top management role was one of the most discussed issues regarding the BIM implementation.	- Top management should be convinced with the efficiency of BIM technology	Not mentioned by the respondents.
Adoption by one Party of the project	- Hergunsel (2011) described that by "lonely BIM" and he clarified that when this type of BIM adoption happens, the designers have to provide their designs in 2D formats and that will restrict the efficiency of BIM.	- The adoption of BIM should be done by all parties of the project, else new problems will rise.	- This is the condition of case 2 such that the firm is the only party who adopt BIM, so the employees have to communicate their designs in 2D format not the 3D model.
Organizational structure of the firm	- Success in BIM implementation comes as a result of innovation in business and organizational concept next to the advancement in technology (Sebastian, 2010).	- This issue was considered by one interviewee, he stated that the firm is divided managerially and functionally, therefore it is difficult to adopt BIM. The	Not mentioned by the respondents.

		interpretation of this related to the organizational structure of the firm do not support adoption of BIM or any new technology.	
Flexibility of BIM software	- Lack of interoperability among BIM software is major obstacle for BIM adoption (Sacks and Barak, 2007) and (Kaner et al, 2007). - Pezeshki and Ivari (2016) clarified that one of the biggest construction industry challenges to achieve fully integration and collaboration among project team, is to exchange models and data between different software. - Clevenger et al (2014) clarified that a major challenge for transportation agencies is to find standards that eases smooth transition of information among software system especially deploying GIS with BIM in transportation projects.	- Also this issue was discussed by one interviewee, he said that the compatibility of BIM software with other software like 3Dmax and AutoCAD is important factor at the beginning of BIM adoption process	- One interviewee stated that BIM software allow sharing information with other BIM software, he considered that as a privilege of BIM

5.2.6.3 Motivators of BIM

According to the interviewee's answers in case 1, the construction firms could be motivated to adopt BIM as a result of the following factors besides overcoming the barriers of BIM:

1- First Mover: Among 8 interviewees that answered the question "who should be the first mover toward BIM adoption" 6 of them said that the government as client should be the first mover in BIM adoption. Interviewee 3 said that the government should consider BIM as requirement for its projects to motivate the construction firm to implement BIM in their construction processes. Similarly, the government of UK strategy was to consider BIM as requirement for all governmental projects by the end of 2016, which make a pressure on design offices and construction firms to adopt this technology (Yusuf, 2014). However, interviewees 4 and 10 said that the designer and contractor should be the first mover because they are the most beneficiary of BIM implementation. Actually, this claim cannot be totally precise, the benefits of BIM are observed at entire construction lifecycle (Shou et al, 2015). Thus, all the project parties are beneficiaries of BIM adoption.

2- Competitors: As mentioned before by interviewee 1, no one of the competitors of the case 1 firm implement BIM in projects. Interviewee 7 stated that in KSA there is a multinational firms that

already implement BIM in their projects. Considering that, these multinational firms are competitors for the national firm. Therefore, the national firms should have the same capabilities and competencies to keep it fortune in competing among the others in KSA construction market such that adoption of BIM will give the firm business advantage that differentiate the firm against the competitors (Autodesk, 2015). Moreover, the change in the global market motivates the engineers and contractors to think about reengineering their tools and processes in a manner that allows them to deliver higher-quality infrastructure projects with less cost, thus they can handle challenges and stay competitive in the market (Autodesk, 2011).

5.3 Summary

This chapter discussed in details the results that gained through the data analysis. The first section concluded the discussion of the current conditions of the design process in terms of design stages, design problems, documentation and communication. Moreover, the current conditions of technology tools that are used in design has been discussed and illustrated.

In the second section, the benefits and potential benefits of BIM implementation have been investigated and connected with the current process problems. In addition, the barriers of BIM implementation have been identified and discussed deeply.

Chapter Six

Conclusion and Recommendations

6.1 Conclusion

This research aimed to analyze the design process, in construction projects of KSA region in order to identify the design process stages and the main problems that face the designers during the design, then to investigate if BIM can overcome these problems and enhance the process of design and the whole facility's lifecycle. Actually, focusing on this stage of project lifecycle was not arbitrary choice. As mentioned earlier, most of problems in construction and operation stages come as a result of problems in the design stage.

To achieve these goals, two case firms have been chosen from the Saudi construction market, the first one was not BIM-adopter and the second one was partially BIM-adopter. Then data has been gathered from these firm's employees and the results has been discussed in the view of literature review.

The results revealed that projects in the first firm following the DBB delivery system, so the design passes through two stages which are "Tendering design" stage that comes before the bidding process and "Modification design" stage that comes after the bidding process as a part of construction stage. However, it can be concluded that this delivery system has problems in both stages such that the results uncovered a high

rate of modifications and reworks in the modification stage, in addition to many other managerial problems in terms of documentation and communication.

The documentation process is performed personally by the employees in most cases which may cause missing of important data, problems in construction as a result of obsolete drawings and problems in delivering “As Built Drawing”.

Moreover, the communication among the project parties and designers has found to be traditional one way communication, on other words, paper based communication. Also, the communication tools that are used by the designers are traditional one like face to face meetings, emails, phones..etc which do not allow visualizing and limit the coordination efforts and collaborative design.

Where in the second case firm, the design process following DB delivery system, also the results revealed problems in the design, especially at early stages of design, in terms of communication with client, missing information and change orders.

In the view of the above, it can be concluded that both delivery systems have problems in design stage in terms of communication and change orders, though in literature DB approach is better than DBB approach in terms of changes orders rate, schedules and reworks.

To investigate about BIM and its potentials to overcome the design problems, the second firm was considered as case study though it's partially BIM-adopter. The results revealed that the firm adopts BIM at detailing stage, the stage where the design transformed into drawings, so all the previous stages are performed without BIM. Moreover, the results uncovered that BIM has benefits in terms of enhancing the quality, saving time, saving cost, clash detection and accuracy of work.

Also, the literature supports that BIM has benefits and potential to enhance the documentation and communication processes, reducing reworks, improving the quality of final product and many other benefits regarding construction and operation stages. Anywise, it can be concluded that the firm gains benefits from adopting BIM at detailing stage, but also it loses potential benefits of BIM, for example, the engineers take advantage of quick doing modifications according to the client comments while they can use BIM and visualization instead of 2D drawings to communicate the design with client and reduce the rate of modifications.

As a result, adoption of BIM should be in the whole process of design not only the detailing process in order to gain the full potential benefits of BIM implementation.

BIM was investigated as a solution to overcome the design, documentation and communication problems. The BIM choice was reinforced by the positive perception of the case 2 respondents about BIM, in addition to the BIM privileges and power that has been discussed in

literature. However, as in case of any change BIM implementation faces many challenges. Unfortunately, most of these barriers are beyond the capability of any specific firm like having a national strategy to adopt BIM, changing the industry style, commitment of all project parties and the high cost of BIM implementation. Though that, the BIM-adopter firm can enhance its experience with BIM by avoiding the other barriers like lack of experience by performing training programs, and cultural issues by spreading knowledge about the benefits of BIM.

Moreover, in literature there are frameworks that facilitate BIM adoption in the construction firm. Framework is defined by Kassem et al (2014) and Succar (2009) as "*network of taxonomic nodes and relations among nodes*". Many researchers in literature discussed how to implement BIM in construction firms (Gu and London, 2010). And according to many of them, BIM is both technology and process that leverage the firm productivity and efficiency (Sanchez et al, 2014). BIM should be seen as integration of product and process modeling not as set of separated processes and technologies (Succar, 2009) and (Kimmance, 2002). However, Nader et al (2013) concluded that organizational, cultural and process issues should be arranged before the technology adoption, else BIM benefits cannot be achieved. Also, Clevenger et al (2014) emphasized that adoption of BIM require reengineering of design, construction, and maintenance processes.

In the view of the above, it can be concluded that BIM implementation requires the effort of many actors. Further, it requires changes in construction management processes to align with changes caused by BIM implementation (Yalcinkaya and Arditi, 2013).

6.2 Research Recommendations

This research was developed based on review of literature in the related field and the conducted interviewees with specialized practitioners. Therefore, the researcher recommends the following:

1- It is recommended to perform more researches in KSA market considering firms that fully adopted BIM in their construction and design processes to investigate the potentials, barriers, and motivators of BIM based on real practical case.

2- The researcher recommends developing practical protocols that facilitate BIM implementation process as successor step of framework development. BIM protocol will act as guidance of BIM implementation with measurable outcome (Kassem et al, 2014).

3- Developing performance metrics is highly recommended in order to facilitate evaluation process of BIM implementation and perform further enhancement.

4- The researcher recommends to start the implementation process with a prototype project. The implementation on a prototype project will

reduce the risk of wasting time and cost in case of failure (Yang and Epstien, 2005).

6.2 Summary

This chapter contained two main sections, the first one provided a conclusion on the derived knowledge from all previous chapters. In the second section, recommendations were provided to be considered in future researches.

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Appendices

Appendix (1)

Transcript of Taped Interview with Designer from case 1 firm

Audio Recorded Interview

Section one: Basic Information

Name …….

Job title …….

Employer…….

Years of experience …….

Email ……

Date of Interview ……

Start time ……

End time ……

Section Two: Introductory questions

1. Do you think that the design process has any problems? If yes, what are the main problems that you are facing during the design process?
2. Could you please give us a brief description of the design process flow?
3. What are the technology tools that you are using in producing yours design?
4. Did you use BIM in your projects? How was it?

Section three: Documentation problems

5. How do you document yours deign? Is it easy to find it again when there is a need to perform some modifications? Is there a specific documentation system for your firm?
6. Do you feel that there is a problems with the current method of documentation? If yes, what are they?
7. Do you think that BIM can overcome these problems? If yes, how?

Section Four: Communication problems

8. During the design process, how do you communicate with the other parties of the project (site engineers, client, consultant……etc)? And at any stages of the design this communication occurs?
9. Is there any involvement of other engineering sections in the design process (electrical, mechanical)? If yes, to any extend this involvement affect the design?
10. Do you think that BIM can provide better communication between project parties? What is the expected changes in the design process flow? How exactly do you use the BIM to facilitate communication among you and other parties?

Section Five: Concluding questions

11. Do you have any suggestion to enhance the design process?
12. Do you think that the implementation of BIM is possible under the current conditions? Why? And in your opinion, what will motivate the company to adopt BIM?
13. Would you like to add any remarks or advices to our discussion?
14. What are the important positive potentials of the BIM to enhance the communication and documentation process through the different design stages?
15. Throughout what stages of the project life cycle which are you prefer to use BIM or other tools to support the design process in term of communication with other parties?

Appendix (2)

Transcript of Taped Interview with Consultant from case 1 firm

Audio Recorded Interview

Section one: Basic Information

Name …….

Job title …….

Years of experience …….

Email ……

Date of Interview ……

Start time ……

End time ……

Section Two: Introductory questions

1. Do you think that the design phases has any problems? If yes, what are the main problems that you are facing during the design phases?
2. Could you please give us a brief description of the design phases flow?
3. To any extent you are involved in the design phases? At what phase your role appears?
4. Did you use BIM in your projects? How was it?

Section three: Documentation problems

5. How do you document the designs that you involved in? Is it easy to find it again? Do you review it? When this would occurs? Is there a specific documentation system for your firm?
6. Do you feel that there is a problems with the current method of documentation? If yes, what are they?
7. Do you think that BIM can overcome these problems? If yes, how?

Section Four: Communication problems

8. During the design phases, how do you communicate with the other parties of the project (site engineers, client, contractors……etc)? And at any phase of the design this communication occurs?
9. Is there a system of communication exist between you and the client? If yes could you explain it? If no is there a specific conditions that the client must be involved in during the design phases?
10. Is there any involvement of other engineering sections in the design phases (electrical, mechanical)? If yes, to any extend this involvement affect the design?
11. Do you think that BIM can provide better communication between project parties? What is the expected changes in the design stages flow? How exactly do you use BIM to facilitate communication among you and other parties?

Section Five: Concluding questions

12. Do you have any suggestion to enhance the design phases cycle?
13. Do you think that the implementation of BIM is possible under the current conditions? Why? And in your opinion, what will motivate the firm to adopt BIM?
14. What are the important positive potentials of the BIM to enhance communication and documentation processes throughout the different design stages?
15. Throughout what stages of the project life cycle which are you prefer to use BIM or other tools to support the design process in term of communication with other parties?
16. In your opinion, which one of parties has the big role to move towards BIM implementation? Why?
17. Would you like to add any remarks or advices to our discussion?

Appendix (3)

Case 1 Interviewees Answers

Case	Text	Open Coding	Axial Coding
Design Stages			
Abdullatif Adam	Surveying data collection. The contractor collect data from site in order to use it in the design process. The collected data are approved by the consultant. Design process, the contractor also do this job. But in some cases the client hire an external design office to finish the design works. And the second case, the contractor may have to do some modification when execution of the project starts.	1- surveyying data collection 2- Design modification	Design Modification Process
Mostfa Othman	However, in most cases when the contractor is identified. The contractor team repeat the surveying data collection process. If any obstacles or mistakes are discovered, the contractor design team perform the required modifications with the coordination of the consultant. For example, if the contractor discovered that the road path crosses a land owned by a citizen, the contractor may suggest to transfer the road centerline to avoid problems with this citizen because the procedure of transfer the ownership of such land from a citizen to the government takes a very long time.	1- Surveying data collection 2- Design modification	Design Modification Process
Ahmed Dahi	Our surveyors take the same proposed path in the client's design and collect surveying data again. In some cases we modify this path but the modification may be in little stations not all the path. In regards to structural elements we repeat the designs of retaining walls and culverts. The design done according to the ministry of transport standards and the shop drawing produced by our technical office.	1- Take the original proposed path 2- Surveying data collection 3- Design modification 4- Repeat structural elements design	Design Modification Process
Nour aldin Ata	Here, in most cases we do not design from zero, most of our works is to modify the designs that comes with tender documents. The surveyors start with checking the centerline coordinates in project site, in most cases they found difference between the designs and reality, here our job starts. We took the new surveying data and modify the designs according to it, we may add retaining wall or culvert or shift the centerline of the road and then change the road geometric design.	1- surveyying data collection2- Design modification	Design Modification Process

Hussien Mahmoud	Gathering surveying data from site. This data is totally collected by contractor surveyors in most cases. However, the client rarely consult a surveying office to gather part of this data. Import the surveying data to computer and classify it. Starting the design process loop, which starts with the contractor designer who produce a draft design. Then the drafts discussed with the client's consultant by the contractor executed engineer – not the designer-. Then modification occurs if needed and discussed again with the consultant and so on until the final design approved. The final design transferred to the site engineer to be executed.	1- surveyying data collection 2- Design modification	Design Modification Process
Mostfa Othman	Studying the topography of the region in order to identify the obstacles and to propose a path for the road. Many aspects are considered during this process demographic, cost, obstacles reduction. After determining the road path a surveying data need to be collected. The ground level and the coordinate of any obstacles in the path is collected. Starts the design process where the roads geometry is designed and any needed structural elements also is designed in this process. Structural element like culverts, bridges, retaining walls. The final design transformed into drawings which is included in the bid documents.	1- Topography study of the region. 2- Evaluate Alternatives. 3- Surveying data collection. 4- Geometric design and structural elements design 5- Design approval and shop drawings delivery.	Tendering Design
Ahmed Dahi	Studying the topography of the region. After determining the road path a surveying data need to be collected. Starts the design process where the roads geometry is designed and any needed structural elements also is designed in this process. Structural element like culverts, bridges, retaining walls. The final design transformed into drawings which is included in the bid documents.	1- Topography study of the region.2- Evaluate Alternatives.3- Surveying data collection.4- Geometric design and structural elements design5- Design approval and shop drawings delivery.	Tendering Design
Malek Alasyote	Topography study for the region of the two point that will be connected. Propose road path alternatives. The suitable alternative chosen based on economical, demographical, topographical criteria. Collecting surveying data from the site. All obstacles, electric poles, manholes, houses that the path passed through it or beside it should be surveyed. Start the design process itself based on AASHTO specifications or any other specifications defined by the client or consultant. This stage also includes the design of any needed structural elements, like bridges, retaining walls and culverts. if the designs performed by external design office the design approvals done with the client –-ministry of transportation- while if it performed by the contractor the designs approved by the consultant. Preparing of the final drawings.	1- Topography study of the region. 2- Evaluate Alternatives. 3- Surveying data collection. 4- Geometric design and structural elements design 5- Design approval and shop drawings delivery.	Tendering Design

Ahmed Dahi	The Design starts with the client. The client hired an external office to do the job. However, the contractor should repeat the designs phases when he start execution of the project. The technical office of the company is responsible on this job. We suggest our modification on the client design if there is a problem in it.	1-Client Starts the design. 2- Contractor modify at execution.	Tendering Design
Abdulmo na'm Jamal	Studying the topography of the region. Surveying data (Gathering data from site). In most cases this job is repeated by the contractor. Surveying data approval from the client or consultant. Starting the design process.	1- Topography study of the region.2- Surveying data collection.3- Geometric design and structural elements design	Tendering Design
Ala Bakkar	The design starts as preliminary design with studying the topography and identifying the road path. After that the surveyors collect a precise surveying data from the site (the path is divided into segments with identified length – stations-) the coordinates of each station are collected and the coordinates of any other obstacle or buildings should be noticed. Then the geometric design is started and the dimensions of the road and the curves are calculated and the profile of the road is produced. Any needed structural element is designed also at this stage such as bridges and culverts.	1- Topography study of the region. 2- Evaluate Alternatives. 3- Surveying data collection. 4- Geometric design and structural elements design	Tendering Design
Design problems			
Abdulm ona'm Jamal	Yes, one of the most important problems is that the designers almost do not have executive experience	lack of experiene	Technical design problem
Hussien Mahmoud	For example, our designs depends on data that have been gathered from site by surveying tools. In many cases this data may be fault. Then, the error discovered at the late stages of the design in such time doing modifications will be disastrous.	fault data	Technical design problem, cause
Ahmed Dahi	Yes. We face a problem with the technical office. The shop drawings of structural elements which produced by the designers may cause a large quantity of wasted steel. The designer should consider the length of bar in a manner that reduce the wasted steel to the minimum.	Do not consider executive aspects	Technical design problem
Malek Alasyote	in some cases the surveyor that collect data from site may be unprofessional I think there is a problem with the employee recruiting.	lack of experiene	Technical design problem
Moham med Abu-hashem	Yes, some problems arise from doing modification on one part of design without considering the other parts.	uncoordinated work	Managerialdesig n problem
Hussen Mahmood	poor planning from the beginning of the project	Poor planning	Managerial design problem, Cause

Ahmed Dahi	Although the bridges design may need some modifications but we do not modify it because we don't have the competency in bridge design. The job is done by the consultant office and the shop drawings produced by our technical office.	lack of design competency	Managerial desgin problem
Nour Aldin Ata	Moreover, preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office,	availability of time schedule	Managerial design problem
Malek Alasyote	Yes, we face many problems during the design phases. For example, most of ministry of transportation projects the designs are produced by a design office hired by the ministry. When the contractor and consultant of the project defined they will make modifications. This process consume time and effort.	Time consuming	Managerial desgin problem
Malek Alasyote	unprofessional I think there is a problem with the employee recruiting.	Employee recruiting	Managerial desgin problem
Mohammed Abu-hashem	the time schedule should be identified at the beginning and all memos and meetings record should be documented	availability of time schedule	Managerial design problem
Mohammed Abu-hashem	if the process of communication organized well and identified clearly in contract, the conflict can be avoided considering that this issue is a main cause of raising conflict between project parties.	Undefined communication	Managerial design problem, Cause
Nour Aldin Ata	Yes. The main problem here is the repeated work that comes as a result of lack of coordination between project parties.	Repeated work, Uncoordinated work	Managerial desgin problem, cause
Amro Sleem	Yes, the main problem that the work does not organized well.	Unorganized work	Managerial desgin problem
Abdulmona'm Jamal	as in case of municipality projects, the executives work in site started before the designs completely finished. As result, doing modifications become harder with the project progress in site.	Random process	Managerial desgin problem
Abdulmona'm Jamal	Yes, one of the most important problems is that the designers almost do not have executive experience.	Employee recruiting	Managerial desgin problem
Mostfa Othman	Yes. I think the process of design approval after modification of the design is very time consuming. The designer should make the suggested modification then send it to the consultant. The consultant may approve the design and then send it to the client to review it or he may suggest another modification. This process is not integrated and very time consuming.	time consuming, not integrated	Managerial desgin problem

Effects of Design Problems			
Abdulmona'm Jamal	Therefore, they may ignore some executive limitations when they put the design criteria. As a result of this, the contractor has to make modifications on these designs to consider such limitations.	make modifications	Direct effect on work
Amro Sleem	This make me confused	confusion	Effect on Personnel
Amro Sleem	affect my productivity.	decreasing productivity	Direct effect on work
Nour aldin Ata	. Moreover, preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office, here we deal with more than one project and every project engineer want his job done in short time even he asks for it when he needs it. This put you under continuous pressure and cause lack of concentration to designer.	lack of concentration,Pressure	Effect on Personnel
Mohammed Abu-hashem	the client will prefer to change the whole design on doing maintenance according to original one considering the cost of maintenance process.	change the whole design	Direct effect on work
Factors That Affect The Design			
Ala Bakkar	Yes, if the project contains electrical or mechanical works the specialized engineer should be involved in the design process. For example if there is electric poles for street lightings, the electrical engineer should be involved when the design engineer checks the road path, if there is a an electrical item cannot be installed the path should changes or the alternative electric solution should be submitted.	check the road path, submmit alternative electrical solution, Tendering design stage	Role of other Engineering section
Abdullatif Adam	Yes, if there is a need to consult electrical or mechanical engineers during the design process. The specialized engineer prepare his consult through a report and give it to the designer. The designer should consider the notes and coordination in that report during the design.	provide consult through report, Both stages of design	Role of other Engineering section
Mostfa Othman	Yes, as I said before if there is obstacles in the road path, we communicate the client to hire a specialized company or the electricity supplier to remove this obstacle. Also there is a study that the design office should do before starting the design.	study by design office, Tendering design, Modification stage	Role of other Engineering section
Abdulmona'm Jamal	Yes. There is studies called “hydrological study” and “electrical study” should be done first before the beginning of the design process. These studies considered any hydrological or electrical structure can affect the design and this can affect the proposed path of the road, or the profile of the road.	consult throuh report, tendering design stage	Role of other Engineering section

Amro Sleem	When I need to explain about some details related to electrical or sewage works. Directly I communicate a specialized engineer even he is not involved in the whole project.	contact directly, Modification stage	Role of other Engineering section
Nour aldin Ata	if there is electrical or mechanical works or not. However, at collecting surveying data stage, the electrical and mechanical elements are considered to distinguish if any of it obstacle the centerline or the project works. Electrical and mechanical engineers should prepare their report and the solution should discussed with consultant.	construction stage, preparing report, discuss with consultant	Role of other Engineering section
Hussien Mahmoud	I need to consult drainage and sewage engineer in determining the suitable path of road or to choose between proposed proposals of road path.	consult to determine the path	Role of other Engineering section
Nour aldin Ata	It depends on the project requirement,	project's requirement	Factors affect the tender design
Mostfa Othman	demographic, cost, obstacles reduction	demographic, cost, obstacle reduction	Factors affect the tender design
Malek Alasyote	The suitable alternative chosen based on economical, demographical, topographical	economical, demographical, topographical	Factors affect the tender design
Nour aldin Ata	It depends on the project requirement,	project's requirement	Factor affect the Modified Design
Ahmed Dahi	we may suggest a modification if there is a method of execution that is better and less cost for us from that suggested in the client's designs.	execution aspect, less cost	Factor affect the Modified Design
Mostfa Othman	For example, if the contractor discovered that the road path crosses a land owned by a citizen, the contractor may suggest to transfer the road centerline to avoid problems with this citizen because the procedure of transfer the ownership of such land from a citizen to the government takes a very long time	demographical aspects, saving time	Factor affect the Modified Design
Mostfa Othman	For example, the contractor may suggest to change a bridge designed by the Design office into culvert, both approximately achieve the same goal but the execution of the culvert comparing with bridge is easier and has a low cost.	cost and time saving	Factor affect the Modified Design
Suggestions to enhance the design			
Abdulmona'm Jamal	Yes. I think that designer should has executive experience at least 5 years before he performs any design.	Technical experience	Technical Enhancement
Nour aldin Ata	I think that the design engineer should visit the site from time to time, this will give him a better imagination about the work and enhance the sense for discovering design errors.	Design office in site	Technical Enhancement

Hussien Mahmoud	I prefer to reorganize the design approval process by making the designer directly communicate the consultant engineer to avoid the misunderstanding of the designer point of view.	enhance the communication	Managerial enhancement
Ahmed Dahi	Yes. I think that our company is responsible on training for the technical office engineers in order to always be up to date and produce design with less time and high quality.	Training the designers	Managerial enhancement
Nour aldin Ata	Moreover, preparing shop drawing or as built drawing or proposals should be done according to time schedule in order to organize the work of technical office,	Time schedule	Managerial enhancement
Nour aldin Ata	Yes. The process should be with better coordination. A comprehensive revision of the project designs should be performed before starting the execution of project not waiting the time of execution to do the job	Coordination, Design Revisions	Managerial enhancement
Mostfa Othman	Yes. I think the design process should be integrated with saving more time. The process of design modification is very time consuming. I should perform the proposed modification then send it to the consultant to review, the consultant may propose another modification or he approve the design and send it to the client for final approval.	Integrating, Saving more time	Managerial enhancement
Amro Sleem	Yes. I think that an engineer should take the responsibility of organizing the work in the technical office.	Organizing the work, Time Schedule	Managerial enhancement
Mohammed Abu-hashem	Yes, the process of design should be coordinated very well especially coordinating the structural and MEP designs with the architectural design. I think all drawings should be coordinated at once by a specialized engineer to avoid wasting time and money at construction stage, such conditions usually occurs in all construction projects and some has extreme bad effect on the whole design. At construction stage, if the execution of some element was wrong due to errors in drawings, the client will prefer to change the whole design on doing maintenance according to original one considering the cost of maintenance process.	Coordination of all designs at once	Managerial enhancement
Technology Tools			
Hussien Mahmoud	I am interested in Autodesk Infraworks and I am trying to learn it.	3D design software	BIM tool
Amro Sleem	Autocad. 3D max. Autocad Civil 3D.	2D drawing software, rendering software, 3D design software	Not a BIM tools
Hussien Mahmoud	SOKKIA Link which used to transfer surveying data from surveying tools (GPS, Total station). Autocad. Microsoft Excel. Autocad Civil 3D.	Assistant softwares, 3D design softwares	Not a BIM tools
Abdulmona'm Jamal	AutoCad. Microsoft office Excel. Civil 3D. Earthwork.	2D drawing software, 3D design software, Assistant software	Not a BIM tools

Malek Alasyote	Autocad. Microsoft Excel. Autocad Civil 3D. Earthwork	2D drawing software, 3D design software, Assistant software	Not a BIM tools
Ahmed Dahi	Autocad. Microsoft Excel. Autocad Civil 3D.	2D drawing software, 3D design software, Assistant software	Not a BIM tools
Nour aldin Ata	Earthwork. Autocad. Microsoft Excel. Autocad Civil 3D.	2D drawing software, 3D design software, Assistant software	Not a BIM tools
Mostfa Othman	Earthwork. Autocad. Microsoft Excel. Autocad Civil 3D. SAP2000.	2D drawing software, 3D design software, Assistant software, Structural design software	Not a BIM tools
Experience with BIM			
Abdullatif Adam	No I did not use it before.	has no experience	Not Used
Abdulmona'm Jamal	No, we do not use it.	has no experience	Not Used
Amro Sleem	I know little about it. But I did not use it before.	know little without experience	Not Used
Hussien Mahmoud	No, but I am interested in Autodesk Infraworks and I am trying to learn it.	no real experience, Training	Not Used
Malek Alasyote	No I did not use it before. But I read about it.	has no experience	Not Used
Ahmed Dahi	I hear about it but I did not use it before.	has no experience	Not Used
Nour aldin Ata	No I did not use it before.	has no experience	Not Used
Mostfa Othman	No I did not use it before.	has no experience	Not Used
Ala Bakkar	No I did not use it before.	has no experience	Not Used
Mohammed Abu-hashem	No I did not use it before,	has no experience	Not Used
Perception of BIM			
Ahmed Dahi	Yes it is true but I think it is more important in the design because it takes a long time but the time plan and cost you can use software like Primavera to track them.	more important in design, use alternative technology in construction stage	Negative
Abdulmona'm Jamal	No. I think it is very hard to perform such technology because our firm does not have the skillful and experienced people in this technology	can not be implemented	Negative

Hussien Mahmoud	No. because our firm is divided managerially and functionally without any coordination between the functional departments. Also there is no actual success case of BIM implementation in the market or among the firm competitors. If the firm see success case, I think it will consider BIM implementation	can not be implemented	Negative
Abdulmona'm Jamal	Sure. I support any revolutionary thinking. Any contractor seeks making highest profit in shortest time with highest quality. Therefore, any process or technology tools improves achieving this goal will be very welcome.	BIM potential	Positive
Ala Bakkar	Yes. I think BIM is the future of construction industry, the engineers association here organized more than one event related to BIM.	future of construction, starts to be mature	Positive
Mostfa Othman	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Hussien Mahmoud	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Nour aldin Ata	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Mohammed Abu-hashem	I think this technology is the future of design process because it gives you a wide range of enhancement	potential of BIM	Positive
Ahmed Dahi	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Abdullatif Adam	Surly I will accept the change because every engineer should develop himself with new skills and capabilities.	Welcome the idea of implementation	Positive
Malek Alasyote	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Hussien Mahmoud	but I am interested in Autodesk Infraworks and I am trying to learn it.	self training on BIM	Positive
Amro Sleem	Sure I will be very welcome.	Welcome the idea of implementation	Positive
Possibility of Implementation			
Malek Alasyote	I think it is possible especially in the KSA, it is one of the largest construction market in the Middle East. Also, the market contain a multinational companies that already use BIM in other countries. I think the perception of BIM is positively increasing. But it will take some time to adopt BIM as national strategy	Possible	possibility of implementation
Hussien Mahmoud	No. because our firm is divided managerially and functionally without any coordination between the functional departments. Also there is actual success case of BIM implementation in the market or among the firm competitors.	Not Possible	possibility of implementation

Nour aldin Ata	It is difficult so say that BIM implementation is possible or not. The implementation means to change the industry style for more than 30 years. However, to implement BIM in our company the management should be convinced with the efficiency of such technology. Moreover, the other parties should also adopt BIM.	Neutral	possibility of implementation
Ahmed Dahi	I think it is possible but the adoption should be by all parties. If I adopt BIM as a contractor the consultant may be not and here new problem will arise. Anyway, I think BIM is more important in the technical office more than in execution work.	Possible if adopted by all	possibility of implementation
Amro Sleem	Yes. It is possible but I don't know how.	Possible	possibility of implementation
Ala Bakkar	Yes. I think BIM is the future of construction industry,	Possible	possibility of implementation
Mohammed Abu-hashem	I think this technology starts to be mature in the market but still it needs more time	Possible	possibility of implementation
Abdulmona'm Jamal	No. I think it is very hard to perform such technology	Not possible	possibility of implementation
Mostfa Othman	I think it is possible but the government as a client should adopt this strategy first. For example, the ministry of transportation as a client does not approve any quantity surveying if it is not produced by Earthwork program.	Possible if adopted by client	possibility of implementation
Abdullatif Adam	Yes. I think it is possible, each contracting firm seeks to decrease the cost and time with better quality. So any technology will achieve this goals will be considered by the contractors.	possible	possibility of implementation
Potential of BIM			
Abdulmona'm Jamal	highest profit	highest profit	Financial Issues
Abdulmona'm Jamal	shortest time with highest quality.	highest profit	Financial Issues
Mohammed Abu-hashem	saving time in doing designs	saving time	Managerial Issues
Mohammed Abu-hashem	better coordination of design process.	better coordination	Managerial Issues

Mohammed Abu-hashem	time saving	time saving	Managerial Issues
Nour aldin Ata	I think at design approval stage (stage of shop drawings submittals) because this stage is the most one that needs to modify the designs and requires to be in continuous touch with the consultant and client.	better communication	Managerial Issues
Ahmed Dahi	I think it is more important in the design because it takes a long time	saving time	Managerial Issues
Malek Alasyote	I think it can overcomes the problem of documentation considering that every thing is done in one model and that model is saved into a database and shared among all project parties.	better documentation	Managerial Issues
Nour aldin Ata	Yes, because you deal with one model to do everything, you do not have to split the work like when using Autocad.	less fragmentation	Technical issues
Hussien Mahmoud	Also you can producing a better quality designs in terms of producing 3D models, images and videos.	better quality of design	Technical issues
Mostfa Othman	I think the existence of data base is very good and make the process easier.	better documentation, less fragmentation	Technical issues & Managerial Isssues
Hussien Mahmoud	providing solutions for SSD – Stopping Sight Distance- and PSD- Passing Sight Distance- errors in design.	providing solutions for design errors	Technical issues
Hussien Mahmoud	clash detection,	clash detectin	Technical issues
Mohammed Abu-hashem	accurate quantity surveying, clash detection	acuurate quantity surveying, clash detection	Technical issues
Hussien Mahmoud	determination the suitable road path among alternatives	providing solutions for design	Technical issues
Mohammed Abu-hashem	decreases the probability of human errors	less design errors	Technical issues
Factors that affect BIM implementation			
Mostfa Othman	our company will be convinced to adopt BIM if the adoption leads to increase the efficiency of the company's design office considering that the top management thoughts about the design office that it has a week performance.	increase the effeciency	Motivators
Malek Alasyote	the government will take the big role in this change because it seeks to develop the country with lower cost and by more efficient project which can be achieved through BIM adoption.	client role	Motivators
Malek Alasyote	Also, the market contain a multinational companies that already use BIM in other countries	competitors	Motivators

Malek Alasyote	I think it is possible especially in the KSA, it is one of the largest construction market in the Middle East. Also, the market contain a multinational companies that already use BIM in other countries	Market	Motivators
Abdulmona'm Jamal	The only thing can motivate our firm and all firms in this country is that the adoption of BIM be requested by the government.	client role	Motivators
Hussien Mahmoud	if the firm see success case, I think it will consider BIM implementation.	availability of success case	Motivators
Amro Sleem	Yes, it has a big role because it is the most important client to the construction and contracting firms.	client role	Motivators
Hussien Mahmoud	Yes, I think it has very influence role. It's the client and the firm seeks to satisfy its need. If the government put BIM as a requirement, many firms will to transform into BIM implementer.	client role	Motivators
ohammed Abu-hashem	the designer is the most influenced or big-beneficiary of BIM adoption	Designer	First Mover
Abdulmona'm Jamal	The only thing can motivate our firm and all firms in this country is that the adoption of BIM be requested by the government.	client	First Mover
Mostfa Othman	I think it is possible but the government as a client should adopt this strategy first	client	First Mover
Hussien Mahmoud	If the government put BIM as a requirement, many firms will to transform into BIM implementer.	client	First Mover
Abdullatif Adam	I think the contracting firms will be the first mover because they are the big winner of higher profits.	contractor	First Mover
Ala Bakkar	I think the client has the most powerful role in adopting BIM, if the client put BIM as a requirement to choose the suitable contractor, you will see many firms turn into BIM adapter.	client	First Mover
Malek Alasyote	the government will take the big role in this change because it seeks to develop the country with lower cost and by more efficient project which can be achieved through BIM adoption.	client	First Mover
Ahmed Dahi	Absolutely the client. In KSA the client has a huge authority and can force the companies to adopt BIM.	client	First Mover
Abdullatif Adam	I think will accept the decision under conditions. One of important conditions that the contractor should train the client and consultant teams to be familiar with changes.	train the other parties	Expected Changes in Duties
Abdulmona'm Jamal	because our firm does not have the skillful and experienced people in this technology.	unavailability of skillful people	Barriers
Hussien Mahmoud	Also there is no actual success case of BIM implementation in the market or among the firm competitors.	unavailability of real success case	Barriers

Nour aldin Ata	in our company the management should be convinced with the efficiency of such technology. Moreover, the other parties should also adopt BIM.	Top management committement	Barriers
Nour aldin Ata	It is difficult so say that BIM implementation is possible or not. The implementation means to change the industry style for more than 30 years	General conditions of the market	Barriers
Ahmed Dahi	I think it is possible but the adoption should be by all parties. If I adopt BIM as a contractor the consultant may be not and here new problem will arise.	adoption by one party of the process	Barriers
Mohammed Abu-hashem	The number of companies that adopt BIM in the market is important factor to encourage the firm to adopt BIM	maturity of BIM in the market	Barriers
Mohammed Abu-hashem	the flexibility of BIM application to be compatible with other applications like 3D MAX is other important factor at this time.	Flexibility of BIM applications	Barriers
Hussien Mahmoud	our firm is divided managerially and functionally without any coordination between the functional departments.	organizational structure of the firm	Barriers
Documentation Method			
Mohammed Abu-hashem	each drawings out from the design office to the consultant office has a unique code with an indication to the number of times that this drawing has been submitted for approval.	Coding system, Revisions	systematic method
Mohammed Abu-hashem	There is a position in design office called document controller	Specialized employee	systematic method
Ala Bakkar	Our office has a document controller position, his job is to organize and document all important documents and memos and drawings	Specialized employee	systematic method
Ala Bakkar	Every shop drawing submitted to the client with a request that clarifies the request goal and its date and time. The document controller should save a copy for each one IN or OUT from the office, specially the request of drawings submittals. Therefore, relating to hard copy there is system and special employee for the job,	specialized employee, systematic documentation for hard copies	systematic method
Amro Sleem	I keep a softcopy in my desktop computer. I use a coding system in naming my drawings. Each project has its own folder and each folder contains subfolders named by a names indicates its function like (profiles, level sheets, images, quantities …etc) and every drawing named by its function and the date of producing this drawing. So I can find the latest modified drawing when I need it.	Naming system	Personal method
Malek Alasyote	The approved designs are saved as soft copy in engineers desktop and as hard copy in the project files.	traditional documentation	Personal method

Ahmed Dahi	I use a system for documentation by naming the folders on my laptop. Each part in the project has its own folder like (bridges, culverts, retaining walls, time plan .. etc). Also, I keep a hard copy of the approved design only in a special folder. In addition, the technical office has its own copies of designs	naming system, traditional documentation	Personal method
Nour aldin Ata	I keep my designs on my laptop and a backup copy on Flash memory that updated weekly.	backup, traditional documentation	Personal method
Nour aldin Ata	. Each project has a folder named by the project name, the folder contains subfolder named by the job name for example (quantity takeoff, structural detailing of culverts, road's profile …etc). The company do not has a documentation system, every engineer should document by his own way.	naming system, traditional documentation	Personal method
Mostfa Othman	Actually there is no documentation system in our firm. I use my own system in documentation process. I keep the work of each month in separate folder, for example, there is a folder named (January,2016) contains a subfolder named like (culvert designs, retaining wall…. Etc). Also I make a backup copy on external hard disk every week.	traditional documentation	Personal method
Hussien Mahmoud	I use email iteratively to upload a backup copy of my designs.	backup	Personal method
Hussien Mahmoud	I keep a soft copy for each design.	traditional documentation	Personal method
Ala Bakkar	but relating to soft copies of my designs I used the traditional way by saving the files in my pc and backup it a once	traditional documentation	Personal method
Abdulmona'm Jamal	Designer, consultant, contractor and the client. Each party has his own soft and approved hard copy.	traditional documentation	Personal method
Abdullatif Adam	Each project has its own files. I keep a soft and hard approved copy.	traditional documentation	Personal method
Importance of Documentation			
Mostfa Othman	Actually I kept it in order to show the top management our actual work. There is an impression that the design office performance is slow and the design engineer does not perform a lot of job. The old design show them that we work on one element more than one time due to modifications.	prove the designer effort	Importance of Documentation
Ala Bakkar	Yes you may need to review it, for example if a change order from client asks to do some changes in some element that actually finished in site, then you need to review the design of this element and note the effect of change. Also after finishing all project's works you must submit as built drawings so you need to review the designs from shop drawings that are documented.	review the design in case of change order, project delivery stage	Importance of Documentation

Mohammed Abu-hashem	The designer may need to review the designs in case of change orders or in case of conflict between parties. However, it is very important to document the meeting with client because the whole design process depends on his requirements.	review the design in case of change order, save the rights of each project party	Importance of Documentation
Problems of Documentation			
Amro Sleem	No, there is no documentation system in our firm.	No documentation system	Organizational
Hussien Mahmoud	No, there is no documentation system in our firm.	No documentation system	Organizational
Abdulmona'm Jamal	Our firm does not have a documentation system.	No documentation system	Organizational
Malek Alasyote	Actually, my firm does not has a documentation system	No documentation system	Organizational
Mostfa Othman	Actually there is no documentation system in our firm	No documentation system	Organizational
Abdullatif Adam	No, my firm does not has a documentation system. Each engineer document his files by his own method.	No documentation system	Organizational
Nour aldin Ata	The company do not has a documentation system	No documentation system	Organizational
Ahmed Dahi	The company does not has a documentation system	No documentation system	Organizational
Ahmed Dahi	No. I think this method is suitable for me.		No problem
Abdullatif Adam	No, I do not have problems with this method. Anyway, if I lost a file, I will take a copy from the contractor.		No problem
Mohammed Abu-hashem	No, but this depends on the commitment degree to the documentation system. More commitment indicates more problem avoidance	depends on commitement	No problem
Amro Sleem	No. I used to use this method of documentation and I find it suitable to me.		No problem
Mostfa Othman	No. I used to use this system from years ago and I found it easy and comfortable.		No problem
Mostfa Othman	I found this system suitable to me and I can found the work that I need easily.		No problem
Abdullatif Adam	Yes it is easy to find it again because as I said each project has its own files.		No problem
Malek Alasyote	when the designs becomes so many, it becomes harder to gets it again especially if that happened after long period of time.	hard to get the design again	Facing Problems
Hussien Mahmoud	existence of several copy of the same design.	uneeded copy of the same design	Facing Problems
Abdulmona'm Jamal	Yes. The hard copy of design is a paper and it may be lost. Moreover, the soft copies also can be lost if the computer of the designer failed. Unless the designer make his own backup copies for the designs.	possibility of losing files	Facing Problems

Hussien Mahmoud	The designer may print out a not approved copy and transfer it to be executed. Such mistake may be extremely costly and waste time	execution mistakes	Facing Problems
Abdulmo na'm Jamal	When we need to do some modifications it may be hard to find the needed design	hard to get the design again	Facing Problems
Malek Alasyote	Yes, as I said before with more designs the current method becomes annoying for the designer and for the executive engineer during the work and later in the process of delivering of project.	Final delivery of the project	Facing Problems
Nour aldin Ata	Absolutely yes, as I said here we deal with more than one project and the amount of work is large, therefore with time the chances to loose files increases.	possibility of losing files	Facing Problems
Ala Bakkar	With soft copies documentation yes, I am always worried about losing my files, I think a recovery server or data base should be available for the purpose of soft copies documentation.	losing files	Facing Problems
Communication method			
Abdullat if Adam	In most cases I use face to face meetings and telephone to communicate with the contractor and designer.	face to face meetingm telephone	Primary
Abdullat if Adam	Yes, there are a periodic meetings with the client.	periodic meeting	Primary
Ahmed Dahi	My communication with site engineer and design engineer is continuous all the time. We set in the same office therefore we always discuss the work and its arrangement.	face to face meeting	Primary
Abdulmo na'm Jamal	prefer to use face to face meetings to communicate with the other parties,	face to face meeting	Primary
Nour aldin Ata	My communication in most times is with my manager (Technical office manager), he asks me to do a job or prepare proposal for execution of such project element. We communicate mainly by face to face	face to face meeting	Primary
Moham med Abu-hashem	At the beginning of design process, it is preferred to use face to face meetings	face to face meeting	Primary
Ala Bakkar	With contractor in most cases by face to face meetings, mobile	face to face meeting, mobile	Primary
Ala Bakkar	I communicate with the client by emails,	emails	Primary
Ahmed Dahi	I communicate the consultant using the mobile calls and face to face meetings	face to face meeting, mobile	Primary
Malek Alasyote	With site engineers I usually use mobile to communicate to explain some design details. With the consultant I use face to face meetings to discuss the design details and the email to transfer the files	mobile face to face meeting	Primary

Hussien Mahmoud	In most times I used telephone	mobile	Primary
Mostfa Othman	With the consultant I contact him face to face in most cases	face to face meeting	Primary
Mostfa Othman	With site engineer and the project manager we always be in touch we set in the same office which make the communication easier	face to face meeting	Primary
Amro Sleem	I contact the specialized person by emails,	email	Primary
Mohammed Abu-hashem	at the stage of structural and MEP design you can use the emails to communicate if the Architectural drawings is clear.	emails	Secondary
Nour aldin Ata	meeting or emails.	meetings and emails	Secondary
Abdulmona'm Jamal	telephone calls could be helpful but in a little way.	telephone	Secondary
Ahmed Dahi	we use a formal communication in the cases that has a high risk. For example, in the case of being late in project time, the consultant send a formal memos that alerts the contractor about the time of the project and asks for developed time plan.	memos	Secondary
Abdullatif Adam	Also the consultant should write a weekly report and send it to the client.	reports	Secondary
Hussien Mahmoud	rarely face to face meeting	face to face meetings	Secondary
Amro Sleem	telephone or face to face meetings.	face to face meeting, telephone	Secondary
Goals of communication			
Abdullatif Adam	The communication occurs with contractor in all stages of design in order to approve the designs and make the needed modifications	Design Approval, Ask for modifications	Goals of Communication
Abdullatif Adam	in order to let the client know where we are now.	inform the client with updates	Goals of Communication
Amro Sleem	In some cases I have to explain about some details at design drafting phase	Ask for Explanation	Goals of Communication
Hussien Mahmoud	to ask for explanation about some details.	Ask for Explanation	Goals of Communication
Malek Alasyote	I usually use mobile to communicate to explain some design details.	Ask for Explanation	Goals of Communication
Malek Alasyote	With the consultant I use face to face meetings to discuss the design details and the email to transfer the files	Dicuss the design, Transfer the files	Goals of Communication
Malek Alasyote	The communication with the client is rare in the design unless there is a special case such as problems with citizens.	Problem solving	Goals of Communication

Ahmed Dahi	If there is electrical work in the project, an electrical engineer coordinate with site engineer and the project manager about the time of performing the electrical work. Also if there is obstacles that have relation with electricity, we send a formal memo to the client to redirect it to the electricity company which in order hire a contractor to fix the conditions.	Coordination of work	Goals of Communication
Nour aldin Ata	. My communication in most times is with my manager (Technical office manager), he asks me to do a job or prepare proposal for execution of such project element.	coordination of work	Goals of Communication
Ala Bakkar	Yes, during the execution of the project we should be always in touch with client, every day we have to submit a report of daily progress, also there is a weekly face to face meeting with client and contractor, in this meeting the progress of the project and its problems are discussed.	inform the client with updates, Problem solving, Monitoring project progress	Goals of Communication
Mohammed Abu-hashem	with client face to face meetings is better because you can gain the other point of view in a better way	Collaborative thinking	Goals of Communication
Mohammed Abu-hashem	for coordination with client and interior designer and in the case of problem solving it is better to communicate face to face.	Problem solving, coordination of work	Goals of Communication

Appendix (4)

Questionnaire Form for Case 2 firm Employees

Name …….

Job title …….

Employer…….

Years of experience ……..

Email ……

Date of Interview ……

1. Do you think that the design process (from shaping the idea of project to construction stage) has any problems? If yes, what are the main problems that you are facing during the design process?

هل تعتقد ان عملية التصميم (من بداية تشكل فكرة المشروع حتى مرحلة الانشاء) تواجه مشاكل ؟ اذا كان نعم ما هي هذه المشاكل ؟

2. Could you please give us a brief description of the design process flow?

باختصار، صف المراحل التي يمر بها التصميم ؟

3. What are the technology tools that you are using in producing yours design?

ما هي البرامج المستعملة في عملية التصميم ؟

4. What are the positive potentials of these tools against the traditional ways of design like AutoCad and any 2D design tool?

بماذا تتميز هذه البرامج عن البرامج التقليدية المستخدمة في انتاج التصاميم مثل اتوكاد ؟

5. How do you think about using this tools (tools that you are using in design) in the construction industry? And what are the barriers of using this tools?

ما رأيك في استعمال هذه البرامج في قطاع الانشاءات بشكل عام ؟ ما الذي قد يعيق انتشار هذه التكنولوجيا ؟

جامعة النجاح الوطنية
كلية الدراسات العليا

بحث تطبيق تكنولوجيا نمذجة معلومات المبنى في مرحلة التصميم للمشاريع الانشائية (المملكة العربية السعودية كحالة دراسية)

اعداد
معتصم ناجح غانم

إشراف
د. ايهاب حجازي
د. أحمد صالح

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في الإدارة الهندسية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.
2017م

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الملخص

تنال تكنولوجيا نمذجة معلومات المباني (BIM) اهتماما كبيرا في مجال البحث العلمي المختص بإدارة العمليات الانشائية حول العالم، بحيث تشير عدة تقارير ان تبني هذه التكنولوجيا يتسع في مجال الانشاءات وخاصة في الولايات المتحدة الأمريكية والمملكة المتحدة، وهو الامر الذي يستدعي توقع انتشار هذه التكنولوجيا قريبا في الشرق الأوسط.

الهدف من هذا البحث كان اجراء عملية تقييم للمراحل التي يمر بها تصميم الأجزاء المراد انشائها، لتحديد مشاكل هذه العملية واستكشاف دور تكنولوجيا الـ (BIM) في معالجة هذه المشاكل للوصول الى عملية تصميم افضل، لذلك تم اختيار شركتين مختلفتين في المملكة العربية السعودية كحالات دراسية لإجراء مقابلات مسجلة صوتيا مع مختصين في مجال تصميم وانشاء الطرق في الحالة الاولى، وتوزيع استبيانات على مصممي الشركة الثانية التي تعمل في مجال تصميم وانشاء المباني المعدنية لتقييم الوضع الراهن لعملية التصميم.

تم اعتماد طريقة البحث النوعي (Qualitative Research) في عمليات جمع و تحليل البيانات، لذلك كان من الأفضل استخدام برنامج حاسوبي يوفر ادوات تحليل جيدة ويسمح بالتعامل مع كمية كبيرة من البيانات مثل برنامج (QDA Miner) الذي تم استعماله في هذا البحث.

أشارت النتائج في الحالة الاولى الى وجود مشاكل في الطريقة الحالية المتبعة في التصميم من حيث اهدار الوقت، التواصل خلال عملية التصميم، عملية توثيق التصاميم ومتابعتها عند

اجراء التعديلات بالإضافة الى مشاكل اخرى مثل تكرار العمل وانخفاض الانجاز، كما بينت نتائج الحالة الثانية مشاكل مشابهة في مراحل التصميم التي لا يتم تطبيق فيها تكنولوجيا (BIM).

في نهاية البحث تبين ان هذه المشاكل يمكن معالجتها من خلال تبني تكنولوجيا (BIM) بالطريقة الصحيحة –كما وضحت نتائج استبيانات الحالة الثانية مع وجود الشواهد من الدراسات السابقة – مع مراعاة وجود عدة عوامل قد تعيق تبني مثل هذه التكنولوجيا، ايضا تم تقديم مقترحات ليتم مراعاتها في الابحاث القادمة.