

Ministry of Higher Education
and Scientific Research
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College of Engineering



Using Building Information Model in Safety Analysis for Iraqi Construction Projects

**A Thesis Submitted to the Council of College of Engineering
University of Diyala in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Civil
Engineering**

by

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2020 A.D

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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Dean of College of Engineering / University of Diyala

Date:

DEDICATION



*Modestly, This Work is Dedicated to
My Parents,
Brothers,
My Wife,
Relatives and Friends*





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First and foremost, all sincere thanks are to Almighty Allah for his generosity and kindness without which this work could not have seen. I would like to express my great thanks and gratitude to my wonderful province (**Diyala**) and all the people of this governorate for their support, help and love throughout the period of my studies. The light words of thanks and gratitude also dedicated to my knowledgeable supervisors **Dr. Wadhah Amer Hatem and Asst. Prof. Nidal Adnan Jasim** for their illuminating instructions and guidance throughout writing this thesis. Thanks are also extended to Dean of College of Engineering as well as the teaching staff of the College of Engineering, University of Diyala, Dept. of civil engineering. Also, I am wholehearted to beloved colleagues namely **Marwan Ghazai Al- Tai, Omer Karim Al-Zuhairy and Saif Al- Izzy** for their sincere encouragement and help. I am no less indebted too to great **Eng. Omer Salim and Dr. Salman Azhar** for their invaluable remarks and generous scientific support. Also, I am indebted too to **safety managers** for their guidance and sincere help.

Researcher

ABSTRACT

Using Building Information Model in Safety Analysis for Iraqi Construction Projects

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The construction industry is among the most dangerous industries in the world. The shortage of governmental support in urging the application of safety measures as well as the weakness of the methods used to identify the risks are the main reasons for the increase in the number of casualties in Iraqi construction projects. The safety risk assessment approach is based on 2D drawings and handwritten, fragmented and uncoordinated notes.

At the present time, with the development of technology, there has been a noticeable interest in the use of modern technologies in the construction industry. One of these techniques is the technology of the Building Information Modelling (BIM), which allows the integration of all information related to the project in the 3D model and makes the work in single environment. The aim of this thesis is to make possible the use of modern techniques in the field of occupational safety, where researcher aims at a set of objectives. The main objective is to use the BIM technique to find a mechanism that allows accurate identification of safety hazards by adopting the principles of 3D visualization, 4D simulation, then comparing the results obtained with traditional methods, the impact of applying safety measures on the project schedule and the cost of the project as a whole, and the impact of the intensity of daylight light on the safety of workers in the workplace. Safety requirements were adopted in accordance with OSHA (occupational safety and health administration) regulations and the Iraqi Safety Blog.

The idea of the thesis is applied to two cases studies. The first case study was carried out in the school buildings sector. The second case study was carried out in the oil sector.

The researcher comes to conclusion with a set of results. At first, safety experts explain that the platform prepared by researchers is more accurate in identifying risks because it helps to create a virtual environment very similar to the real environment and can be used in the preparation of training plans for workers and increase communication between stakeholders. Second, the application of occupational safety does not depend solely on the use of safety equipment but must precede that safe and secure planning of the project time schedule. The thesis shows that the application of safety measures to case study I and II lead to an increase in the total duration of the project (13 days). The thesis shows that the application of safety regulations to a case study I leads to an increase in the cost of the project according to traditional approach by (1.19 %), while the increase in the project cost according to BIM approach by (1.615 %). For case study II the cost of the project according to the traditional approach increased by (0.426 %) while according to BIM approach by (0.563 %). The study also concluded the efficiency of the BIM technology in calculating the analysis of daylight to verify whether the indoor lighting is safe for workers or not.

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LIST of ABBREVIATIONS

Abbreviations	Explanation
BIM	Building Information Modeling
CAD	Computer Aided Design
2D	Two Dimension
3D	Three Dimension
4D	Four Dimension
5D	Five Dimension
6D	Six Dimension
7D	Seven Dimensions
8D	Eight Dimensions
MEP	Mechanical, Electrical, and Plumbing
OSHA	Occupational Safety and Health Administration
ICT	Information and communications technology

CHAPTER ONE

Research Introduction

1.1 Introduction

In the field of occupational health and safety, safety engineers generally rely on 2D drawings to identify site-specific safety hazards and this requires sufficient experience in fully visualizing the work details and site-specific risks.

The employment of BIM technologies can affect in improving occupational safety by means of connecting the safety issues to construction planning, providing safety plans, methods to manage, visualizing up-to-date plans, and site status information. The use of BIM encourages other project stakeholders to share in both planning and risk assessment (Sulankivi et al, 2012).

This chapter, provides an introductory overview to explain the research's background, the research problem and justifications. In addition, the research hypothesis, the research aim and its objectives are explained. The research scope and limitations and research methodology are specified. Furthermore, previous studies are also clarified in this chapter.

1.2 Background

The construction industry is among industries which are widespread at the global level. The construction industry has a series of sequential tasks that start from the idea of the project, the feasibility of its implementation to the planning and design stages. Then, the contractor is chosen for the task and then to the stage of the physical building of the project to the stage of delivery according to the specified specifications (Ghazali et. al., 2016). The most important characteristic of the construction industry is that the dynamic nature and its complexity is widely recognized, unlike the manufacturing industries which have a specific work mechanism.

Therefore, this complexity creates many problems inside the site, the most important of which is safety (Zhang et al., 2013).

Previous accident assessments indicate that there are main sources of accidents in construction job-sites includes falling from the edges and heights, which is the most dangerous types of accidents or injuries due to hitting by fallen bodies, in addition to accidents of machines and electric shocks (Yilmaz, 2014). In addition, the OSHA confirms through statistics recorded in 2017 that out of the (4674) fatalities there are (971) fatalities in the construction sites, where the statistics showed that about (381) fatalities were from falling with percent more than (39%).

More recently, technological development has given a new era to the construction industry, where the development of ICT (information and communication technology) has contributed to the digitization of all information about structural and architectural plans by computer (Azhar et al, 2011).

Building Information Modeling is a part of ICT that can be utilized in the construction industry. This technique is good because it has tools and methods that can help improving safety (Puerto & Clevenger,2011).

1.3 Research Problem and Justifications

There are many problems that lead to a high risk of accident occurrence. The research problems are summarized in the following:

1. The high rates of injuries in the workplace indicate a significant weakness in the application of safety measures, which leads to the loss of workers with experience as well as the loss of equipment, which means heavy financial losses.
2. Weakness in identifying risks because of relying on traditional approach which depends on using 2D schemes and depends on experiences and the weakness in the analysis and management of safety issues of the projects.
3. Need to use modern technologies like BIM approach based on concepts of visualization, simulation and animation to mitigate risks in workplaces through utilizing a single dynamic BIM model which helps to accurately identify the risks in early stages (pre-construction stage) and use the appropriate safety equipment at the right time and place and prevents conflicts. This is necessary to prevent the additional costs of accidents, correction and delay in construction projects.

1.4 Research Hypothesis

There is a necessity to improve safety analysis and management in Iraqi construction projects through the use of BIM technology and relying on its principles in 3D visualization and 4D simulation.

1.5 Research Aim and Objectives

This research aims to study the possibility of analyzing the safety issues of Iraqi construction projects by using BIM technology. Achieving current aim, there are some objectives must be obtained as follows:

1. Find the appropriate mechanism (an applicable mechanism which depends on available software instead of relying on traditional methods based on 2D drawings) in analyzing the safety situation in the construction projects and provide a safe environment for human, equipment and physical components.
2. Create a connection between construction planning and safety issues in single model.
3. Comparing traditional approach used in identifying hazards in the construction industry which depends on using 2D schemes with BIM approach which depend on linking the 3D model with a time schedule of the project (4D).
4. Knowing the impact of applying safety measures on the project time schedule and its cost.
5. Studying the effect of daylight intensity on workers' safety.

1.6 Research Scope and Limitations

The scope and limitation of this research include:

1. The study concentrates on studying the safety issues at the Iraqi construction sector.
2. Two case studies are studied. The first case study is a school building, which is the most common buildings and its design similar to many buildings in Iraq. The second case is in the sector of the Ministry of Oil which is the project of the gas treatment unit and is a special project.
3. Studying safety during the planning and design stage (pre-construction stage) of the project and do not address safety studies in the operation and maintenance stage.
4. Temporal limitation: the research period is one year 2018-2019.

1.7 Brief Methodology of Research

The research methodology mainly included two parts:

Part one (theoretical): A comprehensive literature review concerning the BIM technology and concept of safety issues. Besides, the accidents cause in the construction industry, traditional approach used in safety of the projects and the effect of utilizing BIM on the safety of the projects are shown. A numbers and types of accidents was specified in Iraq according to statistics provided by the Ministry of Labor and Social Affairs.

Part two (practical):

The practical part of research is including:

1. The case studies are selected and modeled by utilizing (Revit) software.
2. Export to (Synchro software) to create (4D models) and applying safety regulations from OSHA and Iraqi safety blog in these models.
3. Make the comparison between traditional approach which depends on 2D schemes and BIM approach, integration between BIM and Augmented reality technology.
4. Studying effect of daylight intensity.
5. Finally, discussions are made as well as the conclusions and suggested recommendations.

Figure (1.1) explains brief research methodology.

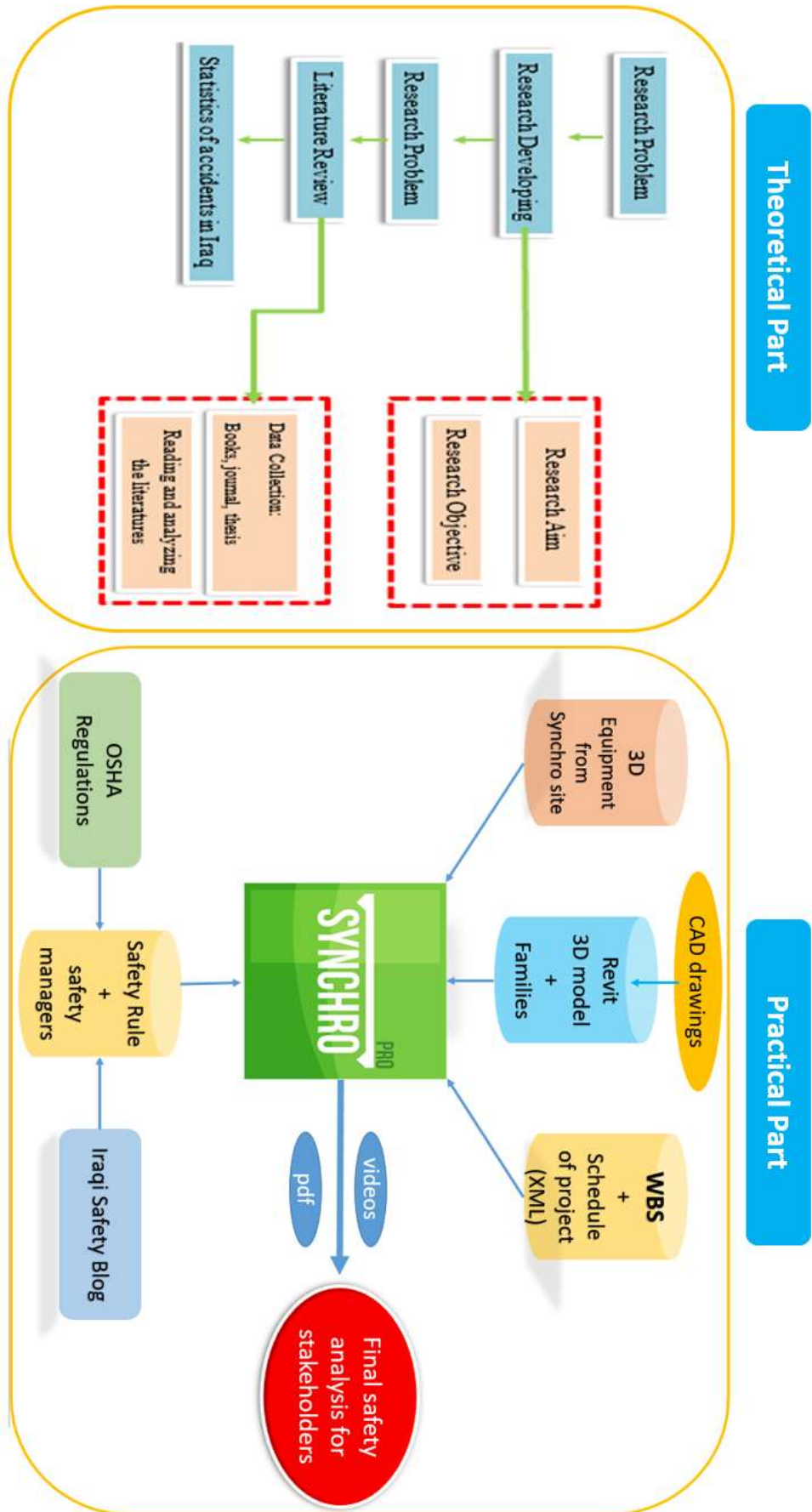


Figure (1-1): Research methodology (researcher)

1.8 The Structure of Thesis

The thesis is divided into six chapters: A summarized description of the chapters is explained follows.

Chapter One: Thesis Introduction

It introduces the background of the thesis, thesis problems and justification, thesis aims and objectives, thesis limitation, a brief explanation of the thesis methodology, and previous studies.

Chapter Two: Literature Review

This chapter reviews the definitions of BIM, dimensions, and popular platforms of BIM. Then, this chapter explains accidents in the construction industry and its causes. Finally, this chapter shows the traditional approach used for safety analysis and significant roles of BIM in safety analysis and management according to the previous researchers.

Chapter Three: Thesis Methodology and Experimental Work

This chapter offers the methodology plan of the research, details of accidents cases in Iraq, data collection from field investigations related to the cases studied projects and creating computerized models.

Chapter Four: Safety Analysis in Iraqi Construction Industries

This chapter shows comparisons between the traditional approach used in identifying construction hazards which depends on 2D schemes and BIM approach which in turn depends on a single dynamic model (4D) in identifying the hazards. It also explains actual processes used in Iraqi construction projects.

Chapter Five: Results and Discussions

This chapter discusses the results after applying the safety measures in construction industries, including the effect of these measures on the cost and time of the projects.

Chapter six: Conclusions & Recommendations

This chapter shows major conclusions and important recommendations, as well as suggestive future studies.

1.9 Review of Previous Studies

Table (1-1) summarizes the previous studies which related to safety analysis and management.

Table (1-1): Review of Previous Studies

No.	Researcher	The Work
Safety		
1	Sawsan et. al., (2014) (Iraq)	The researchers studied a project in the U.A.E that applied safety requirements. This project was used to show how to manage risks at each stage of the work, based on this, the researchers identified (46) cases, and the risks associated with each case by creating a questionnaire and the conversion of the results of this questionnaire into a computer program which recorded most of the risks related to multi-story buildings.
2	Hatem, (2017) (Iraq)	In this research, the researcher studied the extent of safety procedures in Iraqi projects through the work of a questionnaire that included a number of ministries. The result of this research showed the lacking of governmental support for the implementation of safety procedures. The research showed that the Ministry of Construction and Housing was the best ministries in terms of the implementation of safety measures, while the Ministry of Municipalities and Public Works were shown the worst.

BIM + Safety		
3	Kiviniemi et. al., (2011) (Finland)	This research was initiated from April 2009 until June 2011. The benefit of this research is to develop the possibility of utilizing BIM technique in planning and managing safety by linking the project schedule to the 3D model. This technique is tested in 7 field trials and research has reached the possibility of using this technique in improving safety and increasing communication between project partners. In this research, the Archicad and the Takla package were adopted
4	Azhar et. al., (2013) (USA)	This study epitomized the possibilities of applying Building Information Modeling (BIM) in safety planning and identifying the hazards in early stages by using the 4D model. The researcher used five BIM experts to identify the research needs. In this study, it is recommended to utilize BIM to study Auburn University Facilities Division as a case study.
5	Enshassi et. al., (2016) (Palestine)	In this study, the questionnaire approach was adopted to know the extent of the contracting parties' perception regarding BIM technology and its application in safety, and what barriers prevent their adoption in local construction. The survey was a total of 75 questionnaires distributed to contractors and stakeholders with a response rate of 49%. The study showed that 33% of the respondents do not have prior knowledge of this technology and 28% of the organizations do not use this technology and if they use it then it is limited use. The results concluded that BIM technology contributes well to identify risks and minimizing it, training and improving the construction industry.
6	Mihic et. al., (2018) (Croatia)	In this thesis, the researchers aim to benefit from the possibilities of BIM technology in the development of an automated system that contributes to the improvement of occupational safety by linking the BIM model with the developed hazards databases of the construction. Accordingly, the researcher explains that any project is composed of a group of real elements and each element associated with numbers of hazards that pose danger to the lives of workers. This integrated system has thus contributed to the identification of risks for different building elements.

7	Swallow et. al., (2019) (United Kingdom)	The purpose of this research is to demonstrate the extent to which the 4D model is adopted in the field of occupational safety and what are the benefits and challenges of its use. In this research, a survey is conducted by experts from the construction industry. The results show that (70%) of managers and (74%) of experts recognize the importance of the 4D, but only (31.2%) of the respondents use this technology in their work. The study also points out that one of the most important obstacles to use this technique is the cost of training and time required for implementation.
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BIM + Augmented Reality

8	Wang et. al., (2014) (Australia)	The aim of this study was to create a mechanism that allowed the integration of augmented reality technology with BIM technology in order to facilitate the process of tracking the physical development of work activities or tasks during real-time.
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As explained above, many researchers in different countries have studied possibility of applying BIM technology in safety analysis of construction projects.

Research originality: in addition to existing studies concerning BIM technology in all over the world, this study is considered the first study of its kind in safety issues that significantly contributes in explaining the importance of BIM technique for safety analysis and management at the construction industries in Iraq with a view to provide a safe environment work, and to prevent losses resulting from work injuries and damage to machinery. Also, this study explains the effect of applying safety regulations on the time schedule of the project as well as on the total cost. The researcher also experiments the integration of BIM technology with augmented reality technology to help site safety managers more easily check safety requirements, especially in complex projects and provide a 3D model with all the necessary information on their mobile phones. Worthy to mention that is the researcher has a new idea that is to study the effect of the intensity of daylight on the vision of workers inside the building (during the construction stage) using the technique of BIM through the Revit environment to prevent any stress which may impact on them from the low intensity of daylight and comparing results with values from Iraqi safety blog. In fact, there is a focus on importance of studying daylight analysis for design comfortable lighting used during operation stage. However, there is no real interest in using the BIM technology to study the intensity of daylight and its impact on the safety of workers during the construction stage.

In addition, Table (1-2) explains a comparison between the current study and previous studies in term of (location, software used, brief description about research).

Table (1-2): comparison between current study and previous studies

Location	Iraq	Current study
software	Revit software 2017, MS project, Synchro software, Autocad	
Brief description about research	This research explores to study the possibility of using BIM technology in the field of safety analysis in Iraqi construction projects. Where the researcher tries to take advantage of the benefits provided by the BIM technology represented by visualization and simulation in finding a mechanism that allows to create a dynamic environment similar to the real work environment by integrating 3D model with the project schedule, which facilitates safety managers to better understand the worksite and thus more accurate identification of risks compared with traditional methods based on 2D drawings. Study the effect of using this technology in the safety field on the cost and time of the project. The study also discussed the possibility of combining BIM technology with Augmented reality technology for use in the field of safety. In addition, a study of the effect of lighting intensity on worker safety	
Location	Iraq, Palestine, Croatia, United Kingdom, Australia, Finland, USA	Previous studies
software	Archicad, Tekla package, Revit, Synchro, Spss v.21 or v. 22, Visual Basic 6 language, AREL (Augmented Reality Experience Language).	
Brief description about research	Previous studies were divided between the use of BIM technology in finding mechanisms to determine the risks at the work site and between questionnaires, which in turn were also divided into a statement of the extent of application of safety procedures and what are the risks related to the construction elements on the one hand and between the efficiency of BIM technology in improving safety in construction projects. Most of these studies did not address the effect of safety applications on the costs of construction projects.	

1.10 Summary

This chapter provides a brief introduction to safety analysis of projects, and BIM. Illustration of the research problem and justifications, research question, explanation of the goals and objectives, research limitations, the methodology of the thesis, guidelines of the thesis are also provided. Finally, review of previous studies is made.