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Achieving Net-Zero Energy in Educational Buildings Using BIM

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

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CHAPTER ONE

Introduction

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Introduction

1.1 Introduction

Globally, construction sector is responsible for important resource consumption through construction, operation, and demolition. There is a great interest in achieving large reductions in the resources consumed as part of the general movement towards greater sustainability: for example, the energy was a particular interest due to its association with carbon dioxide (CO2) emissions, which are essential for climate change mitigation (Kamaruzzaman et al., 2016). Buildings worldwide were responsible for approximately 32% of energy consumption and greenhouse gases emission around 19% related to energy in 2010.These estimates negatively affect the environment and societies through global warming, with the rising threats of global warming it is not surprising that the construction industry now begins to meet the need for energy-efficiency buildings (net zero-energy buildings) (Bynum et al , 2013).

The emergence of BIM technique helped solve many problems related to the construction industry, such as re-work and poor communication between the work team, inefficiency of energy performance ,and buildings waste(Ismail et al., 2019). BIM is a technique that helps to create a 3D model that contains all the topical or graphical data, allowing easy access and management of this information required for planning, design, construction and operation (Kymmell, 2008).

The term green BIM appeared, which refers to sustainable practices that are largely related to reducing the impact of the building on the environment through the application of building information modeling(BIM) technology (Sheth & Malsane, 2014). Green BIM simplifies the different performance analyzes and evaluations such as

lighting analysis, energy analysis, carbon emissions, water usage analysis, and construction and demolition waste management (Maltese et al., 2017).

This chapter presents an introductory overview of the research that has been made, the research problem and justifications, clarifying the aim and objectives of the research. In addition, the research limitations, research methodology is specified, as well as discussing previous studies.

1.2 Research Problem and Justifications

The research problems are clarified in the following:

1. High energy consumption in Iraqi construction projects, which indicates a poor assessment of energy performance at the design phase due to using traditional methods that depend on 2D schemes and experiences which is an ineffective way to assess energy performance. In fact, this led to an increase in the rate of energy consumption and pollution in recent years.
2. The need to use modern techniques such as BIM technique based on concepts of simulation, and analysis to improve energy performance.

1.3 Research Hypothesis

There is a necessity to improve energy performance:

H_0: Improve energy performance efficiency using BIM.

H_1: Improve energy performance not efficiency using BIM.

1.4 Research Aim and Objectives

This research aims to define benefits provided by BIM technique to improve energy performance in educational building. To achieving the current research aim, some objectives must be achieved as follows:

1. Study the Sun's path analysis and its role in assessing the actual building orientation, and improve indoor daylight performance of building.
2. Study the effect of photovoltaic(PV)panels on improve energy performance.

3. Study the role of BIM in analyzing energy performance as well as creates and evaluate design alternatives.
4. Investigating the capabilities offered by BIM technique in water usage analysis and improve natural ventilation.

1.5 Research Limitations

The limitation of this research include the following:

1. This research focused mainly on energy performance, water usage, and natural ventilation
2. This research will have limited in the design stage of the project; other stages not be included in this research.
3. Case study: selecting Deanship building of Agriculture Collage at University of Diyala in Iraq as a case study.
4. Temporal limitation: the research period is only one the year 2019-2020.

1.6 Research Methodology

The research methodology mainly includes two parts:

1.Part one (theoretical study): A literature review is conducted for previous studies related to the scope of research, including books, papers, thesis.

2.Part two (practical study):

The practical part of research includes the following:

1. The case study is selected and data collection which includes (CAD drawings, schedule of quantities).
2. Create 3D model by using Autodesk Revit 2018 software.
3. After the completed 3D BIM model, various sustainability analyses have performed that help to improve energy performance using Revit 2018.
4. Analysis of building performance by using Autodesk Insight360 cloud plugin to Revit 2018 to assess sustainable design options.
5. Export 3D BIM model to Autodesk Green Building Studio (GBS) by using gbXML format to energy simulation, create and evaluate design alternatives, water usage analysis and wind analysis.
6. Export 3D model to Autodesk flow design software by using FBX format to create airflow simulation.
7. Finally, illustrates the conclusions and recommendations reached by the researcher.

Figure (1.1) shows the framework of the research methodology.

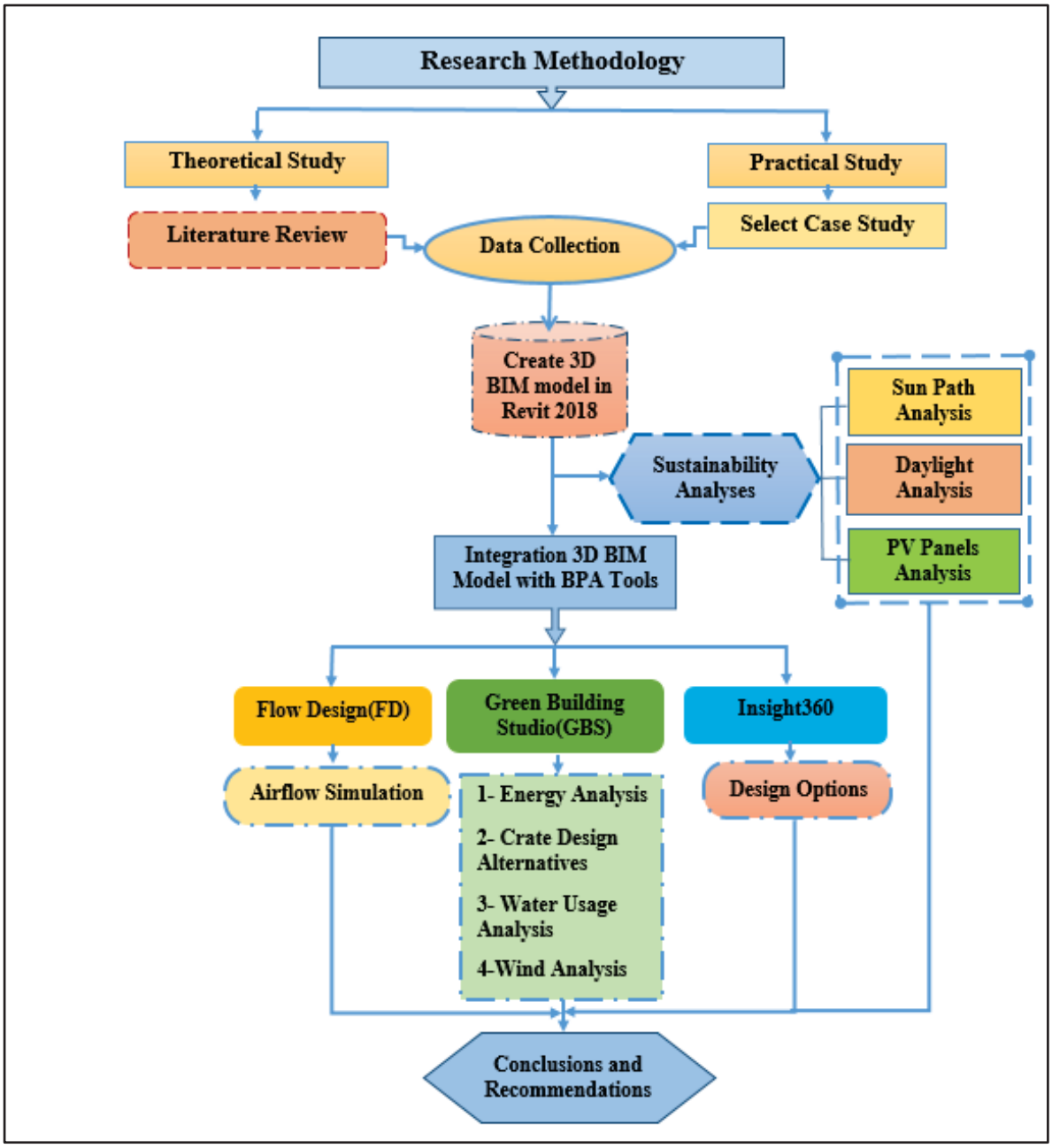

Figure (1.1): Research methodology (Researcher)

1.7 Outline of Research

The research is divided into six chapters: A summarized description of each chapter is explained below.

Chapter One: Introduction

It introduces the background of the research, research problem and justifications, research aim and objectives, research hypothesis, research limitation and scope, explanation of the research methodology as well as explain previous studies.

Chapter Two: Literature Review

This chapter clarifies the basic theoretical background that is required to understand the entire work contained in this thesis. Therefore, this chapter divided into three main parts. The first part starts with net-zero energy building Concept, sustainable design concept, principles of sustainable building, sustainability implementation, sustainability assessment systems as well as the definitions of BIM and BIM dimensions. The second part of this chapter is the Building Information Modeling (BIM) involves its definition according to each researcher, its dimensions. Finally, the third part consists of using BIM in sustainable design, green BIM concept, building performance analysis (BPA)tools as well as utilizing BIM technology for solar & daylighting analysis, wind analysis, water efficiency analysis. In addition to that this chapter explains ASHRAE 90.1 standard, and barriers of implementation green BIM approach.

Chapter Three: Data Collection &Analyses

The purpose of this chapter is to clarify the energy supply and demand problems in Iraq, explain case study, the motives and reasons for selecting a case study, obstacles to applying the research methodology, creating 3D model for case study as well as shown various sustainability

analysis which improve sustainability such as sun path analysis, daylight analysis, photovoltaic (PV) panels analysis.

Chapter Four: Integration BIM Model with Building Performance Analysis(BPA) Tools

This chapter explains the method to integrate 3D BIM model with performance analysis (BPA) tools to improve building performance through used the tools provided by BIM technology (Insight360, GBS, FD).

Chapter Five: Conclusions & Recommendations

This chapter illustrates the main conclusions and recommendations, as well as suggestions for future studies.

1.8 Review of Previous Studies

Table (1.1) shows summarizes the previous studies related to improve energy performance.

Table (1.1): Review of previous researches

NO.	Researcher and country	The Work
1	**Shoubi et al, (2015) (Canada)**	Title "Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches" Aim: The main purpose of the study was to identify several sustainable designs that can have positive effects on energy saving and to evaluate the annual lifecycle performance of a building in terms of its thermal aspect of energy consumption in the operational stage by using BIM. Methodology: The building is simulated in Revit Architecture 2012 software. After simulation, for integrating between Revit and Energy Modeling tool (Autodesk Ecotect Analysis

		software), After creating zones, for exporting the simulation file from Revit to Ecotect, the gbXML based export way. Software: Revit Architecture 2012 software, Autodesk Ecotect Analysis. Results: This study show which of the materials helped in reducing the operational energy use of the building to the greatest extent throughout its annual life cycle. It was apparent that the annual amount of the building's energy could be reduced to 12,580 kW h by replacing the baseline design with a carefully designed, alternative design.
2	**Najjar et al, (2017)** **(Brazil)**	Title "Daylight Assessment and Energy Consumption Analysis at an Early Stage of Designing Residential Buildings Integrating BIM and LCA" Aim: This study aims to present the interests of BIM–LCA integration in examining different design alternatives and orientations in order to increase daylight efficiency and energy performance in buildings at an early designing phase Methodology: The methodology of this study aims to conduct a conceptual energy consumption analysis using Autodesk Green Building Studio, a plug-in that allows designers to perform building performance simulations in a cloud-based service to optimize energy efficiency. Software: GBS cloud, Autodesk Revit. Results: The results show that BIM–LCA integration is considered as an optimistic course in terms of sustainable development and decision-making process in the construction sector. Furthermore, it encourages reviewing some critical factors, such as building orientation, HVAC systems and the construction of external walls and roofs in the construction projects at an early stage of design in order to increase energy efficiency and capture natural daylight in buildings.

3	**Singh & Sadhu, (2019)** **(Canada)**	Title "Multicomponent energy assessment of buildings using building information modeling" Aim: This study aims to analyze the effect of various envelope parameters and dynamic shading techniques, Heating, Ventilation, and Air-Conditioning (HVAC) type and lighting systems on energy performance. Software: Autodesk Revit, Autodesk GBS. Methodology: selected two case studies where in the first case study, a residential building is modeled as the majority of cities would have a large number of houses built-in networks. The second case study features a walk-in-clinic that could also be considered as a shop from any plaza center in metro cities, after this optimize the suitable chosen internal and external configurations for these two types of structures can have implications in improved design and energy assessment methods of urban infrastructure. Results: The overall results show that changes in external or internal configuration of a structure can impact the annual and life-cycle budget of the building.
4	**Najjar et al, (2019)** **(Brazil)**	Title "Integrating Parametric Analysis with Building Information Modeling to Improve Energy Performance of Construction Projects" Aim: This study examines several building components of the exterior parts of buildings, along with different window-to-wall ratios in order to improve energy efficiency in buildings. Software: Autodesk Revit, Autodesk GBS. Methodology: This study proposes a framework based on various performance parameters to enable decision-makers utilizing standard procedures and software to empower the process of sustainable energy use and management in buildings, through a parametric analysis in different climatic conditions. Results: The results of this study indicate that climate data plays a fundamental role in the choice of design factors that are best suited for effective energy consumption in buildings.

		In particular, sub-type climate classifications, as opposed to the primary climate group, have a minor influence. Around 15% improvement in the energy consumption in buildings is noticed due to changes to the design factor such as the window-to-wall ratio.
5	**Yarramsetty et al., (2020)** **India**	Title "An investigation on energy consumption in residential building with different orientation: a BIM approach" Aim: The main purpose of this study is to examine numerous impact (focus point is energy demand) of multifamily residential buildings on varying orientation using potential BIM and energy evaluation tools. Software: Autodesk Revit, Autodesk GBS. Methodology: The first step is to develop a 3D model of the building. The second step is to study the energy scenarios for different orientations through simulations. Then the energy analysis is performed. In this study taking the whole building as a unit for energy analysis. Results: It is observed from the analysis of data collected that a saving of $1393 from the best orientation (+ 315° clockwise) to the worst orientation (+ 165° clockwise). The simulated electricity demand is validated by taking the original bills of the actual orientation and it is observed the values are 2.65% greater than the simulated values.

In addition, Table 1.2 shows a comparison between the current study and previous studies in term of (location, software used, brief description about research).

Table 1.2 Comparison between the current study and previous studies

Location	**Iraq**	
Software	**Autodesk Revit(ver. 2018), AutoCAD (ver.2019), Autodesk Insight 360 ,Autodesk GBS, Autodesk Flow Design**	Current Study (2020)
brief description about research	This research explores to study the benefits of BIM in improve energy performance of educational buildings in Iraq. Where the researcher take advantage of the benefits provided by the BIM technique represented by visualization and analysis to researcher carried out different sustainability analyses and integration 3D model with building performance analysis(BPA) tools for purpose improve energy performance efficiency.	
Location	Canada, Brazil ,India	
Software	**Autodesk Revit , Autodesk Ecotect analysis, Autodesk GBS**	
brief description about research	Previous studies BIM technique in improve energy performance. The pervious researcher using different software's to give acceptable result in the topic (Autodesk Revit, Autodesk Ecotect analysis Autodesk GBS). Most of these studies did not used Autodesk Insight 360 cloud in assess design options as well as did not address used Autodesk Flow Design software in airflow simulation to improve natural ventilation.	Previous studies

1.9 Summary

This chapter illustrates a brief introduction, an explanation of the research problem and justifications, illustration the aim and objectives of the research, research hypothesis, research limitations, the methodology of research, and outlines of the research. Finally, a review of previous studies is discussed.

Abstract

Achieving Net-Zero Energy in Educational Buildings Using BIM

By

Farah Faaq Taha

Supervised by: **Co- supervisor:**

Ass. Prof. Nidal Adnan Jasim **Ass. Prof. Dr. Wadhah Amer Hatem**

The construction sector in Iraq is considered to be the most energy□consuming and affecting sector on the environment, which indicates a poor assessment of energy performance at the design phase due to using traditional methods that depend on 2D schemes and experiences which is an ineffective way to assess energy performance. Therefore, appeared needed to use modern technologies such as Building Information Modeling (BIM) technique based on simulation and analysis concepts to improve energy performance.

This research aims to define benefits provided by BIM technique to improve energy performance in educational buildings through achieving many ob□ectives, including study sun path analysis and improve internal daylight performance of the building as well as study the effect of photoelectric panels on improving energy performance. In addition, study the role of BIM technique in analyzing energy performance, create and evaluate various design alternatives as well as investigation of capabilities provided by BIM technique in water usage analysis and improving natural ventilation.

The researcher starts with literature review and previous studies related to using BIM technology in improve energy performance field. In addition to this, the researcher selects one of the buildings at □niversity of Diyala, which is the Deanship of the Agriculture College as a realistic case study to apply the research idea on it. The researcher was able to use the tools provided by BIM technique (Autodesk Revit 201□, Autodesk Insight 360, Autodesk GBS, Autodesk Flow Design) through which the research ob□ectives achieved.

The results show that using of BIM technology at the design stage helps to improve the performance of internal daylight in the building where helps in reduce

artificial lamps around (16.□□) and reduce the cost of artificial lamps around (6□00ID). Also , the results show that the use of Photovoltaic(P□) panels can reduce energy consumption around (□0□) of total energy consumption as well as illustrate through energy analysis that electrical energy consumption about (□21,6□□kwh □year) and the fuel consumption about (□6□,633 M□ □year) and that the best alternative is □□AC type (package terminal heat pump(PT□P)) where energy□saving about (□0□).In addition to the results explain that BIM technology is useful in water usage analysis and improve the natural ventilation of the building.

Based on the above results, the researcher concludes that tools provided by BIM technique have contributed in finding the best to various problems related to energy performance during the early design stage, which leads to saving time and costs compared to traditional methods that depend on 2D schemes and experience as the adoption of methods conventional is an ineffective way to evaluate energy performance.