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Economic Sustainability and Life Cycle Cost for Iraqi Construction Projects 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

By

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

﴿ يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ

دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ ﴾

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DEDICATION

This thesis is dedicated to

my parents for their endless love and my beloved husband for support and encouragement.

my beating heart my dear child, my dear brother, my beloved sisters and their children.

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Abstract

With the continuous rise in energy consumption and the general inefficiency of existing buildings in terms of functional, economic and human terms, in addition to the environmental damage resulting from the excessive and inefficient use of resources in setting up projects. The need to reduce energy costs and choose building materials that will enhance this has become necessary, especially with the modern trend towards achieving the principles of sustainability in construction projects. As a solution, some research is attempting to include operational energy calculations for buildings in a Life Cycle Cost (LCC) calculation by integrating it with Building Information Modeling (BIM). BIM is currently one of the most prominent trends in the sectors of architecture, engineering and construction. The research deals with Iraqi artistic and cultural projects because they are characterized by their large open spaces such as galleries or theaters, in addition to their high altitudes that require increased operational energy costs. This research aims to explore the advantages offered by BIM technology to enhance the sustainable economy in the establishment of Iraqi artistic and cultural projects by investigating the capacity of BIM and energy simulation tools to reduce the cost of the building life cycle as well as the impact of building material selection on enhancing the energy performance of buildings. The questionnaire tool was design for experts in building projects of an artistic and cultural nature, to find justifications for carrying out the research. The experts were asked to express their opinions about the actual need for this type of research, the extent to which building information modeling technology is used in the creation of artistic and cultural projects, and the most significant issues that impede its use. In addition to emphasizing the value of BIM technology for enhancing this kind of project's sustainable economy. The method used in this study involved making a 3D model

of an existing building to determine the initial construction and the annual energy costs, then creating alternatives for the exterior building envelopes, which include walls, roofs, and windows, and re-modeling them to calculate the initial cost and annual energy costs, comparing them with the original model, and determining the most cost-effective option. The results showed that annual energy savings of about 4.5% can be achieved when energy costs are included in the life cycle cost calculation of the building, as it showed a decrease in its present value of (41,389,361) Iraqi dinars. The study has come to the conclusion that BIM tools may be used to assess a building's performance and select the best and least expensive option in the future. The researcher recommended the creation of government regulations for the use of BIM technology; the significance of educating the next generation about sustainability and the sustainable economy; and the necessity of instructing government officials on how to efficiently use environmental resources and lower energy consumption.

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List of Abbreviations and Symbol

Abbreviations	Explanation
aecXML	Architecture-Engineering-Constructio XML
BIM	Building Information Modelling
BPA	Building Performance Analytics
CAD	Computer-Aided Design
CD	Construction Detailing
CA	Construction Administration
DB	Design Builder
DD	Design Development
eQUEST	Quick Energy Simulation Tool
ecoXML	Examining CommerceNet's XML
FM	Facility Management
GBS	Green Building Studio
GBXML	Green Building Extensible markup language
gbXML	Green Building XML
HEED	Home Energy Efficient Design
HVAC	Heating, Ventilation and Air conditioned
HBIM	Heritage Building Information Model
HKD	Hong Kong Dollar
IPD	Integrated Project Delivery
IES-VE	Integrated Environmental Solutions-Virtual Environment
IFC	Industry Foundation Classes
LCA	Life-Cycle Cost Analysis

Chapter One
Research Introduction

1.1 General

Due to its high energy consumption, the building sector has been recognized as one of the key contributors to global environmental consequences, which has led to an increase in demand for sustainable construction [Junnila, and Horvath, 2003] [Bribián et al.,2009]. Artistic and cultural buildings are characterized as buildings with large areas and high elevations, so the necessity of adopting modern technologies when constructing such buildings has become a necessity with the trend of the times towards green construction. Currently, the usual practice prefers sustainable building designs, often known as green buildings, that consume the minimum energy to run [EPA,2016].

BIM is presently one of the prominent trends in the architecture, engineering, and construction sectors. It has gotten a lot of interest from academics and industry [Eastman et al.,2011]. It is the graphical depiction of the building in the future and also incorporates the basic, physical, and intrinsic aspects of a building. It can support various sustainable design features like: building orientation, building form analysis, day lighting analysis, water usage analysis, reducing energy needs and identifying other renewable energy options; reducing material requirements by using sustainable materials; and lessening the wastage and carbon footprints [Eddy and Nies, 2008]. BIM not only adds technical value to the development process, but it also provides an innovative and integrated working platform that improves efficiency and sustainability across the project life cycle [Elmualim et al.,2014].

In addition, it has been demonstrated that BIM enhances a constructed facility's life-cycle cost savings. According to [Lu et al.,2014], a cost benefit analysis undertaken in a sample BIM project resulted in a cost savings of 6.92 percent (490.86 HKD/m2). [Guo et al.,2016], on the other hand, used BIM in conjunction with an energy-simulation system to conduct an energy consumption study, which gave more complete data for optimum design choices. BIM technology can find the best alternatives to energy problems during the early design stage, which saves time and cost compared to traditional methods that rely on two-dimensional diagrams, as traditional methods are an ineffective way to evaluate energy performance [Taha et al.,2020].

This chapter provides an overview of the research that has been done, the research challenges, and the reasons for the research, making the aim and objective of this research clear. Research limitations, research methodology, and discussions of previous studies are also included.

1.2 Problem of the Research

There are a number of issues that necessitate the use of building information modeling (BIM) in Iraq to assess the economic sustainability of artistic and cultural projects, the most important of which are:

1. Finding methods to reduce the amount of energy used by buildings and improving them functionally, economically, and socially.
2. Developing strategies to increase resource efficiency and environmental protection.
3. Developing a system to address the weakness of government efforts to adopt BIM.

1.3 Aims and Objectives of the Research

This research aims to determine the benefits provided by BIM technology to promote a sustainable economy in the establishment of Iraqi artistic and cultural projects. To achieve the objective of the present research, some objectives must be achieved as follows:

1. Studying the ability of BIM and energy simulation tools to reduce the life cycle cost of a building.
2. Studying the effect of choosing building materials on improving the energy performance of buildings.

1.4 Limitations and Scope of the Research

This research has the following limits:

1. This research focused mainly on energy performance and life cycle cost (LCC) calculation for building materials.
2. Iraqi artistic and cultural projects as a case study.
3. Time one year not sufficient.

1.5 Methodology of the Research

The following is a summary of the research methodology:

1. Theoretical aspects of reviewing the literature about the research topic by summarizing the local and international studies, including books, papers, and theses.
2. Practical aspects containing the following:

A. Conducting a questionnaire for evaluating the benefits of BIM to promote a sustainable economy

B. Questionnaire design: The questionnaire tool was used to analyze the barriers to using information modeling technology in the development of Iraqi artistic and cultural projects, as well as the value and need for its implementation. It included questions distributed to respondents who work in the construction sector for such projects to express their opinions on the most important paragraphs that the use of information modeling technology can contribute to improve when it is used in the establishment of these projects and to know their desire to develop the current construction system.
C. Statistical analysis utilizing the SPSS version (26) program to analyze the questionnaire's data.
D. The case study was selected, and related data was collected, including CAD drawings and photos of the building at the time of implementation and at the moment, as well as the BOQ.
E. Autodesk Revit 2022 software is used to create a 3D model.
F. Export 3D BIM model to Autodesk Green Building Studio (GBS) by using gbXML format to energy simulation, create and evaluate design alternatives.
G. Discussion the results.
H. Finally, reaching conclusions and recommendations.

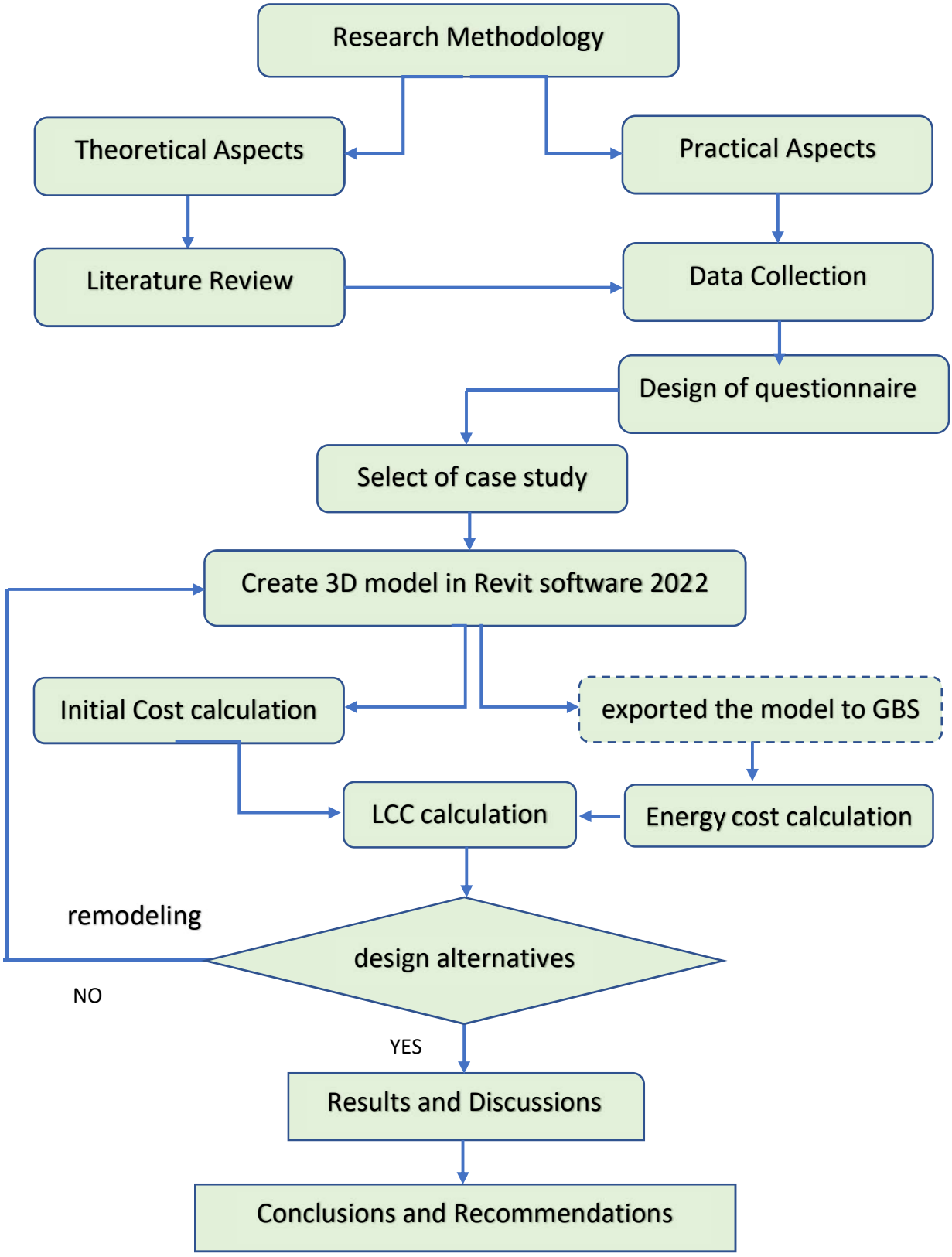

Figure (1-1): Research Methodology (Researcher).

1.6 Theses Structure

Chapter One: Research Introduction

The chapter begins with an introduction to the study, followed by a discussion of the research problem and justifications, the aim and objectives, limitations, methodology, structure, and a review of previous studies concentrating on BIM integration with sustainable analytic tools.

Chapter Two: Literature Review

This chapter tries to create a theoretical foundation for the notion of BIM and sustainable construction Based on prior studies and research. This chapter defines Building Information Modeling, its dimensions, and the benefits that may be realized when it is implemented, as well as the definitions of sustainable development and sustainable economy, and the potential of accomplishing them through the use of BIM.

Chapter Three: Field Survey for Justification

This chapter reviews the questionnaire method, which is used to determine the barriers to using information modeling technology in the development of cultural projects and the rehabilitation of archaeological and historical sites, as well as the value and necessity of its implementation. It includes questions issued to respondents who work in the construction industry for such projects to express their perspectives on the most significant elements that the use of information modeling technology may contribute to improv when utilized in the planning and execution of these projects, to improve the present construction system.

Chapter Four: Results Analysis and Discussions

This chapter reviews the research methodology in detail, as well as use of the Revit program according to BIM with tools for sustainability analysis, finding alternatives, and discussing the results.

Chapter Five: Conclusions and Recommendations

This chapter outlines the main conclusions and important recommendations, as well as proposed further research.

1.7 Previous Studies

The previous studies are summarized in the Table (1-1).

Table (1.1): Review of previous studies

No.	Researcher and country	The Work
1.	Mahmoud H. Dawood (2016). (Sultanate of Oman)	**Title:** "BIM Based Optimal Life Cycle Cost of Sustainable House Framework." **Aim:** This study aims to identify the best design that provides the lowest life cycle cost throughout the course of the building's lifespan. **Methodology:** In this study, a combination of the Genetic Algorithm (GA) and Building Information Modeling (BIM) is utilized to arrive at a near-optimal solution. GA is utilized to arrive at the best option with respect to the lowest lifecycle cost of residential buildings. The quantity takeoff data and energy consumption

		data of a project are produced using BIM in this study. **Results:** The proposed model automatically selects the components of the house that are most suitable to reach the minimum LCC during the design phase.
2.	Muhammed Mahdi Sadeq abed (2018). (Iraq)	**Title:** "Using BIM in Assessing Economical Aspects for Sustainable Buildings Design." **Aim:** This study intends to evaluate, using a closed questionnaire, the status of BIM usage in the Middle East (GCC), as well as the difficulties BIM users experience, the benefits of BIM usage, and how BIM may best promote sustainability ideas. **Methodology:** The case study was used to show how the integration of BIM and sustainability analysis tools might improve the design's economics by using life cycle costing (LCC) analysis to select the best option among several design, construction, and system options. **Results:** The results indicate the ability of BIM integration with performance analysis tools like LCC will increase the capability of analysis team. LCC tool enable the designer to evaluate different alternatives of constructions and design options based on total life cycle cost in compliance with sustainable concepts.

3.	-Tayyab Ahmad, Muhammad Jamaluddin Thaheem. (2018) - Pakistan	**Title:** "Economic Sustainability Assessment of Residential Buildings: A dedicated assessment framework and implications for BIM." **Aim:** The goal of this study is to create a comprehensively representative framework for evaluating the economic sustainability of residential construction with applications for BIM. **Methodology:** This study employs a mixed-methods approach, constructing a framework for the RBESA (Residential Building-related Economic Sustainability Assessment) and supporting it with quantitative data from a survey conducted and online interviews. The framework was subsequently evaluated using a case study of three residential structures once the acquired data had been added. **Results:** A case study that validates the framework's operation gives a decisive value of 48.25 percent for the economic performance of subject construction, which is an indicator of how well assessments work as a tool for decision-making.
4.	Shang-yuan Chena (2018) (Taiwan)	**Title:** "A green building information modelling approach: building energy performance analysis and design optimization". **Aim:** This study focuses on the integrated application of Building Information Modeling (BIM) and Building Performance Analysis (BPA) software

		as tools for designing and analyzing construction projects. **Methodology:** The research uses Autodesk Energy ®'s Analysis for Revit as a validation tool and utilizes the evaluation of building energy consumption as an example to show how green BIM can be used in integrated design processes. **Results:** BIM is emphasized as a fundamental tool from the beginning of the design phase in green BIM. Additionally, use of a design and analysis decision-making cycle when performing while conducting BPA in response to local climatic circumstances, can result in optimal design proposals with strong environmental effectiveness and eventually help accomplish the objective of environmental sustainability.
5.	Yussra Mohamed Rashed et al. (2019) (Egypt)	**Title:** "A BIM-based Life Cycle Cost (LCC) Method to Reduce the Operation Energy Costs in Buildings." **Aim:** The aim of the research is to suggest a more organized approach that may be built by utilizing the current efforts made and integrating the LCC with the energy simulations and BIM capabilities. **Methodology:** The suggested methodology is adopted in a case study.

		Results: The results indicate that when incorporating the energy expenses into roof assemblies, LCC savings of around 17% may be made.
Current Study		
This research aims to improve sustainability standards and study ways to reduce energy consumption in the establishment of Iraqi artistic and cultural projects. The researcher used Autodesk Revit software 2022 to create a 3D model and find quantities and costs of construction materials for the project, in addition to using sustainability and energy analysis tools to find the amount of energy consumed for the project and compare it with alternative models.		