

**Ministry of Higher Education  
and Scientific Research  
University of Diyala  
College of Engineering**



# **Sustainability in Airport Construction Project By 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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**2021 A.D**

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## **Dedication**



**I dedicate this study with much Gratitude and Love to;**

**My Dear Father;**

**His words of inspiration and encouragement in pursuit of  
excellence.**

**My Affectionate Mother;**

**Whose prayers and love took me to zenith of glory and  
transform my dreams into reality**

**My Brothers & Sisters;**

**Which always encouraged and supported me.**

**Finally, to My Friends.**



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## List of Abbreviations and Symbols

<b>Abbreviations</b>	<b>Explanation</b>
<b>BIM</b>	Building Information Modeling
<b>LEED</b>	Leadership in Energy and Environmental Design
<b>PRS</b>	Pearl Rating System
<b>PORS</b>	Pearl Operational Rating System
<b>2D</b>	Two Dimension
<b>3D</b>	Three Dimension
<b>4D</b>	Four Dimension
<b>5D</b>	Five Dimension
<b>6D</b>	Six Dimension
<b>7D</b>	Seven Dimension
<b>8D</b>	Eight Dimension
<b>BPA</b>	Building Performance Analysis
<b>GBS</b>	Green Building Studio
<b>ASHRAE</b>	American Society of Heating, Cooling and Air Conditioning Engineers
<b>gbXML</b>	Green Building Extensible markup language
<b>R</b>	Thermal Resistance
<b>U</b>	Heat Transfer Coefficient
<b>EUI</b>	Energy Use Intensity
<b>HVAC</b>	Heating, Ventilation and Air conditioned
<b>PV</b>	Photo-voltaic( PV) Panels
<b>VRML</b>	Virtual Reality Modeling Language
<b>DPH</b>	design Peak Hour Traffic
<b>GHG</b>	Green House Gases

## **Abstract**

Airport construction is the most important infrastructure projects, which has a remarkable influence on the environment and economics. The airport terminals are the largest parts of buildings of energy consumption. Meanwhile there is a lack of research available in Iraq on how to obtain an optimal use of the available resources such as electricity and water efficiency in airport project and space management that can be used to obtain an environmentally and economically sustainable airport.

In this research, the adopted methodology was applied as three parts, the first part was related to Building Information Modeling (BIM) techniques in 3D simulation and energy analysis as well as comparison of simulated energy consumption results with real energy consumption, The second part includes adding different alternatives to the existing building and studying their impact on the energy consumption and gases emissions by simulation of 3D model in green building studio. Finally, the third part studied the possibility of increasing the capacity of terminal by increasing the number of passport counters on the passenger arriving floor was studied to increase the number of passengers as a pivotal strategy in airport renovation, beside the reduction of Co<sub>2</sub> emissions factor per passengers.

This research aims to use modern technologies in designing and constructing airports to control energy consumption and to know the possible strategies to obtain the lowest consumption and the most appropriate cost, by investigating the impact of sun path analysis on energy performance, analysis and evaluation of energy performance and water usage analysis using BIM technology tools.

The results illustrate that BIM technique is a very useful tool to perform various analyses that help to find different strategies for improving the energy



efficiency in the project, in case study (Baghdad Airport) , the GBS tool based on BIM technique was a fruitful tool to energy analysis as its results illustrate the energy Use Intensity to this case study is 924 MJ/m<sub>2</sub>/year.

Also, the results concluded that applying BIM technology using different alternatives in early design stages, using photo-voltaic(PV) panels reducing annual energy consumption around 45%,13%and 23% when used in different places of roof, and achieves cost-saving about (258,601\$/year, 76,471\$/year, 130,483\$/year) respectively, and the use of double glazing, foam material and replacing part of the curtain wall to a block wall is the most effective alternative in reducing energy use intensity from 924 MJ/m<sub>2</sub>/year to 857, 856,851 respectively, and reduce Co<sub>2</sub> emissions from 472.2 Mg to 343.9Mg,344.2 Mg,339.9 Mg respectively. Also the results showed that rearrangement of counters distribution allows to add two counters in arrival floor, this leads to increasing of the annual terminal passengers from 2500000 to 2762000 passengers, therefore, increasing annual airport passengers in Baghdad International Airport from 7,500,000 to 8,762,000, and achieving terminal environment sustainable by reducing Co<sub>2</sub> emissions from 0.17 Mg to (0.11Mg). .

# **Chapter One**

## **Introduction**

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## CHAPTER ONE

### INTRODUCTION

#### 1.1 Introduction

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 Background

Airports are an essential component of the complex international air transport system that supports and promotes the movement of passengers, cargo, and tourists all over the world ((Brouder, 2010)). Over the past 20 years or so the awareness of the environmental impacts of human activity has increased substantially (Cowper-Smith and de Grosbois, 2011).

The concentration of carbon dioxide  $\text{CO}_2$  in the atmosphere has increased, and it remained above 400 ppm for the first time in 2016. The aviation industry is a significant contributor to greenhouse gas emissions. In this sense, the aviation sector in general, and airports in particular, are attempting to reduce their carbon footprint. A potential alternative is to replace the airport's traditional power energy use with clean energy sources. Although solar PV is a non-polluting energy source, a MW-scale plant need more land, because large expanses are required as buffer zones in airports, this property can be successfully utilized for utility scale solar PV plant (Sukumaran and Sudhakar, 2017).

The ability to meet the needs of modern human growth without jeopardizing future generations is the widely accepted definition of sustainability (Brundtland *et al.*, 1987). Airports are networks that are a

part of today's society and play an important role in meeting the need for mobility (Knudsen, 2002).

According to the UN Intergovernmental Panel on climate change, the aviation industry is responsible for up to 2.5 percent of worldwide CO<sub>2</sub> emissions. Although the aviation industry will not become more environmentally friendly overnight, airports have the capacity, means, and opportunities to engage in long-term development (Ruble, 2011).

The electricity crisis in Iraq creates air pollution and low quality, which has a significant impact on the health and safety of Iraqi inhabitants (Chaichan, 2016). The traditional CAD planning process does not allow for early judgments; energy and performance analyses are often undertaken after the preparation of architectural and construction design documents (Azhar, Brown and Farooqui, 2009). Building information modeling (BIM) is a novel technique that combines a variety of tools for assessing the energy performance of a building (Najjar *et al.*, 2017).

The most major role of a terminal building is to provide a link between "landside" and "airside," and it is thus interconnected to all other airport activities (Kılıkış, 2014). Airport passenger buildings cater to a wide range of consumers' requirements. The buildings not only serve passengers, but also the airlines that manage the planes, the owners who give the funds, and the operators of the many services (De Neufville *et al.*, 2013)

As demand for passenger and freight air traffic increased, there was a need to build new passenger terminals or expand and operate existing stations, reducing environmental costs and the impacts of their operations by being aware of and considering the challenges of sustainable development. Various practices to develop a balanced approach in order to maximize their potential and potential In terms of the environment, society, and the economy (Hussain and Ramdan, 2020).

Building Information Modeling(BIM) technology is one of the modern technologies that allow multidisciplinary information to overlap in one model, which creates an opportunity to perform sustainability measures percentages of Co<sub>2</sub> emissions in the early design stage by simulated project from Revit to green building studio.

Green Building Studio(GBS) is a cloud service that allows the user to simulate the performance of the building for improving energy performance, work towards carbon neutrality, increase water efficiency, and climate analysis in the early design stage (Studio, 2008).

### **1.3 Research Problem and Justifications**

The research problems are clarified in the following:

1. The existence of airports play a substantial role in the terminal building's construction and operation are primarily concerned with sustainability, thus sustainable approaches to create a “clean” airports may be considered as a necessity, architectural designs included.
2. A sustainable airport construction usually encounter rather high investment cost as well as the annual and periodical maintenance operations, while on the other hand, this kind of projects have minimal impact on the environment what may add substantial benefits to the society, users, and stakeholders in a justifiable values.
3. The case study of Baghdad International Airport terminal building(Nineveh terminal) which has been designed and constructed without considering the sustainability issues due to the history of establishment .
4. The need for an analyses technique by which the newly designed airport could be analyzed in order to explore the impact of its various

components on multiple parties involved as well as its environmental impact.

5. 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.
6. study how can the BIM modern techniques in improve energy performance.

#### **1.4 Research Aims and Objectives**

The research main objective is to assess the impact of a sustainable local airport design and construction project both economically and environmentally. To achieve this objective, many steps are in order:

1. BIM Modeling for the local airport in its traditional form
2. Modeling the same project considering sustainable compliance case
3. Cross comparison is conducted on the various outcomes of the BIM analyses in order to identify the pros and cons of adopting sustainable airport structures .
4. Study the Sun's path analysis and its role in assessing the actual building orientation, and improve indoor daylight performance of building.
5. Study the effect of photovoltaic(PV)panels on improve energy performance.
6. Study the role of BIM in analyzing energy performance as well as creates and evaluate design alternatives.
7. Investigating the capabilities offered by BIM technique in water usage analysis and improve natural ventilation.

8. The final conclusion represents a decisive tool to the decision maker

### **1.5 Research Limitations**

The limitation of this research include the following:

1. This research focused mainly on energy performance, water usage, ,natural ventilation and increase the capacity of terminal.
2. This research will be limited to the design stage of the project; other stages not will be included in this research because the researcher cannot study other stage such as change selections of site and it's orientations was selected in planning stage or choice of selected material used in construction stage, and other.
3. Case study: selecting is Baghdad International Airport in Iraq as a case study.
4. Temporal limitation: the research period is only one the year 2020-2021.

### **1.6 Research Methodology**

The research methodology mainly includes :

**1. Theoretical Study:** A literature review is conducted for previous studies related to the scope of research, including books, papers, thesis.

#### **2. Practical Study:**

The practical part of research includes the explorations for selected case study, which selected Baghdad International Airport of Nineveh terminals ,it is one of three identical terminal building. After selecting the study case, the researcher made frequent visits to the specified building to collect the data required to achieve the research methodology, such as described in the chapter three.

## 1.7 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	(Kaszewski and Sheate, 2004)  (UK)	<p>Title “Enhancing the sustainability of airport developments”.</p> <p>Aim: this paper focuses on improving the sustainability of airports – their terminals and operation, and whether existing, expanded or new.</p> <p>Methodology: examined the feasibility of options for encouraging more sustainable airport development through the use of a scenario-based approach, focusing on airport surface access transport and terminal building design.</p> <p>Results: The economy, social equity and environmental sustainability of a given UK region could be improved, and possibly each element improved to an equal extent, by properly managing the demand for air travel and making the <i>best use of existing infrastructure</i>.</p>
		<p>Title “Green Airport Design Evaluation (GrADE) – methods and tools improving infrastructure planning“</p>



2	(Ferrulli, 2016)  (Italy)	<p>Aim : aimed to develop method and tools to check and evaluate the sustainability design performances during the whole project development. In order to maximize opportunities for growth, it is necessary to consider all the specific factors involved in airport design that can have an influence upon the environmental consequences of its subsequent operations and therefore impact upon integrated sustainability strategies</p> <p>Methodology: GrADE method will contribute in achieving the goal of sustainable development of airport infrastructure providing a methodological framework to measure and monitor environmental sustainability Performance</p> <p>Results: The goal of the GrADE method and tools is to help airports identify, evaluate, priorities, and select sustainability practices for airport capital projects, programs, and operations. The Green Airport Design Evaluation (GrADE) method and its respective tools will contribute in achieving the goal of sustainable development of airport infrastructure providing a methodological framework to measure and monitor environmental performance and creating new opportunities for the aviation regulatory organisations and airport owners to define business model and strategies to enhance sustainable airport infrastructure design within the regional transport</p>
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		network.
3	Setiawan, M. I. et al. 2019 (Vietnam )	<p>Title “Green sustainable airports: The deployment of renewable energy at Vietnam airports. ”</p> <p>Aim: this paper includes two groups of recommendations: developing PPP policy framework and building institutional capacity and enhancing the facilities for domestic capital market.</p> <p>Methodology : summaries the deployment of renewable energy in airports worldwide, then critically assess both prospects and constraints of renewable energy projects in Vietnam.</p> <p>Results: The government needs to recognize that the efficiency and improved infrastructure services gains that can be accrued through successful PPPs are, over the long term, more important than the simple objective to mobilize private investment and to help fill a public sector budget gap. In this context, government needs to ensure greater policy clarity and consistency with respect to opening up more private sector participation opportunities.</p>
	(Vélez-Vega	<p>Title “Sustainable Construction Practices in Aviation Facilities ”</p> <p>Aim: Sustainable airport design principles all</p>

4	and Bardt, 2013)	<p>contribute to sustainability's triple bottom line, which includes social, environmental, and economic benefits. The practices described here are just few examples; there are many more sustainable practices that can be instituted at airport rehabilitation projects. The keys to successfully implementing these practices include both the design team and the owner's review team taking an informed design approach that openly considers the best material use, as well as close collaboration between the design team and the owner's review team.</p> <p>Methodology: This paper will discuss current sustainable practices used in the new construction of airport facilities at FXE and other airports across the United States, such as buildings and airfield pavement rehabilitation projects. The City of Fort Lauderdale's Executive Airport is the fifth busiest general aviation airport in the United States based on itinerant operations.</p> <p>Results: General aviation projects offer a once-in-a-lifetime opportunity to incorporate sustainable practices into the design and construction phases. The project's scope, size, and approach are typically more flexible than those of other types of airport projects. Close collaboration among the designer, consultant, and client provides more opportunities to investigate more innovative material and pavement recycling techniques, as well as acceptance for these</p>
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		practices.
5	(Hussain and Ramdan, 2020)  Iraq	<p>Title “Sustainability in the Design of Passenger Terminals for Airports ”</p> <p>Aim: The primary goal is to introduce this knowledge in a more clear and comprehensive manner, as well as to provide the option of achieving it locally. To achieve this goal, studies and practical projects have required the use of a descriptive-analytical approach in order to construct a comprehensive theoretical framework that defines the various dimensions of sustainable passenger terminals.</p> <p>Methodology: Baghdad International Airport, specifically its passenger terminals, has been chosen to represent the model, which includes: Samarra, Babylon, and Nineveh terminals, which are equivalent in repeated design, consistent with the time and capacity of the search (due to the difficulty of implementation on all passenger terminals at Iraqi airports), and as a general model that can be adopted in the future.</p> <p>Results : The application findings showed that the constructed local passenger terminals met some environmental issues, as well as the demands of</p>

		<p>water efficiency and site sustainability, with the highest values when compared to the results of the other secondary vocabularies, while the economic sustainability also met high levels. When compared to the results of the other secondary vocabularies, the results revealed that the dependence on achieving airline revenues, among other concessions, had the highest values, whereas the constructed local passenger terminals lacked the social dimension of passenger satisfaction.</p>
6	<p>(Brunetta, Righi and Andreatta, 1999) <i>Turkey</i></p>	<p>Title “ Energy consumption and Co<sub>2</sub> emission responsibilities of terminal buildings: A case study for the future Istanbul International Airport “</p> <p>Aim: This paper broadens the scope of the terminal building energy performance analysis and expands the analysis envelope to reveal the true impact of a terminal building on energy consumption and total emissions. In this regard, this study investigates whether a green terminal building in a new airport planned for the city of Istanbul with an annual passenger capacity of 150 million can offset the loss of Co<sub>2</sub>sequestration potential from cutting at least 657000 trees for airport construction. Additional Co<sub>2</sub> emissions associated with the estimated longer approach and climb out flights as a result of the unfavorable site selection have also been considered.</p> <p>Methodology: This article compares a conventional</p>

		<p>terminal building to four green terminal building scenarios, each with a different potential for CO<sub>2</sub> emission reduction. The first-law and second-law thermodynamic analyses revealed that constructing an environmentally friendly terminal building complex may not offset its CO<sub>2</sub> emissions responsibility unless a highly intensive re-forestation action is implemented and the site is properly re-selected.</p> <p>Results : This study illustrated the critical boundaries for an airport terminal building's energy consumption analysis envelope and its true emissions responsibility.</p>
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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. 2021), AutoCAD (ver.2020), Autodesk Insight 360 ,Autodesk GBS	021)

brief description about research	<p>This research explores to study the sustainability of airport to improve energy performance of terminal buildings in Baghdad International Airport 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, and Study the Possibility of Increasing the capacity of terminal to increase the number of passengers in the same area and in the same level of service for decreasing Co<sub>2</sub> emissions per passengers . also study the Possibility of study various alternatives to improve the performance of building.</p>	
Location	Iraq, Vietnam , Italy, <i>Turkey</i>	
Software	Autodesk Revit , Autodesk Ecotect analysis, Autodesk GBS	
brief description about research	<p>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 different process to achieve sustainable airport such as assume different alternatives and study effects on sustainability ,increase in passengers to decreasing Co<sub>2</sub> emissions per passengers</p>	Previous studies

## **1.8 Summary**

This chapter illustrates a brief introduction, an explanation of the research problem and justifications, illustration the aim and objectives of the research, research limitations, and the methodology of research