Utilize BIM Technology for Achieving Sustainable Terminal Building of Airport

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Abstract: The airport industry is the world's largest energy consumer, which negatively influences the environment. In this article, the research methodology is applied Building Information Modeling (BIM) technology in 3D simulation and energy analysis. This research aims to use BIM technology and its advantages in improving the sustainability of the building through the use of solar panels and adding different alternatives to the building to see the extent of their contribution to reducing the energy used and the percentage of emissions. The case study of this research was applied in one terminal of the Baghdad international airport. The researcher found that using BIM technology helps a lot in improving energy performance in various ways, improving the percentage of emissions, and controlling them during the design stage. The results concluded that applying BIM technology, use photovoltaic (PV) panels reduced annual energy consumption around by 45, 13, and 23% when operating in different places of the roof and achieves cost-saving about (258,601, 76,471, and 130,483 $/year, respectively, total electricity consumption equal to (4,466 MWh/year and annual fuel consumption are 9,472, 795 MJ/year) this results reduced by using different alternatives. The use of double glazing, foam material, and replacing part of the curtain wall with a block wall is the most effective alternative in improve energy saving and reduce CO2 emissions.

Keywords: BIM; building performance analysis; GBS; green energy strategies; Create design alternatives; photovoltaic panels analysis.

1. Introduction
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 (Airports Council International, 2008). Over the past 20 years or so, awareness of human activity's environmental impacts has increased substantially [1]. The concentration of carbon dioxide CO2 in the atmosphere has been increasing. It remained above 400 ppm for the first time in 2016 for the first time. The aviation industry is a significant contributor to greenhouse gas emissions. In this sense, the aviation sector in general, and airports, 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, an MW-scale plant needs more land. Because large expanses are required as buffer zones in airports, this property can be successfully utilized for a utility-scale solar PV plant [2].

The ability to meet the needs of modern human growth without jeopardizing future generations is the widely accepted definition of sustainability [3]. Airports are networks that are a part of today's society and play an important role in meeting the need for mobility [4]. Air traffic is a rapidly expanding industry around the world. This creates issues with long-term sustainability [5]. The future of airport planning is developing sustainable airports. Airports have an effect on the atmosphere as well as the people who live nearby. As a result, airports must be both socially and environmentally conscious. Many
airports have begun to work on creating a more sustainable climate [6]. Buildings accounted for approximately 32% of global energy consumption and 19% of energy-related greenhouse gas emissions in 2010 [7]. Global warming has a negative impact on the environment and societies, according to these assessments. With the mounting concerns of global warming, it is unsurprising that the construction industry is increasingly attempting to meet the need for energy-efficient structures [8]. The electricity crisis in Iraq creates air pollution and low quality, which significantly impacts the health and safety of Iraqi inhabitants [9]. 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 [10]. Building information modeling (BIM) is a novel technique that combines various tools for assessing the energy performance of a building [11]. BIM technology offers the potential to model virtual settings that are identical to the real work environment, allowing all difficulties to be solved early in the project [12]. The usage of computer technology can substantially aid in the facilitation and improvement of labor [13]. Building energy modeling (BEM) is a new methodology based on building information modeling (BIM) [14]. The design team can benefit from BEM when utilized at the design stage, where design alternatives in terms of energy consumption and thermal comfort can be explored and evaluated [15]. The terms "green building" and "high-performance building" have been used interchangeably [16]. According to the Energy Independence and Security Act (NIBS 2011), a high-performance building involves the optimizing and integrating of all major performance attributes of a building over its life cycle. These include not only environmental sustainability (for example, energy conservation), but also cost–benefit analysis, occupant productivity, and operational factors. As a result, the optimization and integration of various building systems is the key to a high-performance building. In this study, the authors seek to achieve the following goals:

1) Improve performance of airport building by adopting BIM technology.
2) Use technology to calculate the amount of renewable energy and cost-saving obtained from the photovoltaic panels.
3) Use BIM technology to assess and energy performance analysis at the design stage.
4) The adoption of BIM technology in creating design alternatives to increase energy efficiency and reducing CO₂ emissions.

2. Literature review
Several researchers have focused on improving energy efficiency in the Airport building. For example, Azhar and Brown [17] investigated the feasibility of using BIM in sustainability analysis [18]. This paper focuses on improving the sustainability of airports – their terminals and operation, and whether existing, expanded, or new. Examined the feasibility of encouraging more sustainable airport options using a scenario-based approach, focusing on airport surface access transport and terminal building design. Sustainable design practices at airports contribute to the triple bottom line of sustainability—social, environmental, and economic benefits. The procedures outlined here are just a sampling; many additional sustainable practices can be implemented at airport rehabilitation projects. The keys to successfully implementing these practices include an informed design approach by both the design team and the owner's review team, which openly considers the best use of materials and close collaboration between the design team [19]. Kılıç [20] this paper extends the terminal building energy performance analysis to a broader context. It expands the analysis envelope to expose the true impact of a terminal building on energy consumption and the combined emissions.

Najjar et al. [21] suggested a framework that depended on various performance criteria to enable decision-makers to use standard procedures and software for sustainable energy use and management in the building. Najj et al. [22] investigated the reasons for the displeasure of the Iraqi citizens with the privatization of electricity due to a significant increase in electricity bills and different alternatives to reduce electrical energy consumption. Singh and Sadhu [23] offered innovative ways to identify crucial elements contributing to energy efficiency and designing more sustainable buildings. Kaveh and Vazirinia [24] found the best timetable for the appliance by using multi-criteria decision-making (MCDM) and multi-objective optimization (EMOO) approaches to create a trade-off between design standards. Various Building Sustainability Assessment (BSA) methodologies are available that enable
designers to analyze and optimize the amount of sustainability in a building [25]. Because of Building Information Modeling (BIM), there is a possibility for BSA approaches to adopt and profit from BIM. Despite the benefits of simplifying the strategy for assessing building sustainability, the method has not been employed extensively in the review process thus far. This article examines how leveraging BIM can help optimize BSA procedures, emphasizing the SBToolPT-H.

3. Research methodology and experimental work

3.1. Research methodology

In this study, the author will depend on the tools provided by BIM technology through simulation and energy analysis at the design stage to find the best strategies to increase energy performance efficiency and reduce CO2 emissions in the Airport project. Figure 1 illustrates the research methodology selected to achieve the goals of this study. This research methodology is organized as follows:

1) Select the case study and collect data related to the Airport construction project (traditional drawing of Nineveh terminal).
2) Create a 2D model of the case study by using AutoCAD 2021, such as shown in Figure 2 below
3) Create a 3D model of case study:
   • Revit 2021 was used to model the case study, as shown in Figure 3.
   • Revit 2021 is easy to use compared to other modeling software.
4) Using Autodesk, insight 360 Plugin added to Rivet 2021 for:
   • Photovoltaic (PV) panels analysis: PV panels analysis is performed using a solar tool added to Revit 2021, which contributes to increased energy efficiency.
5) Create and simulation energy model and generate energy model to Autodesk Green Building Studio (GBS) for:
   • Energy performance analysis of the building.

Autodesk (GBS) cloud service analyzes the environmental effect of building components during the design stage where can perform energy analysis, CO2 emissions, water efficiency analysis, etc. Figure 3 shows GBS helps create different alternatives and find their effect on energy consumption and CO2 emissions.

![Image of the research methodology diagram]

Figure 1. Research methodology.
3.2 Experimental work: a case study
This project includes one Terminal of the Baghdad International Airport at Baghdad Iraq, Nineveh terminal was selected of three terminals). This building consists of two floors with a total area of 24,789 m². The material used in the case study and other components is shown in Table 1 (resource Technical Library of Baghdad International Airport).

Fig. 3. Create3D model of the case study.

| Building element | Material/Components | Thickness (m) | Thermal Conductivity (W/m.k) |
|------------------|---------------------|--------------|-----------------------------|
| Exterior walls 1 | Oil paint           | 0.01         | 0.51                        |
|                  | Gypsum wall board   | 0.02         | 0.42                        |
|                  | Solid block         | 0.24         | 0.13                        |
|                  | Internal insulation | 0.02         | 0.72                        |
| Exterior walls 2 | Oil paint           | 0.01         | 0.51                        |
|                  | Gypsum wall board   | 0.02         | 0.42                        |
|                  | Solid block         | 0.28         | 0.12                        |
| Interior walls 1 | Gypsum wall board   | 0.02         | 0.42                        |
|                  | Hollow Block        | 0.24         | 0.12                        |
|                  | Internal insulation | 0.02         | 0.72                        |
| Interior walls 2 | Oil paint           | 0.01         | 0.51                        |
### Gypsum wall board
- Hollow Block: 0.02
- 0.20

### Hollow Block
- Concrete: 0.2
- Asphalt: 0.03
- Soil: 0.15
- Concrete tiles: 0.04

| Roof 1                      |                   |       |
|-----------------------------|-------------------|-------|
| Standing Seam              | 1.2               | 1.0461|
| External Insulation         | 0.5               | 0.95  |

| Roof 2                      |                   |       |
|-----------------------------|-------------------|-------|
| Standing Seam              | 1.2               | 1.0461|
| External Insulation         | 0.5               | 0.95  |

| Floors                      |                   |       |
|-----------------------------|-------------------|-------|
| Concrete                    | 0.2               | 1.0461|
| Marble                      | 0.02              | 2.9   |

| Curtain walls doors         |                   |       |
|-----------------------------|-------------------|-------|
| Single glass                | NA                | 0.93  |
| Single glass                | NA                | 0.93  |

### 4. Results and discussion

The results were conducted and discussed according to the following stages:

#### 4.1 Photovoltaic (PV) panels analysis

Photovoltaic (PV) panels are one of the most important sources of renewable energy generation in the world. PV panels convert solar energy into electrical energy used for cooling, lighting, heating, and other purposes. Solar tool added to Revit 2021 allows for PV panels analysis. This analysis needs to enter some information to perform the analysis correctly such as the location, building area, energy use intensity, electricity cost per kilowatt-hour, and the efficiency of the solar panels and coverage from the total surface area and payback filter to payback limit. Figure 4 shows the result of applying PV panels analysis in different places of the roof; when using PV panel on all roofs, where energy production is 2,870 MWh/year, which reduces energy consumption by about 45%, achieves cost-saving around $258,601/year and payback limit around 29 years.

![Figure 4. Result of PV panels analysis for all roofs.](image)

Figure 5 shows the result of applying PV panels analysis for part of the roof, where energy production is 850 MWh/year, which reduces energy consumption by about 13%, and achieves cost-saving $76,471/year and a payback limit of around 13 years.
Figure 5. Result of PV panels analysis for the external part of the roof.

Figure 6. Result of PV panels analysis for the external part of the roof.

Figure 6 shows the result of applying PV panels analysis for another part of the roof, where energy production is 1,450 MWh/year, which reduces energy consumption by about 23%, achieves cost-saving around 130,483 $/year, and a payback limit of around 13 years. According to the results above, which show that the use of solar panels (PV) the panel can reduce energy consumption. Therefore, the researcher recommends using solar panels in Iraqi buildings.

4.2 Energy analysis
The summary of the energy simulation shows the annual carbon emissions are 472.4 Mg, the annual energy consumption of electricity is 4,466 MWh/year, and the annual fuel consumption is 9,472,795 MJ/year as shown in Figure 7.
Figure 7. Energy analysis results in GBS.

Figure 8 shows the results obtained from GBS analysis, where most energy consumption is for cooling purposes because the weather is hot for most months of Iraq.

Figure 8. Monthly energy consumption.

Table 2 shows the results obtained from GBS analysis, where the significant variations of monthly energy consumption during the year, which fluctuated between 521 Mwh in August where most consumption in this month around 26% for purposes of equipment, and 771 MWh in Jan where most consumption in this month around 36% for purposes space heat.

Table (2) Shows significant variations of monthly energy consumption

| Month          | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Total monthly  | 771 | 578 | 611 | 569 | 574 | 542 | 550 | 544 | 521 | 551 | 583 | 703 |
| energy (MWh)   |     |     |     |     |     |     |     |     |     |     |     |     |
| Area light (%) | 7   | 10  | 16  | 15  | 10  | 8   | 7   | 7   | 9   | 13  | 11  | 6   |
| Misc. equip (%)| 18% | 22  | 23  | 24  | 24  | 25  | 25  | 26  | 26  | 25  | 23  | 20  |
| Space cooling (%)| 10 | 7   | 8   | 12  | 19  | 20  | 22  | 21  | 17  | 15  | 9   | 6   |
| Space heat (%)  | 36  | 28  | 24  | 17  | 9   | 8   | 8   | 9   | 13  | 16  | 27  | 33  |
| Hot water (%)   | 16  | 21  | 22  | 22  | 20  | 18  | 16  | 16  | 15  | 16  | 17  | 16  |
4.3 Create alternatives

Based on the analysis acquired from the model analysis, the researcher suggested different Alternatives to improve the performance of the building and decreasing CO₂ emissions as follow:

1) Using double glazing in curtain wall, because these glazings have high thermal resistance, which can reduce the transfer of thermal conditions to the building, and these glazing can reduce CO₂ emissions, this analysis reduces annual energy use intensity (EUI) to 857 MJ/m²/year, the energy consumption of electric to 4,601 MWh, fuel to 6,896,210 MJ, and CO₂ emissions to 343.9 Mg as shown as in Figure 9.

![Figure 9. Using double glazing.](image)

2) Using foam material above roofs because of its high thermal and acoustic insulating qualities makes it a very different application than conventional concrete [26]. The result of using this material as shown in Figure 10 which decrease the Energy Use Intensity 856 MJ/m²/year, Electric 4,603 MWh, Fuel 6,901,601 MJ and CO₂ emissions to 344.2 Mg.

![Figure 10. Using foam material.](image)
3) Using limestone in finishing wall: Limestone is a sedimentary rock made up of calcium carbonate and calcium and/or magnesium. A wide range of limestones on the market, both foreign and domestic, vary dramatically in density, hardness, porosity, and aesthetics. The ability of limestone to adapt to different architectural styles and its pleasing natural color, ease of shaping, and longevity have contributed to the stone's popularity over time [27]. The researcher suggested using this stone to find out how useful it is in reducing energy consumption and the percentage of emissions from it to give an opinion on whether it is helpful for use or not good. These results of using this material as shown in Figure 11 which decrease the Energy Use Intensity 922 MJ/m²/year, Electric 4,468 MWh, Fuel 9,428,548 MJ, and CO₂ emissions to 470.2 Mg.

4) Using granite in the finishing wall: The only natural stones harder than granite are diamonds, rubies, and sapphires. Therefore, choose granite when permanence, enduring color and texture, and complete freedom from deterioration and maintenance are prime requirements. Granite is highly heat, scratch, and stain-resistant and is commonly used to face commercial and institutional buildings and monuments [27]. The researcher suggested using this granite to find out how useful it is in reducing energy consumption and the percentage of emissions to decide whether it is helpful for use or not good. These results are shown in Figure 12 below, decreasing the Energy Use Intensity 921 MJ/m²/year, Electric 4,462 MWh, Fuel 9,396,405 MJ, and CO₂ emissions 468.6 Mg. These results showed that the use of granite in the finishing of walls reduced energy consumption by a small percentage and reduced the rate of emissions. These results can be explained by few walls in the building, as the curtain wall is used in most buildings.

5) Using glass fiber insulation in finishing wall: This material has a comprehensive list of favorable: it withstands inclement weather, it behaves well in sub-zero temperatures, it doesn't suffer from corrosion, it's easy to maintain, it has low thermal conductivity, it's sturdy, acts well in tension, and compression, it's light, allows a smooth finish, and it's cheap compared to concrete or other traditional materials. Fiberglass has been considered one of the materials of the future because of its dielectric qualities. The researcher suggested using this fiberglass insulation to find out how useful it is in reducing energy consumption and the percentage of emissions from it to give an opinion on whether it is helpful for use or not suitable. The results of using this material as shown in figure 13 which increase the Energy Use Intensity to 1573 MJ/m²/year, Electric 2,077 MWh, Fuel 10,689,200 MJ, and CO₂ emissions to 533.1 Mg. Where this results of the analysis showed that the fiberglass is a good insulator of electricity, but the percentage of emissions is significant.
7) Replacing part of the Curtain Wall to a block wall: The curtain-wall system, which combines aluminum and glass, is a typical secondary structure in buildings; curtain walls are used in buildings due to their aesthetic, thermal, and lighting aspects. In this case, the researcher studies the possibility of replacing part of the Curtain Wall with a block wall, and the difference in energy consumption and emissions was noted, as all walls of the first floor were constructed in Curtain Wall with an extensive area. These results as shown in Figure 14, which the Energy Use Intensity to 851 MJ/m²/year, Electric 4,594 MWh, Fuel 6,815,141 MJ, and CO₂ emissions to 339.9 Mg, Where this results of the analysis showed that the replacing case is suitable for decreasing energy consumptions and CO₂ emissions.
Figure 14. Replacing part of the Curtain Wall to a block wall.

8) Selecting the Best Alternatives: To choose the best alternative, one must know each energy consumption decreeing and the extent to which it reduces energy consumption and CO2 emissions, as shown in Table 3 below.

| Alternatives                        | Energy Use Intensity (EUI) MJ/m²/year | Electric (MWh) | Fuel (MJ)  | CO2 emissions (Mg) |
|-------------------------------------|--------------------------------------|----------------|------------|--------------------|
| Actual Material (non-alternatives)  | 924                                  | 4,466          | 9,472,795  | 472.2              |
| double glazing                      | 857                                  | 4,601          | 6,896,210  | 343.9              |
| Foam material                       | 856                                  | 4,603          | 6,901,601  | 344.2              |
| lime stone                          | 922                                  | 4,468          | 9,428,548  | 470.2              |
| Granite                             | 921                                  | 4,462          | 9,396,405  | 468.6              |
| Glass Fiber                         | 1537                                 | 2,077          | 10,689,200 | 533.1              |
| Replacing part of the Curtin Wall to a block wall | 851                                  | 4,594          | 6,815,141  | 339.9              |

So, The researcher recommends using double glazing, foam material, and replacing part of the curtain wall with a block wall because it reduces energy consumption and the percentage of emissions. By a reasonable rate because of facilitating heating and cooling, compared to other alternatives where the ratio was low or negligible in reducing energy consumption and emissions. The difference between the alternatives used in the ceiling and curtain walls can be explained from the other alternatives because the heat transfer is more excellent through the ceiling and walls, as shown in addition to the wide areas of the ceiling and curtain walls. Finally, it can be explained why the energy consumption was not significantly reduced from the original project after adding alternatives, because the building was basically during its implementation, adding insulation materials to the ceiling and walls, which reduced the impact of adding alternatives on energy consumption.

5. Conclusions
Depended on the result, the researcher concludes the following:
• photovoltaic (PV) panels analysis contributed to the knowledge that photovoltaic panels have a significant role in reducing energy consumption and reducing the effect of building energy on the environment.
• The use of Autodesk Green Building Studio in energy analysis provides accurate details, helping designers and architects understand and evaluate the building's energy performance in the early design stages.
• Autodesk Green Building Studio is an effective tool in designing and evaluating the effect of different alternatives on energy consumption and carbon emission. It provides designers and architects the opportunity to find the best alternatives that increase energy efficiency at the early design stage.

So, The researcher recommends using sustainable materials in construction design to reduce energy consumption and preserve the environment by reducing emissions by adding environmentally friendly materials.

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