Building Energy Management in Airport Construction Projects Utilizing BIM Technique

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Abstract. Building Information Modeling (BIM) is one of the modern technologies that has become widely applied in many aspects of construction projects and energy management. This paper aims to use modern technologies in designing and constructing airports to control energy consumption, know the possible strategies to obtain the lowest consumption and the most appropriate cost, and compare simulated electrical energy outcomes with actual electrical energy consumption. 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. As the airports are the largest part of buildings in energy consumption and due to the lack of research available in Iraq on how to obtain optimal use of the consumption of available electricity and water efficiency in Airport projects that can be used to obtain an environmentally and economically sustainable airport. Using BIM technology and the associated programs, it is possible to know the optimal strategies in terms of economic terms. The environment in the early stages of the life of the project. The idea of this study applied to one terminal of Baghdad international airport. The results illustrate that BIM is very useful to perform various analyses that help find different strategies for improving the project's energy efficiency, such as sun path analysis and GBS tool based on BIM helpful technology tool to energy analysis. The result illustrates that most energy electricity consumption goes for cooling space with consumption around 63871 kWh in August month and most fuel consumption for the purpose space heat with consumption around 1409261 MJ in January month and where indoor water-saving around (23.7%). GBS tool based on BIM technology is an effective tool that can help designers and architects to energy performance assessment and calculate energy costs in the early design stage were help in finding the best solutions that contribute to improving energy efficiency in the early stages of the project life cycle.

Keywords: BIM; Energy management; energy analysis; Sun path analysis; Green Building Studio (GBS), water usage analysis

1. Introduction
Airport Building Information Modeling emphasizes Building Information Modeling as a new airport methodology [1]. Because Building Information Modeling is inextricably tied with building construction. There is a preconceived notion that BIM is only effective for buildings, especially existing or heritage buildings, and not civil engineering projects such as motorways, trains, or other infrastructure projects. Airport construction, by definition, can include all types of construction features, such as buildings, trains, parking lots, and roads. The energy required to create airport buildings is estimated to be 5.9 GJ/m², with approximately 460 kg CO₂ of GHG emissions per m² produced. This is presumptively predicated on the notion that airport structures are similar to shopping malls. If the energy
used in construction is expressed as energy consumed per passenger-mile traveled, this corresponds to around 1.1 kJ/passenger-mile traveled [2].

The perception is that the multidimensional concept of a sustainable airport is based on the interaction of numerous aspects, including airport services and quality, energy consumption and generation, CO₂ emissions and mitigation planning, environmental management and biodiversity, and low atmospheric emission transportation [3]. According to [4], the construction of sustainable airports includes the following goals: reducing energy consumption; reducing impacts on water and air quality, minimizing waste, reducing pollution, and/or minimizing other environmental impacts; improving construction operations; improving construction safety; reducing construction impacts on airport operations; benefiting the surrounding communities; and reducing construction costs.

In recent years, Iraq's electric power has suffered from a lack of national demand [5]. Traditional CAD scheme environments cannot usually undertake performance assessments early in the design process, with performance evaluations being performed after all architectural design and construction papers have been completed [6,7]. Building Information Modeling (BIM) technology is one of the contemporary technology which allows multidisciplinary information to overlap in one model, allowing for the performance of sustainability measures and energy performance analysis from the early design stage [5]. BIM technology aids in enhancing energy efficiency in various ways, and it also provides the capacity to tackle all energy-related concerns within the project's early design stage [2]. Building components have the most significant impact on energy dissipation, with walls at 35%, roofs around 25%, windows around 10%, and floors about 15% [10].

In Iraq, many researchers focused on using BIM technology to improve the various aspects of the construction sector [11]. The purpose of this research is to investigate the impact of design parameter alternatives (orientation, window-to-wall ratio, window glass type) on electric energy performance and cost, to investigate the role of BIM tools in water usage analysis and increasing water efficiency, and to investigate the capabilities provided by BIM tools to improve natural ventilation. Taha [12] studied the possibility of using BIM technology to address conflict detection during the project life cycle. Also, Taha [12] studied the effect of the lightweight foamed concrete brick as an alternative to clay bricks on cost and energy consumption by using BIM. The results illustrate that the cost of a lightweight foamed concrete brick is higher than normal clay brick, and lightweight foamed concrete brick is lower energy consumption than normal clay brick.

The results illustrate the ability of BIM technology to detect conflicts and to re-document buildings. Taha et al. [13] studied the obstacles that guide the adoption of BIM technology in Iraqi construction projects. This study showed that many obstacles guide the adoption of BIM technology in Iraq. The top three obstacles were weak efforts by the government, resistance to change, weak awareness and knowledge of BIM benefits. Ewaid et al. [14] studied the effect of the application of BIM technology in improving safety for Iraqi oil projects and its impact on schedule time and costs. The results showed that BIM technology helps solve all safety problems in the early stages of project life.

Many authors focused on the use of BIM technology in improving and energy evaluation. For example, Azhar and Brown [15] explored the benefits of sustainability assessments based on BIM technology and the evaluation of numerous building energy analysis methods. The findings of this study are intended to be relevant to construction and architecture firms interested in using BIM technology for sustainable design. Shouibi et al. [16] used BIM technology to examine a collection of materials to discover the best sustainable solutions for reducing operating energy use. Finally, this study proposed several sustainable methods to reduce energy consumption. The findings of this study will be valuable for designers and architects in the future to use BIM technology to develop energy-efficient buildings to attain sustainable development in the construction sector. In this study, Revit 2012 and Ecotect Analysis tools were used [17]. The function of BIM technology in performing energy analysis and enhancing energy performance was investigated, as well as the influence of building orientation on energy consumption was illustrated. Naji et al. [18] evaluated effective roof and wall solutions for decreasing electricity power. The findings of this study demonstrate an excellent capacity to use BIM technology in conjunction with AHP to identify the best construction materials for reducing power usage. In recent
years, Iraq has suffered from many energy problems where electrical energy has become insufficient for national demand. The construction sector is one of the most contributors to energy consumption and environmental impact. Therefore, the authors in this study relied on BIM technology as it is a modern technology that contributes significantly to energy management. This study aims to the following:

- Study the effect of sun path analysis in improving energy performance.
- Analysis and evaluation of the energy performance based on the tools of BIM technology.
- Energy performance.
- Electrical energy cost calculation.
- Comparison of simulated electrical energy outcomes with actual electrical energy consumption.

2. Research methodology

From the previous studies related to BIM and considering different methods in building energy management, the research framework is developed as shown in Figure 1. The research methodology mainly includes two parts:

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

Part two (practical study): The practical part of the research includes the following:

1) Explorations and case studies are selected, and data collection includes (Traditional drawings and energy consumption data).
2) Create 2D model by using Autodesk AutoCAD 2021 Program, as shown in Figure 2.
3) Create 3D model by using Autodesk Revit 2021 software, as shown in Figure 3.
4) Create an energy model, calculate heating and cooling and generate a model for optimizing 3D BIM model using Autodesk Green Building Studio (GBS) as shown in Figure 4.
5) Evaluate energy performances of the project.
6) Comparison of simulated electrical energy outcomes with actual electrical energy consumption.
7) Compare actual cost of electrical consumptions with simulated electrical cost.
8) Discuss the conclusions and recommendations reached by the researcher.
9) Comparison cost.

![Figure 1. The research methodology.](image-url)
3. Case study
To achieve the aims of this study, one terminal of the Baghdad international airport is selected as a case study (Terminal Nineveh). The terminal's basic form is built on a 19-meter-long equilateral triangular shape, which is repeated as a foundation to generate functional and structural formations. This building
consists of Three floors (Two floors were studied due to reservations made by the airport administration on basement data for security reasons). Two floors with a total area (24,789 m²). The airport was designed by a British consultant (Monsal), and it was built by two French businesses (Fougerolle and Spie Patignolles).
1) Project location: Baghdad, Iraq.
2) Ground floor: with height 6 m.
3) First floor: with height 15.6 m. It contains open halls and architectural structures.
4) Material type used for different building components illustrated in Table 1.

Table 1. Material building components.

| Components       | Material Type   | Components      | Material Type   |
|------------------|-----------------|-----------------|-----------------|
| Walls 1          | Solid block     | Roof 2          | Metal Deck      |
| Walls 2          | hollow block    | Floor           | Marble          |
| Curtain walls    | Single glazed   | Doors           | Single glazed   |
| Roof 1           | Reinforced concrete | -           | -              |

4. Sun path analysis
The sun's path analysis provides a visual interpretation of the sun's location and its effects on the various building portions at different times of the day, month, and year. It is also helpful in visualizing the building's shadow throughout the day and assessing building orientation, which assists designers in finding an appropriate direction for the building that can reduce energy consumption in the building. Figure 5 depicts sun path analysis in the winter and summer seasons. The researcher found that the building's real orientation is excellent because the front side of the building is exposed to good sunlight during the day in both the winter and summer.

Figure 5. Sun path analysis.
5. Results and discussion
After the optimized 3D model in the GBS cloud, a complete simulation of energy performance is performed. The results were performed and discussed according to the following steps:

5.1 Monthly Electricity Energy Analysis
Using Green Building Studio gives a very detailed electricity energy analysis; this results showed that most electricity consumption goes for cooling space, equipment, and vent fans due to Iraq weather is considered dry and hot in most months and using HAVAC system in the project as shown in Figure 6.

![Figure 6. Monthly electricity energy consumption.](image)

The total electricity consumption per month shows large variations during the year, fluctuating between $15.7 \times 10^3$ kWh in February and $63.9 \times 10^3$ kWh in August, as shown in Table 2 below.

| Run total          | Jan | Feb | Mar | Apr | May | Jun | Jul  | Aug  | Sep  | Oct  | Nov  | Dec |
|--------------------|-----|-----|-----|-----|-----|-----|------|------|------|------|------|-----|
| Electricity $\times 10^3$ (kWh) |     |     |     |     |     |     |      |      |      |      |      |     |
| Area light         | 17  | 15.7| 21  | 27.5| 44.9| 56.9| 60.6 | 63.9 | 44.7 | 34.7 | 17.7 | 16.9|
| Misc. equip.       | 22% | 25% | 24% | 22% | 20% | 20% | 19%  | 20%  | 19%  | 21%  | 22%  | 24% |
| Space cooling      | 37% | 42% | 41% | 38% | 34% | 33% | 34%  | 36%  | 37%  | 40%  | 38%  |     |
| Vent fans          | 21% | 14% | 14% | 20% | 26% | 27% | 28%  | 27%  | 23%  | 21%  | 16%  | 19% |
| Pump aux           | 7%  | 8%  | 8%  | 8%  | 8%  | 8%  | 8%   | 8%   | 8%   | 8%   | 8%   | 7% |
| Space heat         | 5%  | 2%  | 2%  | 0%  | 0%  | 0%  | 0%   | 0%   | 0%   | 0%   | 0%   | 2% |

5.2 Monthly fuel analysis
Most fuel consumption for the purpose space heat as shown in Figure 7. The total fuel consumption per month shows large variations during the year, which fluctuated between 465944 MJ and 1409261 MJ as shown in Table 3. The chart shown in Figure 8 reflects the annual percentage of electricity and fuel consumption get from the simulated model to GBS.
5.3 Monthly electrical energy cost

After calculating energy consumption by using BIM technology, it helps designers and architects to calculate energy costs in the early stages of the life of the project. Because the energy used in the terminal is only electricity, the fuel consumption is converted into electrical energy and then combined with the
electricity consumption to obtain total consumption (1 MJ to kWh = 0.27778 kWh). The cost calculates according to the following Eq. (1).

$\text{Total electrical cost} = \left( \text{Total Electrical consumption} \times \text{Electricity cost of Kwh} \left( \frac{120 \text{ ID}}{\text{kWh}} \right) \right)$  \hspace{1cm} (1)

### Table 4. Monthly electrical energy cost.

| Month | Electrical con. for 24 hrs. (MWh) | Fuel (kJ) | Total electrical consumption (MWh) | Electricity cost (ID/kWh) |
|-------|---------------------------------|----------|-----------------------------------|--------------------------|
| Jan   | 17                              | 391461.3 | 408                               | 49,018,236               |
| Feb   | 15.7                            | 275760.0 | 291.5                             | 34,977,480               |
| Mar   | 21                              | 275201.9 | 296                               | 35,559,588               |
| Apr   | 27.5                            | 215783.6 | 243                               | 29,190,312               |
| May   | 44.9                            | 167193.6 | 212                               | 25,447,752               |
| Jun   | 56.9                            | 141811.6 | 198.7                             | 23,843,712               |
| Jul   | 60.6                            | 129428.8 | 190                               | 22,808,376               |
| Aug   | 63.9                            | 131686.6 | 195.6                             | 23,466,912               |
| Sep   | 44.7                            | 145560.0 | 190.3                             | 22,832,640               |
| Oct   | 34.7                            | 172885.0 | 207.6                             | 24,908,520               |
| Nov   | 17.7                            | 249047.5 | 266.8                             | 32,013,060               |
| Dec   | 16.9                            | 335511.3 | 352                               | 42,291,036               |
| Total |                                 |          | 3,053                             | 366,357,624             |

The annual electricity consumption data with the cost was obtained from the main fuel station of the airport, and the data for the year 2018 were approved as a result of the stability of conditions in that year to ensure actual consumption with normal conditions. As shown in Figure 9 below, the researcher focused on the Nineveh terminal, which represents Tamim 3 in the figure below, Where was the number of units consuming electricity 3,291,000 kWh, and the total cost of consumption is 394,920,000 ID/kWh.

![Figure 9. Actual annual electricity consumptions and cost (Source fuel station of the airport).](image)

The results showed a small percentage between the results obtained from CRIN and the realistic results, the researcher recommends using BIM technologies in the early stages of airport design to ensure that the lowest level of electricity consumption is maintained and cost control.
6. Water usage analysis
Through the use of Green Building Studio (GBS), it summarizes water usage where indoor around (73,414,449 L/year) and outdoor about (904,489 L/year) based on the type of building and fixture type, according to building a summary of water efficiency this building should contain 440 toilets, 440 sinks, 440 showers, and nine clothes washers shown in Figure 10.

![Figure 10. Result of water usage analysis.](image)

The calculation of water in GBS is valuable because it helps increase water efficiency and meet the LEED water efficiency category, as shown in Figure 11. designers can change fixture efficiency to improve water efficiency and find the optimal strategy to achieve the required LEED point, where indoor water-saving around (23.7%) as shown in Figure 12. Green Building Studio (GBS) allows taking some measures to achieve Net-zero water usage through rainwater harvesting, greywater reclamation, savings of net-zero can be estimated as shown in Figure 13.

![Figure 11. LEED water efficiency credit requirements in GBS.](image)
Figure 12. Change fixture efficiency and efficiency saving in GB.

Figure 13. Net-zero measures of water usage.

7. Conclusion
The airport sector is a significant contributor to energy consumption and environmental effect. As a result, the authors attempt to identify appropriate tools and strategies that improve energy management by utilizing modern technology such as BIM technology. Based on the results, the authors concluded the follows:

- BIM is beneficial to perform various analyses that help find different strategies for improving the project's energy efficiency, such as sun path analysis.
- GBS tool based on BIM helpful technology tool to energy analysis where result illustrate most energy electricity consumption goes for cooling space with consumption around 63871 kWh in August month and most fuel consumption for the purpose space heat with consumption around 1409261 MJ in January month.
- Autodesk Green Building Studio (GBS) is a good tool in water efficiency analysis to calculate water usage in the building as well as increase water efficiency, where water usage indoor around (73,414,449 L/year) and outdoor about (904,489 L/year) and indoor water-saving around (23.7%) based on fixture efficiency.
- GBS tool based on BIM technology is an effective tool that can help designers and architects to energy performance assessment as well as calculate energy performance in the early design stage were help in finding the best solutions that contribute to improving energy efficiency and water usage in the early stages of the project life cycle.

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