Using BIM for Optimizing the Upgrading Cost to Convert the Traditional Buildings to Sustainable Buildings in Iraq

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Abstract. A high percentage of existing buildings in Iraq are traditional buildings, yet there is approximately no such green building in Baghdad or other governorates. Most of these buildings require urgent upgrading to increase their performance (operationally, economically, and environmentally), also the building owners looking for identifying and implementing many of the green building measures to reduce the operational and maintenance costs of their buildings. The decision-makers need to support the possibility of achieving sustainable measures of existing building rating systems such as LEED or BREEAM, and that would require an optimization model. The goal of this study is to maximize the building’s operational efficiency, health, and comfort of the building to its occupants through minimizing upgrading cost and reducing the environmental impacts of the building. An existing building will be used as a case study to illustrate the optimization process and demonstrate the plans and processes required to achieve the green building measures, the capability of reducing the required upgrade costs. For this type of problem, the building drawings are represented Using Building information modeling (BIM) (Revit program), and the life cycle costing and environmental impact can be found using analytical tools (ONE CLICK LCA STUDENT VERSION online software). The results show that up to (15.4 and 23.2) % reduction in discounted and nominal costs respectively could be achieved, the CO₂ emissions also had decreased from 34233 Ton to 19299 Ton.

Keywords: BIM, sustainability, LEED, Pearl, ONE CLICK LCA STUDENT VERSION

1. Introduction
From studies, one can notice that around 30% of the total energy uses in modern countries comes from the energy uses in existing buildings and it may induce that almost 30% of carbon emissions are caused by the energy of existing buildings. The energy consumption of existing buildings in some modern countries has exceeded those in the industrial and transportation sectors. Therefore, it is of urgent need to find tools and methods focus on the retrofitting of existing buildings (which forms a high percentage in Iraq) not only from the economical aspect but also from the social and environmental aspects. It’s also required to minimize the temperature rises and the effects of its climatic changes in the future while reducing the upgrading cost [1]. BIM is considered to be a revolutionary technique and process which transforms the method of designing, planning, constructing, and managing the buildings. It also can serve as an approach to help the construction industry to create new thoughts and practices. According to Smith [2], BIM digitally representing the physical and functional features of a facility. BIM offers a mutual knowledge source for information of a facility and forms a rational foundation for decisions through the life-cycle from the inception onwards. So, BIM is a clever technique for designing, producing, visualizing, and lifecycle managing of buildings. BIM’s software combines multi-dimensional conception with the complete scientific databases. This facility the joint design and the facility management among the project team members.
Some researchers have faith that BIM is a typical change rather than a representation of two-dimensional building design, collecting, and management of the life cycle [3]. BIM processes are well-known for constructing new structures, but a high percentage of existing structures are not maintained, updated, or deconstructed using BIM so far. The huge benefits of effective resource management inspired research to overcome worries of structure circumstances and lack of documentation in existing projects. Because of the quick developments in BIM research, relevant stakeholders require a recent overview of implementing BIM and researches in existing structures. The results show that the BIM application in existing structures is so frightened because of the following challenges: (1) hard process of modeling and conversion from structure data captured to BIM semantics, (2) hard updating of information in BIM software and (3) handling with the inexact data, objects, and relationships in BIM that occurs in existing structures [4]. The greatest capacity of BIM is its nature of integration among different construction processes, as it is relating to a sustainable world from the front of the project, until operation and maintenance.

2. Green Building Rating
For buildings under LEED® certification, numerous LEED® credits need the drawings to be presented, to achieve the requirements for the credit. Even though that most of the drawings could be done by traditional CAD programs, BIM programs deliver it more effectively as a portion of the building information modeling with the benefit of parametric change technique, this technique coordinates alterations and keeps consistency at any time. [5] In every construction project, the cost plays an important role. Lifecycle cost (LCC) means determining the entire cost of the structure over the expected life of it, companies with the cost of operation and maintenance. Alternative modern techniques can be used to improve calculating LCC without much changes in the structure. The lifecycle cost can be determined at any stage of the building, which may assist the decision-makers in providing the necessary financial information for maintenance, improvement, and construction facilities [6].

The Net present value (NPV) is the most suitable method for calculating the life cycle cost (LCC) since it considers the money's time value. This method calculates the sum of all the annual and non-annual costs comprising investment, replacement, operation, maintenance, and the resale value. [7] \( \text{NPV} \) is shown in Eq.1

\[
\text{NPV} = C+R+A+M-S
\]

Where
C: is the investment cost
R: is the Replacement costs
A: is the annual operating, maintaining, and repairing costs.
M: is the Non-annual operating, maintaining, and repairing costs.
S: is the Resale value.

To determine the lifecycle cost there may be difficulties in collecting the necessary information about the initial and future expenditures like the original acquisition, current, overheads, operating, maintaining, discounts, critical, escalating, and end of life costs [7]. One Click LCA student version calculates LCC depending on Eq.1

3. Measures and Technologies for Existing Buildings
The following are some techniques used to provide efficient lighting with lower energy consumption:

3.1. Energy Efficient Lighting
A. Fluorescent lamps consist of: (1) tabular lamp and (2) ballast, for more efficient energy, one can use smaller diameter of tabular lamps, or use the electronic ballast [8].
B. Induction lighting as a technique to gain more durable lighting sources used mainly in high ceilings or in very cold temperatures, it may stay valid for 100000 hours, however, the main problem is the relatively high initial cost. Another solution is using Lighting Emitting Diodes
(LED) for high efficiency and long-life lighting by converting electricity to light. [9]. It could stay valid for 50000 hours.

C. Motion-activated lighting is a technique to save energy by activating lights when needed using infrared sensors to sense the motion of a heat source in the place as soon as the MAL system detects a motion in the place it turns lights bulbs on, and they remain on as the movement still detected. After the last motion, the system will be kept in detection mode for a short time, then it turns off automatically [10].

3.2. **HVAC@ R Systems**

LEED verified not to use chlorofluorocarbon (CFC)-based refrigerants HVAC&R systems. When these refrigerants are used in the building, it should minimize the annual leakage to equal or less than 5%, and the total leakage to less than 30% of the refrigerator’s charge, not to use refrigerants, or use refrigerants of zero ozone depletion potential (ODP) and less than 50 global warming potential (GWP) [11]. Pearl has also required to verify that all gaseous fire defeat systems installed in the project site must have zero ozone depletion potential (ODP). CO₂ monitors should be installed in all densely occupied spaces. Rooms of area less than 14 square meters are exempt. These monitors should be above the floor between 900 to 1800 mm. The system should be designed to create a visual alarm to the operator if the concentration of differential CO₂ in the zone rises 15% or more above that comparable to the minimum required outdoor air rate [12].

3.3. **Thermal Pane Glass**

Typically, windows cause 3 to 10% heat loss greater than the heat loss in walls, as a result, careful selection of windows type is important to reduce energy consumption in buildings. Thermal Pane Glass provides better insulation than the regular pane glass, it has a separate double or triple pane of glass and air space to reduce the loss or gain of the heat flux. The thermal conductivity of the glass and the frame is the Base of the insulation of windows, the metal frame’s insulation can get better by installing a thermal break to split the frame into two parts. Fourier’s heat low is used to describe the windows overall insulation [13].

3.4. **Photovoltaic System**

Solar systems are renewable and sustainable techniques using the solar energy to produce electricity, save energy up to 100%. This system utilizes photovoltaic cells made of semiconductor materials that have a sensitivity to the sunlight. With an area of 1 to 100 cm² for each cell, the cells are connected and form a module with an area of 0.5 to 2 m², by combining modules a photovoltaic array is created to provide electricity [14]. The photovoltaic arrays are either separated on the ground or installed on the roof of the building. Another important factor affecting the output of the system is the orientation of the panels which depends on the season and altitude of the building to get the maximum power by tilting the panels in a specific angle to face the sunlight [15]. There are two types of solar photovoltaic systems: grid-connected and stand-alone systems.

3.5. **Solar Heating Systems**

Using the sunlight energy in the process of heating water is another technique to conserve energy and can be used in many purposes in the building, the hot water amount’s provided by this system changing according to the type and size of the system and the climate conditions, a backup system of water heating could be installed and used in case the sunlight energy is not enough to meet the demand or when the sunlight is absent [16].

The system of solar water heating is categorized as active uses electrical pumps and valves, and passive depends on the natural convection. This system is also classified into direct and indirect according to whether the water is heated in collectors directly or by using a mechanism to exchange heat, this system provides a clean and sustainable renewable energy source, reduces the consumption of fossil fuel and greenhouse gas emissions, and reduces the energy cost [16].
3.6. Water-Saving Plumbing Fixtures

Reducing indoor water consumption by using water-efficient urinals, toilets, and faucets is another technique to enhance the efficiency of buildings. For example, using a dual flush technique in toilets that uses compressed air in flushing, the air is compressed in the dual flush vessel while it is filled with water, the approximate water consumption per flush by this technique is about 0.8 to 1.1 gallons and 1.6 gallons for liquid and solid wastes respectively. One can upgrade the manual faucets by installing flow restrictors on the head of the faucet to reduce the flow of water to about 0.5 to 2.5 gallons in a minute, or by replacing the faucet head with flow aerators which add air to the stream of water [17]. Pearl specified the requirement to color all pipes that contain recycled water to distinguish them easily from other pipes, to reduce the water demands through irrigation strategies, plant selection, and developing the reclaimed water use.

Ensuring that 100% of the demand for outdoor irrigation is served by the use of Exterior Water Allowance and that a recycled water mainline loop for reclaimed water is installed. The reclaimed water use is not available to allow for future change from potable to reclaimed water for outdoor irrigation demands. Pearl also suggested rainwater management system can collect and treat at least 90% of rainwater and the treating can accomplish the minimum standards of quality control:

- Remove 80% of total suspended solids (TSS), 95% of litter (gross pollutants, >1 mm), at least 90% of hydrocarbons and use of oil interceptors or suitable paving for parking for more than 4 lines.
- Use either Non-structural solutions for rainwater management contain sustainable urban drainage systems (SUDS) for example ponds, Vegetable granules, wetlands, etc.

Or structural solutions for rainwater management using structures for example pipes, tanks, concrete channels, etc [12].

3.7. Indoor Air Quality

LEED had forbidden smoking inside the building, and forbid smoking out of the building too except in designated areas for smoking which should be located at least 7.5 m from the entries, operable windows, and outdoor air intakes. It also forbids smoking out of the property line in case the space is used for business [11]. Pearl requires the following:

- Use low emission paints and coatings to enhance the desirability of the building to improve the health of occupants.
- Provide permanent access systems of at least 3 meters in the main direction of movement to eliminate the particles and dirt entering the building at the outside entrances regularly used.
- Establish that interior noise levels are of no more than 50 dB in the space to be employed.
- Pearl has demonstrated to use no Asbestos Containing Materials (ACMs) in the improvement and to remove all ACMs from renovated buildings.
- All insulation materials have a Zero Ozone Depleting Potential, and equal or less than five low Global Warming Potential
- Replace chlorine-based materials like Chlorinated polyethylene (CPE), Polyvinyl Chloride (PVC), Polychloroprene, Chlorosulfonated polyethylene (CSPE), and Chlorinated polyvinyl chloride (CPVC), with more green alternatives [12].

4. Building Description

The case study will be applied to a building that lies in Aletaifia, Baghdad, Iraq, the building is of (463.75) m² and 8 floors (including the ground level and the basement) as shown in Fig. 1 and Fig. 2 the building contains 90 small offices most of them are medical clinics, the details of the building are:

1) The building is 26.5 m width, 17.5 m length;
2) It contains 8 floors (ground floor and basement with 4 m high each and 6 floors with 3 m high each);
3) A 662 m$^2$ of 12 mm thick glass façade;
4) 33 columns of (300 mm * 450 mm) for each floor, finished with gypsum boards;
5) 7407 m$^2$ of walls, the external face of the building (1843.47 m$^2$) is finished with cement plaster and the inner face (and all the internal walls) are all finished with gypsum boards;
6) 90 rooms ranging in areas from 20 m$^2$ to 27 m$^2$;
7) 90 wooden doors of 1 m *2 m, and 90 aluminum doors of 0.8 m *2 m;
8) 14 windows (3*1.8 m), 7 windows (2.5*1.8 m), 7 windows (1.5*1.8 m), 7 windows (1*1.8 m), 21 windows (0.915*1.8 m), 21 windows (0.915*0.61 m), and 69 windows (0.61*0.61 m), the total area of windows is 539.77 m$^2$;
9) The building consumes 767 CFL (23 W) lights and 90 (1.5 Ton) split units;

![Figure 1. Plan of the case study building (researcher).](image)

5. Methodology
First, the researcher gets the case study’s drawings (hard copy) and built the model by using Revit (all the small details are important and can make a difference in the process of optimization) many errors occurred through building the model, but they all were solved and the model had been built successfully, as shown in figure (2), after that the researcher exported the model to the LCC software which is ONE CLICK LCA STUDENT VERSION, (can compute LCA and other environmental impact issues) then the real data of the building from the materials used to the annual consumption of electricity and water were collected and entered to the program after that the researcher run the program and got the LCA and LCC results (discounted and nominal) of the building before starting the optimization process, the researcher examined more sustainable alternatives to get the best set of alternatives, till got the set number 17 which had the less LCA and LCC results. Fig. 3 and Fig. 5 show the LCC results for the building before and after retrofitting respectively. The X-axis presents the LCC components and the Y-axis presents the percent of these components to the total LCC. Fig. 4 and Fig. 6 show the LCA results for the building before and after retrofitting respectively. The X-axis presents the LCA components and the Y-axis presents the percent of these components to the total LCA.

ONE CLICK LCA STUDENT VERSION is a Building Life Cycle software that calculates Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and other impacts of the environment such as the Carbon footprint in like few minutes as a result to the simplicity and the advanced automation, this
software is a web-based software used for sustainable Building credits, Low Carbon buildings, Eco-design, and Infrastructures. It is accommodating with LEED, BREEAM, and about 40 other sustainable rating systems, the user does not need to be an LCA or LCC expert [18]. The LCC discounted and nominal of the building before any retrofit were 6042275940 IQD and 17221281230 IQD respectively. LCC discounted and nominal of alternatives are shown in (table 1) in Iraqi Dinar (IQD), the negative signs in rows (5, 12, and 14) means additional costs will be used if those alternatives were applied.

Figure 2. The case study building after rendering (researcher).

Table 1. LCC discounted and nominal of the alternatives

| No. | Technique         | LCC dis. [IQD] | % reduction | LCC nom. [IQD] | % reduction |
|-----|-------------------|----------------|--------------|----------------|-------------|
| 1   | Solar heater      | 5987510455     | 0.9          | 17035953880    | 1.076       |
| 2   | LED lights        | 5918686093     | 2            | 16801608360    | 2.4         |
| 3   | PV panels         | 5986086655     | 0.93         | 16917827510    | 1.76        |
| 4   | PV (on grid)      | 5771432480     | 4.478        | 16313363086    | 5.27        |
| 5   | Solar façade      | 6195695724     | -2.5         | 16846602360    | 2.175       |
| 6   | Solar façade (on grid) | 5667142663 | 6.2         | 15275608844    | 11.29       |
| 7   | Inverter AC       | 5636495167     | 6.72         | 15826188080    | 8.1         |
| 8   | Central AC        | 5854734438     | 3.1          | 16385309890    | 4.85        |
| 9   | VRF AC            | 5618978010     | 7            | 15694193740    | 8.867       |
| 10  | Water saving      | 6026922624     | 0.25         | 16078887807    | 6.63        |
| 11  | Wall painting     | 5537567762     | 8.35         | 15837795510    | 8           |
| 12  | Marble tiles      | 6343176603     | -4.98        | 18154702270    | -5.4        |
| 13  | Vinyl carpet      | 5990194910     | 0.86         | 17288118960    | -0.38       |
| 14  | Granite tiles     | 6164604075     | -2           | 17311205450    | -0.5        |
| 15  | Ceiling painting  | 5812555564     | 3.8          | 16591580987    | 3.65        |
| 16  | Insulation        | 6024080984     | 0.3          | 16779628398    | 2.56        |
| 17  | Best alternative  | 5111379097     | 15.4         | 13225352521    | 23.2        |
Figure 3. LCC results for the building before any retrofit.

Figure 4. LCA results for the building before the retrofit process.

Figure 5. LCC results for the building after the retrofit process.
6. Conclusion

This research motivates using BIM to retrofit (upgrade) existing buildings, and it shows many reasons for what this technique is not used mainly for retrofit existing buildings. Verified some measures for the upgrading process, results of Table 1, by comparing LCC dis. and LCC nom. of the alternatives with those of the building before retrofit which are (604275940 IQD and 17221281230 IQD respectively) and shown that saving in costs can reach up to 15.4 % and 23.2 % in discounted and nominal calculations respectively by adopting the set 17 which is the best alternatives, as shown in Table 1. At the same time, the CO₂ emissions had decreased from 34233 Ton to 19299 Ton as calculated by One Click LCA student version. The measures used in the optimum case include using solar water heater, LED lights, VRF inverter air condition, insulation for external walls, paint the internal walls with light colors, insulation for roof and basement, porcelain for other floors, paint the ceiling with light colors, double glass for the façade, photovoltaic panels in the roof and on the façade, using water-saving toilets, and greywater recycling system. The results also show that even if the initial cost increased, the total life cycle costing will be reduced to a reasonable percent by reducing the costs of operation, maintenance, energy, and end of life.

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