Employ 6D-BIM Model Features for Buildings Sustainability Assessment

Hussain M. Habib\textsuperscript{1a*} and Kadhim R. Erzaij\textsuperscript{1b}

\textsuperscript{1}\textsuperscript{1}\textsuperscript{1}

Civil Engineering Department, University of Baghdad, Baghdad, Iraq.\textsuperscript{1a,b}

\textsuperscript{1}<h.habib1001@coeng.uobaghdad.edu.iq, \textsuperscript{1}kadhim1969@yahoo.com

\textbf{Abstract.} To translate sustainable concepts into sustainable structure, there is a require a collaborative work and technology to be innovated, such as BIM, to connect and organize different levels of industry e.g. decision-makers, contractors, economists, architects, urban planners, construction supplies and a series of urban planning and strategic infrastructure for operate, manage and maintain the facilities. This paper will investigate the BIM benefits as a project management tool, its effectiveness in sustainable decision making, also the benefit for the local industry key stakeholders by encouraging the BIM use as a project management tool to produce a sustainable building project. This paper presented a basic idea about the Building Information Model (BIM) technique and explain the levels of BIM and its dimension, the potential of BIM in sustainability design and the role of BIM in sustainability aspects had been discussed. The role of BIM in the planning and design stages explained the BIM role in sustainability rating system and grant credits in classification processes. Processing of creating 6D had been detailly explaining starting from the framework (ISO 1440) which adopted in the processing of establishing 6D complete system, phases of this system, and development steps from 3D to 4D, 4D to 5D and 5D to 6D. The 6D model features in the sustainability buildings had been explained in this research. As a result, many conclusions have been reached, the most important is there are still significant constraints in adopting of the integration approach between the (BIM) technology with sustainability in Iraqi buildings projects, both are facing great challenges in terms of economic, technical and the awareness level of government and society.

\textbf{Keywords:} Sustainability, BIM, 6D Model, LOD, Life Cycle Costing

1. \textbf{Introduction}

Building information modeling (BIM) is an approach of innovative new to building design, construction, and management, had been introduced by Autodesk in 2002. BIM is an integrated and technically coordinated process to create intelligent and informative 3D representation for stakeholders and the designers to take the design decision, build and run the projects in a cost-effect and sustainability manner [1]. It is a set of interactive policies, techniques, and processes that generate methodology to manage the project basic design and data in digital format through the building life cycle [2], is using 3D models along with additional information and data, like as schedule-related data (4D) and the component pricing and cost or budgeting information (5D). Recently the 6D of CAD is proposed to be the sustainability dimension in BIM technique as a tool for life cycle sustainability assessment and decision-makers and designers’ approach to take the informed decision related to sustainability design facility management.

2. \textbf{Levels of Development (LOD) in BIM}

Level of Development (LOD) describes the level of completeness to which a Model Element is developed. LOD is often referred to in Building Information Modeling (BIM) delivery documents. It is
an essential parameter for describing digital content in the context of BIM. It is an important tool for determining the exchange of information during the life cycle of a building [3]. The levels of BIM had been determining in three levels as described in Table 1, but only level one currently using by most users [1].

Table 1. Levels of Details (LOD) in BIM [3].

| Level | Character | BIM |
|-------|-----------|-----|
| 0     | Unmanaged CAD, in 2D, data interchange by paper or electronically. Managed CAD, in 2D or 3D format in Common Data Environment (CDE) provided by using a collaborative tool with a unified strategy to the structure and format of data. Content information is created in level 1 using standard methods of data structures and storing (CAD standards) in standard formats to be transferred between varying CAD applications | No. |
| 1     | BIM Level 2 is a managed BIM environment that contains intelligent BIM forms maintained in separate disciplines (specialized models), sharing and formatting by using a structured approach and integrated using a special or customized design program for the design, project management, and maintenance purposes. | Yes |
| 2     | Level 3 BIM is an integrated and collaborative BIM system that is made by Web Services for concurrent Building Information using open codes Without interoperability problems and expansionary BIM applications to project life cycle management. | Yes |

2.1. BIM Dimensions

There is no consensus among experts on the number of dimensions in BIM that can be utilities in the construction industry because it is continuously expanding into new additions that meet the construction requirements in various phases of construction and contribute greatly to reducing project uncertainty. Table 2 contains explanations for 7 of BIM dimensions.

Table 2. BIM Dimensions adapted by authors [4].

| No. | BIM Dimension |
|-----|---------------|
| 3D  | The main difference between BIM 3D and Assisted Computer 3D (CAD) is that the latter describes the building in separate 3D views such as plans, sections, and heights that require scanning the entire document. They are described in aspects such as distances, columns, beams, and walls [5]. |
| 4D  | 4D is realized when linking 3D data to a management program makes the users able to visualize the entire project process and a detailed analysis of the project phases requirements and the owner or client benefits from the process conception, the contractor benefits from risk management and prevention. The 4D BIM effective management can help to visualize confliction before it happens, thus resulted in money and time saving on site |
| 5D  | To develop BIM 5D, the quantity data and cost plan are linked to the BIM data set; the quantitative and qualitative measurement is automatically taken from the 5D model, which is connected to the cost of the data and establishes a dynamic cost plan. |
The emergence of 6D has been strongly associated with an increase in global concern for sustainability resulting from the awareness of the seriousness of sustainability issues within the global context, and in all its economic, social and environmental aspects that are influential in the construction industry. Respectively, 6D can affect the other dimensions of BIM, because the characteristics of sustainability are likely to change over time and have a wide-ranging impact [5]. Designers have taken advantage of the integration of sustainability into the BIM model in achieving important objectives in assessing and achieving building performance in terms of sustainability such as carbon emissions and energy analysis. It helps to select the appropriate decisions in the early phases of the project and test alternatives and compare them because it enables easier integration of the elements of sustainability such as daylight, natural and mechanical ventilation, water efficiency, heat effect and renewable energies in the early stages of the building project. Finally, it allows the validation of design decisions [6].

The seventh dimension (7D), Facility Management (FM), and life cycle costs (LCC) are called 7D BIM data. When integrate FM processes with the BIM models using and data, thus, provide significant financial savings and improved maintenance operation in the long-term. The application of BIM in the building’s operation leads to many capacities and challenges. Many scientists, which use BIM in FM, appear to provide significant potential support [7].

There is no agreement on what on the sixth dimension should constitute the experts argue that due to the significance of sustainability should be in this dimension [4]. Dimensions 6 and 7 of BIM evolve so far and their understanding. Some researchers argued that BIM can unleash any dimensions number, describing them as nD modeling, noting that BIM model applications are multiple and can be at any dimension number in the next few years [9].

2.2. BIM in Sustainability Areas
In the design stages and prior construction stages, the most important decisions on sustainable design alternatives will be made by using the potential of BIM [10]. BIM technique may address many sustainability areas as explained in Table 3.

| No. | Sustainability Area          | The benefit of BIM using                                                                 |
|-----|-------------------------------|------------------------------------------------------------------------------------------|
| 1   | Building orientation          | Decide the best orientation for energy costs reduction for building form analyzing and building envelope optimizing |
| 2   | Building massing              | Day-lighting analysis lighting and cooling loads reduction.                               |
| 3   | Day-lighting analysis         | water demands reduction in a building                                                     |
| 4   | Water harvesting              | Reducing energy requirements and renewable energy choices analyzing to contribute to lower costs energy |
| 5   | Energy modeling               | Sustainable materials reducing material needs and using recycled materials               |
| 6   | Site and logistics management | waste and carbon footprints reduction                                                    |

2.3. BIM Roles in Sustainability Aspects
To improve the overall building design and performance, BIM can play a large role in its ability to provide the necessary information. It offers an ideal benefit of sustainable building design through an Integrated Project Delivery (IPD) as well as design optimization. BIM supports solutions that can significantly contribute to identifying the best alternatives to reduce energy consumption and resource consumption [10]. The great importance of this technology in model development lies in combination visualization and performance simulations readily available for decision making through the rapid
application of groups in the BIM model (enabled by the BIM platform). This BIM project is in fact due to its current role in building sustainability as shown in Table 4 [12].

2.4. *BIM with Sustainability Rating Systems*

In recent years, BIM’s ability to provide a classification of sustainable building systems has been studied [22]. They were trying to have integration between BIM and sustainable building classification certificate, an argument that the Autodesk Revit BIM tool can evaluate thirteen credits and one requirement directly for the LEED rating system. Some studies argue that BIM applications adopting is assessing additional seventeen credits and two basic requirements in LEED [23].

| Table 4. BIM role in sustainability aspects. |
|---------------------------------------------|
| **Role of BIM in sustainability Aspects**    |
| **Environmental**                           |
| BIM's contributions to integrated project implementation and design improvement are well recognized as important in reducing the use of materials and energy. It gives users the ability to perform full lifecycle assessments and use the data of lifecycle assessment to run comparative analyses for different design options. By using BIM software, the designers will be able to move from models and environmental impact calculations to “rule the experiment” to real-time assessments at crucial moments, and easily, to produce understandably and customizable data graphics [12]. |
| **Economic**                                |
| When using BIM technique to estimate the project cost generates rapid cost feedback throughout the building lifecycle [13]. BIM facilitates the process of cost estimation simpler and more accurate, the design of the digital model requires the architect and engineer cooperation, BIM provides more detail within lesser time and expenses [14]. BIM software has the potential to perform the quantity take-offs and pricing necessary for cost estimating while recognizing actual materials used in construction. The cost estimation accuracy is often positively related to the available volume of project information [15]. |
| **Social**                                  |
| There are some indirect means added by BIM to social sustainability. Such as a centered indoor localization algorithm, developed by BIM for supporting the response in building fire emergency [16]. The critical path method was also used by BIM to simulate the effect of overall temperature and humidity on a building project [17]. BIM proposed a system for forecasting air pollutant concentration while the construction process [17]. Finally, BIM use in building safety [18]. BIM may address some issues related to social sustainability in the built environment by proposing a MIB-based quality inspection process on building safety issues. But there is still a big gap that BIM needs to bridge in this dimension. |

2.5. *BIM in Stages of Sustainability Planning and Design*

The basic decisions on sustainability, energy consumption, and the environment are taken at the planning and design phases are the point. It is indisputable that as soon the accurate and informed design decisions been taken as possible can help develop a more efficient and cost-effective sustainable design [10][5]. BIM analysis tools can rapidly assess different design options to help the design team for choosing the best green designs and make informed decisions [23]. These analyses provide more understand to the planners for their design’s performance on the environmental aspects, the building efficiency, and the occupants. In the traditional projects, the design system makes project stakeholders and designers be much lower efficiency in early design decisions making because of the conceptual difficulties [24].

In the past few years, the developments in technology fields and the increasing use of BIM have made the use of BIM applications make design decisions more sustainable. The BIM applications
supporting the sustainable construction in the planning and design phases were identified and classified in seven areas [25].

1) Evaluation of the direction of construction (choosing a suitable direction can reduce energy consumption);
2) Analysis of the building structure and improvement of the building envelope in equal transparency ratio manner.
3) Analysis of daylight.
4) Water harvesting assessment for building water needs reducing.
5) Energy performance modeling for energy demands to reduce and to analyze renewable energy options that help to lower costs of the energy.
6) 6. Study the requirements of sustainable materials and then of replacing recycled materials;
7) Reduce waste and carbon footprints through appropriate site design and logistics management.

3. Procedure of Conceptually 6d Model
The motivation to establish a 6D system comes from the existing sustainability rating systems can’t provide quick and reliable support for the design decision. The major purpose of this model is the assistance for design and a post-construction assessment tool, it can automatically evaluate lifecycle build-up estimates. It includes 3D design, 4D (schedule), 5D (cost) and 6D (sustainability). Estimate the sustainability performance for the options of the alternative design, the assessment included the building life cycle phases starting from material production through construction and operation phases to maintenance, demolition and disposal in the end [4]. The design of a complete 6D system can achieve the automatically building life cycle sustainability assessment and has a major contribution to help design buildings and support decision-making are:

- Quantities can be derived automatically from a 5D CAD model.
- A lifecycle cost analysis can be provided.
- Provide an assessment of the sustainability of the life cycle.
- Comparison of impacts of environmental, social and economic in different design
- Help designers and developers in making more informed decisions for sustainability designs, all of the buildings life cycle stages should be included in support for design decisions [24].
- Government departments will also be able to develop a sustainable building performance database and setting minimum standards for sustainability.

By providing an easy and quick sustainability evaluating to the design phase and facilitating the performance standards and database development, it hopes that more sustainable buildings will be executed in the future. This requires the coordination of efforts among the competent public bodies, including academic, technical, governmental, legislative and supervisory.

3.1. Phases of 6D CAD Model
According to ISO 14040 for LCA requirements (Figure 1), developing a 6D MODEL will consist of three phases, named:

1) The goal and scope definition,
2) The 6D model development for inventory analysis automatically and the assessment of the impacts.
3) Results interpretation.
Figure 1. Stages of life cycle assessment as defined by ISO 14040 [25].

3.2. First Phase: Goal and Scope Definition

The goal is developing an integrated 6D model able to conduct the buildings life cycle sustainability assessment automatically to help buildings designers and support decisionmakers. All the buildings life cycle stages should be included in the vision of the three sustainability aspects (Environmental, Social, and Economic).

3.3. Second Phase: Inventory Analysis and Impact Assessment

Some software such as SimaPro (LCA tool) and EcoInvent LCA (an embodied database) will be used at this stage [26]. The life cycle inventory data and estimate the impact results for a particular commodity unit will construct the database, including construction products [27]. For example, (according to some advanced means, such as Ecological Ecacity 1997 or Environmental Indicator 1999) by the database can calculate the inventory data and can the assessment environmental impact against 1 cubic meter of the building block or 1 concrete cubic meter and calculate the amount of material used in the building [26]. To complete this phase, the impacts of the other two sustainability aspects (social and economic) must be assessed. The 6D system must contain three modules Input unit, core unit, and output unit Figure (2), all necessary data will be collected in the input unit of the model. These include:

- Based on 3D object design model, which may be created using, for example, Revit or Autodesk Architecture
- 4D schedules can be developed with, for example, Primavera or Microsoft Project.
- Site and location data, it may use to conduct the requirements for the heating and cooling calculation.
- Assumptions of life service recurring material servicing and maintenance costs must be included in the assessment. For example, repainting is usually performed in 10 years, but the carpet tiles need to replace every 8 years, etc.
4. Steps for 6D Model

4.1. Step One. From 3D to 4D
For equipment information, labor, and materials in the temporary work, table 4D should be linked to the 3D design, this can be automatically linked to any unique object ID and activity chart. When it connected, the 4D model becomes available by some software, such as the Autodesk Naviswork program [28].

4.2. Step Two. From 4D to 5D
In traditional methods can automatically calculate the permanent works quantities in the design with bills of quantities (BQs). And can verified These quantities with those measured according to shown in the BQ. and the priced BQ can derive rates of each item, or the quantity surveying firm provide the cost database. This gives the permanent works cost. but project cost besides the permanent works comprise the preliminaries costs too, including site staff, temporary works, plants, etc. 4D can derive most items of the preliminaries according to the included method of construction.

4.3. Step Three. Life Cycle Costing
The aim of this step is the life cycle cost determining, the user model is assigning the default building life as 25 years or they can adjust it to suit their standards. The operational cost consists of several types of costs such as energy for lighting, ventilation, cooling, heating, and electricity for electrical appliances. Some programs can be commercially available to use for simulate annual energy usage such as TRNSYS or EnergyPlus after obtaining the energy cost of the processed companies[31]. Future energy costs should be considered at an appropriate rate of interest, as well as the cost of maintenance and the replacing materials cost [4]. The age of components or equipment has a shorter lifecycle than the building lifetime should be determined for calculating the replacing cost. For the demolition and disposal cost, we can use the building size and the appropriate cost database to estimate the demolition cost at the end of life. The cost of disposal includes the transport the destroyed construction waste to landfill sites and associated taxes.
4.4. Fourth step. From 5D to 6D
Since the economic aspects been addressed in step three of the model procedure, this step is assessing only the environmental and social impacts of the building life cycle (Figure 4). For this purpose, the quantities derived from the 4Dh construction schedules are exported to EIA system, as SimaPro software. The program will calculate the construction materials environmental impacts. The 4D schedule provides information about the worker's number in each construction activity, which means employment opportunities and a significant impact social aspect.

4.5. Third phase: Interpretation of the Output Module
The environmental impacts which it been derived from the second phase, many different categories are included, such as, resource consumption, ecosystem spoiling, energy use, and each category comprises the number of sub-categories, some of the qualitative and other quantitative they cannot be aggregated, such these environmental impacts, the economic and social aspects. this problem was a motivation for developing the analysis tool can assess the impact of the interrelationship between the environmental, economic, and social [8].

Figure 3. Conceptual map of economic assessment framework.

Figure 4. Conceptual map of environmental and social assessment framework.
5. 6D Model Features
Besides providing the sustainability index, some of the analyses can be produced by the 6D model:

1) The performance comparison for a certain standard of building (e.g. the air conditioning electricity annual consumption), to declared or to national or international standards. Forms of bar charts or tables can be used to present the results.

2) Comparison between standard performances with, for example, compare the performance of the embodied energy and the operation performance, maintenance, and life-cycle energy performance.

3) The store data ability and performance comparing of different alternatives in the same function, such as, conducting comparison for the cost of individual glass and double glass windows, or compare steel and concrete structure, etc.

6. Conclusions
One of the most important constraints of the sustainability rating system is the inability to provide rapid and reliable design decision support, therefor it is creating a CAD 6D model that can assess the sustainability of a building automatically. will help stakeholders and designers to make more informed decisions at the design stage. This research presents a description of a conceptional model in detail. For much more sustainability performance in the building need to a database created for performance standards.

Recommendation
Despite the great benefit of the integration of BIM technology in sustainability assessment for construction projects, the process of transition in this field should be considered and not quick and sudden and according to a roadmap involving all relevant institutions (academic, technical and economic) and supported by government procedures in both legislative and regulator

References
[1] C.N. Preece, M.T. Shafiq, Z.I. Syed, C.M.M. Isa, and H. Golizadez, Towards BIM enabled sustainable urban developments in the UAE, In Proceedings of Sustainable Built Environment Conference 2016 in Cairo 332-345.
[2] B. Succar, Automation in Construction Building information modelling framework : A research and delivery foundation for industry stakeholders, Autom. Constr., 18(3) 2009 357–375.
[3] R. Volk, J. Stengel, and F. Schultmann, Building information modeling (BIM) for existing buildings - Literature review and future needs, Autom. Constr., 38(March) 2014 109–127.
[4] P. Yung and X. Wang, A 6D CAD model for the automatic assessment of building sustainability, Int. J. Adv. Robot. Syst., 11(1) 2014 1–8.
[5] G. Kapogiannis, M. Gaterell, and E. Oulasoglou, Identifying uncertainties toward sustainable projects, Procedia Eng., 118 2015 1077–1085.
[6] K.D. Wong and Q. Fan, Building information modelling (BIM) for sustainable building design, Facilities, 31(3) 2013 138–157.
[7] B. Becerik-Gerber, A. M. Asce, F. Jazizadeh, N. Li, and G. Calis, “Application Areas and Data Requirements for BIM-Enabled Facilities Management,” vol. 138, no. March, pp. 431–442, 2012.
[8] C. Fu, G. Aouad, A. Lee, A. Mashall-Ponting, and S. Wu, IFC model viewer to support nD model application, Automation in Construction, 15(2) 2006 178-185.
[9] S. Azhar, Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry, Leadership and management in engineering, 11(3) 2011 241-252.
[10] S.L. Shareef and H. Altan, Building sustainability rating systems in the Middle East, In Proceedings of the Institution of Civil Engineers-Engineering Sustainability, 170(6) 2016 283-293.
[11] T. Ahmad, A. Aibinu, and M. Jamaluddin, BIM-based iterative tool for sustainable building design : A conceptual framework, Procedia Eng., 180 2017 782–792.
[12] F. Jalaei and A. Jrade, Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings, Sustain. Cities Soc., 18 2015 95–107.
[13] A. Sattinemi and R.H. Bradford, Estimating with BIM: A survey of US construction companies, Proceedings of the 28th ISARC, Seoul, Korea, 2011 564-569.
[14] S. Azhar, M. Khalfan, and T. Maqsood, Building information modelling (BIM): now and beyond, Construction Economics and Building, 12(4) 2012 15-28.
[15] G. Kim, J. Yoon, S. An, H. Cho, and K. Kang, Neural network model incorporating a genetic algorithm in estimating construction costs, Building and Environment, 39(11) 2004 1333–1340.
[16] N. Li, B. Becerik-Gerber, B. Krishnamachari, and L. Soibelman, Automation in construction a BIM centered indoor localization algorithm to support building fire emergency response operations, Autom. Constr., 42 2014 78–89.
[17] Y. Shan and P. M. Goodrum, Integration of building information modeling and critical path method schedules to simulate the impact of temperature and humidity at the project level, 2014 295–319.
[18] S. Park, and I. Kim, Bim-based quality control for safety issues in the design and construction phases, Archnet-Ijar, 9(3) 2015.
[19] L.C. Bank, M. McCarthy, B.P. Thompson, and C.C. Menassa, Integrating BIM with system dynamics as a decision-making framework for sustainable building design and operation, In Proceedings of the First International Conference on Sustainable Urbanization (ICSU) 2010.
[20] S. Barnes and D. Castro-Lacouture, BIM-enabled integrated optimization tool for LEED decisions, In Computing in Civil Engineering, 2009 258-268.
[21] S. Azhar, A. Nadeem, J.Y. Mok, and B.H. Leung, Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects, In Proc., First International Conference on Construction in Developing Countries, 1 2008(August) 435-46.
[22] T. Ahmad and M.J. Thaheem, Economic sustainability assessment of residential buildings: A dedicated assessment framework and implications for BIM, Sustainable cities and society, 38 2018 476-491.
[23] E. Krygiel and B. Nies, Green BIM: Successful Sustainable Design with Building Information Modeling, John Wiley & Sons (2008).
[24] A. Haapio and P. Viitanemi, A critical review of building environmental assessment tools, Environ. Impact Assess. Rev., 28(7) 2008 469–482.
[25] M.A. Rosen and H.A. Kishawy, Sustainable manufacturing and design: concepts, practices and needs, Sustainability, 4(2) 2012 154–174.
[26] https://simapro.com/
[27] R. Frischknecht, N. Jungbluth, H.J. Althaus, C. Bauer, G. Doka, R. Dones, and Y. Loerincik, Implementation of life cycle impact assessment methods, ecoinvent report No. 3, 2007.
[28] A. Russell, S. Staub-french, N. Tran, and W. Wong, Automation in construction visualizing high-rise building construction strategies using linear scheduling and 4D CAD, Autom. Constr., 18(2) 2009 219–236.
[29] D.B. Crawley, L.K. Lawrie, F.C. Winkelmann, W.F. Buhl, Y.J. Huang, C.O. Pedersen, and J. Glazer, EnergyPlus: creating a new-generation building energy simulation program, Energy and Buildings, 33(4) 2001 319-331.
[30] D. Crawley and I. Aho, Building environmental assessment methods: applications and development trends, Building Research & Information, 27(4-5) 1999 300-308.