Green BIM potential in assessing the sustainable design quality of low-income housing: A review

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Abstract. This paper intended to investigate the potential use of Building Information Modeling (BIM) as an assessment tool that can evaluate and support optimization of sustainable design quality, especially for low-income housing or “Masyarakat Berpenghasilan Rendah” (MBR) in Indonesia. The consideration of sustainability aspects in the preliminary design phase is no longer a choice but a need for every stakeholder involved in the Architecture, Engineering, and Construction (AEC) industry. BIM here was developed to be the effective technology that supports all stakeholders in integrating the needs of sustainable building design through sustainable workflow which is also known as "Green BIM". The first phase of this study is conducting a critical review of integration between BIM and Green Building Rating System for Home, including LEED, BREEAM, GBI, Green Mark, and GREENSHIP. Then it is followed by reviewing BIM implementation in the housing sector based on case studies in several countries. The findings revealed that there is a potential use of BIM for small-scale project especially to support the sustainability of MBR in Indonesia. Even so, there are also challenges to be considered, including financial support and incentives from the government in the effort of implementing this Green BIM approach.

1. Introduction

In the Architecture, Engineering and Construction (AEC) industries, the growing trend of using information-based digital technologies can help the collaboration process between each stakeholder, known as Building Information Modeling (BIM). BIM technology has several advantages, namely, it can streamline the time and cost of building construction work [1]. Besides, the BIM platform has quite good interoperability because it can be integrated with other platforms such as Building Performance Simulation (BPS) to evaluate the performance of a building [2]. The integration process uses the universal format known as the Industry Foundation Classes (IFC) [3]. The increasingly significant development of BIM raises other innovations which are then considered able to support the realization of sustainable building construction processes, especially at the stage of the design process and design development conducted by the architect. Krygel and Nies expose his theory that BIM can be used to support a sustainable design by using BIM as an attempt at creating a form and creating a system [4]. The use of BIM in the process of sustainability through creating a form is based on aspects of building orientation, building mass, and lighting in buildings. While the use of BIM in creating a system is based
on water conservation aspects, energy analysis, renewable energy, and environmentally friendly materials [4]. The BIM integration as a technology that supports green building and sustainable design by the guidelines on the Green Building Rating System is also known as the term Green BIM [5].

Good technology should be beneficial and perceived by all walks of life without exception. BIM technology is expected not only to provide benefits to large-scale building projects, but it can also be beneficial for low-income housing projects. The construction of affordable homes in various countries is always developed to fulfill the people's desire and ability in the effort to have a home. The existing house buildings that have been awakened need to be evaluated in terms of quality to be further improved in the process of designing the house and searching the typologies of sustainable home in the future. In this research, will be conducted a review of two case studies of buildings that have implemented BIM technology in the design process of the building. This research is expected to be the current information for the process of implementation of BIM technology in the case of small and medium-scale study objects, especially such as low-income housing.

2. Methods and results: Green BIM as assessment tool

The study uses qualitative methods by conducting reviews of some articles relating to the topic of Green BIM and BIM topics in the housing sector. Research on Green BIM has begun to be developed and has some shortcomings and benefits respectively. Based on research conducted by Lu et al [6], that the discussion related to Green BIM is known still slightly compared to the discussion on BIM itself, this topic could potentially be an opportunity to be studied more deeply on the process of its implementation in general, especially [6]. There are approximately 4 similar studies discussing the topic related to Green BIM with the case study's description method. Based on these studies, it is known that the research gaps have not been studied and therefore need to be examined.

| No | Author                  | Building Type | Parameter Goals | Software                        | Rating | Output                                      |
|----|-------------------------|---------------|-----------------|---------------------------------|--------|---------------------------------------------|
| 1  | (Azhar et al., 2011)    | University    | BIM for Sustainability Analysis | Autodesk Revit and IES VE | LEED (USA) | BIM-LEED Integration Framework             |
| 2  | (S. Y. Chen, 2018)      | Hotel         | Green BIM implementation as an approach for sustainable design optimization | Autodesk Revit and Revit Energy Analysis | N/A    | Energy Optimization in Building            |
| 3  | (C. J. Chen et al., 2017)| Hotel        | Identifying the Integration Pattern between BIM and BPA in Green BIM concept | Autodesk Revit, Revit, and Vasari | N/A    | BIM as a Supporting Tools for BPA          |
| 4  | (Lin et al., 2019)      | Traditional Market | Exploring the current situation of energy efficiency and comfort level of the market | Autodesk Revit, Ecotect, 360, Vasari, Green Building Studio, IES VE | LEED (USA) | Analysis results from simulation and market optimization |

*) N/A: Not Available

Based on table 1, the four studies have an almost similar goal of testing the Green BIM System Integration Framework on case studies or selected study objects, with some being done at the Pre-Design
Stage (before construction) and Building Operation (already in operation). The variation of the study object also became an important instrument in seeing the study gap that took place. The majority studies examines the implementation of the Green BIM system in medium-scale buildings to complex with the allocation of hotels, traditional markets, and educational facilities. Seeing this, there is a gap in research studies conducted on the residence type has not been found much. Though the house has a pretty important essence in human life, and needs to be improving the quality of the design and the quality of its space. Earlier studies have implemented several green building rating systems as standard references in their research, such as LEED (USA) and BREEAM (UK). Unfortunately, for research with the Green Building Rating System is GREENSHIP (Indonesia) as a standard reference has not done much.

Integration of BIM platforms and building simulation platforms such as Building Performance Simulation (BPS) in a green building assessment system has benefiting primarily in terms of evaluation of the sustainability aspects of a building as well as the use of Revit and IES VE to support LEED assessment system [11]. There is also the use of ArchiCAD, Trynsis and Ecotect to support the Australian Green Star Rating System [12]. In table 2, explained a number of green building assessment systems from several countries for residential building type category. The assessment aspect of some of these rating systems is found to be similar such as assessment of energy aspects, water usage, materials, and the quality of indoor environment.

| System (Country) | BREEAM (UK) | LEED (USA) | Green Mark (Singapore) | GBI (Malaysia) | GREENSHIP (Indonesia) |
|------------------|-------------|------------|-----------------------|---------------|-----------------------|
| Established Source | https://www.breecam.com/ | https://www.usgbc.org/leed | https://www.bca.gov.sg/greenmark/green_mark_buildings.html | https://www.greenbuildingindex.org/ | https://www.gbcinindonesia.org/ |
| Code for Sustainable Homes | LEED v4.1 Residential Single-Family Homes | Energy and Transportation (LT) Sustainable Sites (SS) Water Efficiency (WE) Energy and Atmosphere (EA) Material and Resources (MR) Indoor Environmental Quality (EQ) Innovation (IN) Regional Priority (RP) | Energy Efficiency (EE) Building Energy Performance Resource Stewardship Smart and Healthy Building Advanced Green Efforts | Energy Efficiency (EE) Indoor Environmental Quality (EQ) Sustainable Site Planning and Management (SM) Materials and Resources (MR) Water Efficiency (WE) Innovation (IN) | Appropriate Site Development (ASD) Energy Efficiency and Conservation (EEC) Water Conservation (WAC) Material Resource and Cycle (MRC) Indoor Health Comfort (IHC) Building Environment Management (BEM) |
| Assessment Aspect | Energy and CO2 Emissions Water Materials Surface Water Run-Off Waste Pollution Health and Well-being Management Ecology | Energy and CO2 Emissions Water Materials Surface Water Run-Off Waste Pollution Health and Well-being Management Ecology | Energy and CO2 Emissions Water Materials Surface Water Run-Off Waste Pollution Health and Well-being Management Ecology | Energy and CO2 Emissions Water Materials Surface Water Run-Off Waste Pollution Health and Well-being Management Ecology | Energy and CO2 Emissions Water Materials Surface Water Run-Off Waste Pollution Health and Well-being Management Ecology |
| Certification Rating | Level 1 LEED Certified | Level 2 LEED Silver | Level 3 LEED Gold | Level 4 LEED Platinum | Level 1 LEED Certified | Level 2 LEED Silver | Level 3 LEED Gold | Level 4 LEED Platinum | Certified LEED Certified | Silver LEED Silver | Gold LEED Gold | Platinum LEED Platinum |
| Guidance Available | Available | Available | Available | Available | Not Available |
| BIM Tools | ArchiCAD, Autodesk Revit, Bentley Architecture, and others [13-15] | Energy Plus, IES VE, DIALux, Autodesk CFD, DesignBuilder, OpenStudio, Sefaira, DIVA for Rhino, HoneyBee (GH), Autodesk Insight 360, Tally, others [16-18] |
GREENSHIP system for Indonesia is still relatively new because viewing from the year of its implementation compared to BREEAM, LEED, Green Mark, and GBI are the youngest, i.e. the new emerged in 2010. Its use in the project is somewhat difficult to implement, seen from the absence of technical guidelines for the evaluation system in the category of residential projects. This is similar to Zhang's research, that the building that has been certified by the GREENSHIP system is still relatively low compared to other systems [19]. Meanwhile, BIM-based software can be integrated with some of the assessment systems including Autodesk Revit, ArchiCAD, and Bentley Architecture. As for the simulation process and evaluation of sustainability aspects in the building can use BPS system-based software for energy simulations such as Energy Plus, IES VE, Sefaira, Autodesk Insight 360. Software such DIALux used for lighting simulation, Autodesk CFD for thermal and air flow simulation, and a simulation of carbon footprint calculations with Tally.

Integration between the BIM system and green building assessment system in the AEC industry, especially in housing projects, besides having the benefit, it is also raising challenges in the adoption and implementation process. As the example, the use of BIM system in the housing sector in the United Kingdom, it has obstacles in terms of skill, awareness, and investment in the software of each related stakeholder [20]. Governments are expected to provide incentives for stakeholders in the AEC industry that implementing BIM systems and sustainable design concept in the planning and construction of its projects.

3. BIM implementation for housing: Case study

The design of residential buildings based on the BIM system has been started to be applied in various countries, one of them in Indonesia. Based on table 3, there are two case studies of BIM-based software use in the design process until the construction of the residential house. The first case study is Villa Patio located in Bandung, Indonesia, and the second case study is a temporary house building in the form of a shelter for Syrian society. Both case studies use ARCHICAD's software in design planning process.

| Project Info | Villa Patio | Earth-bag house |
|--------------|-------------|-----------------|
| Location     | Bandung, Indonesia | Syria, Transitional Shelter |
| Type         | Residential | Transitional Shelter |
| Architect    | J Beneitez, Eugenio Fontan, J Gil | Anas Aljbain |
| Software     | ARCHICAD   | ARCHICAD        |
| Cost         | 245,000 USD | 16,000 USD      |
| Sustainability Aspects | Has a Patio (good for natural ventilation and daylight) | Has a Patio (good for natural ventilation and daylight) |
| Advantages   | Easy 3D and 2D documentation in a smart way. | Using a method of 3D documentation to explain the desired details to unskilled workers. |
| Source       | https://www.graphisoft.com/users/bim-case-studies/enzyme-villa-patio-case-study.html | https://www.graphisoft.com/users/bim-case-studies/transitional-shelters-designed-using-archicad.html |

According to both case studies, there are differences in terms of housing building costs designed with BIM-based software. Both also consider the sustainability aspects in their concept design by using local
materials and creating a patio inside the house. The Villa Patio building is intended for high-income earners, while the Earth-bag house building is intended for low-income people. Seeing this means that the use of BIM systems in residential projects can be intended for various communities, not only for complex and luxurious buildings but can potentially be implemented on simple residential projects for Low-income communities to achieve sustainable development.

4. Conclusion and future research
Based on the review above, it is found that there is a potential use of BIM for small-scale project especially to support the sustainability of MBR in Indonesia. Even so, there are also challenges to be considered in the effort of implementing this Green BIM approach. From the case studies can also be concluded that the Indoor Environmental Quality Aspects are could be the top priority in improving the sustainability value of the houses itself. The implementation of Green BIM in a real case study of a low-income housing project in Indonesia would be developed in the next study.

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