The Role of Virtual Reality in Green Building Design

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Abstract. Green buildings have now become the basis of the ideal sustainable development. The application of the green building concept can be seen from three points of view, namely environmental, economic, and social aspects. Virtual Reality allows researchers to conduct real-time analytical studies of green building indicators and compare them with scenarios at the next design stage. This paper discusses the role of Virtual Reality in green building. The methodology in this paper uses a literature study research method, the data obtained are compiled, analysed, and concluded, to get a conclusion about the role of Virtual Reality in green building. From several literature studies, there are many things that can be done by Virtual Reality technology in applying the concept of green building.

Keywords: virtual reality, green building, sustainable architecture, immersive technology

1. Introduction
Green building has provided tangible benefits through design, it can reduce carbon emissions, reduce energy, reduce waste, save water, prioritize safer materials, and reduce pollution. Based on research conducted by the US Green Building Council (USGBC), as shown in the infographic in Figure 1, Green building design has a good impact on environmental sustainability, including reducing electricity consumption by 24%-50%, reducing carbon emissions by 33%-39%, reduce energy consumption. water up to 40% and reduce the amount of waste by 70% [1]. Green building is a building that meets building requirements and has measurable performance in saving energy, water, and other resources through the application of green building principles in accordance with functions and classifications in each stage of its implementation. Green building currently has become the basis of an ideal sustainable building [2]. Not only green, but green building also pays attention to aspects of sustainability, savings, protection, and quality from the beginning of planning until the building is built.

To assess whether a building has implemented environmentally friendly concepts and energy efficiency, there is a rating system. In the United States this rating system is often referred to as LEED (Leadership in Energy and Environmental Design). This LEED tool has been adopted in many countries such as Japan, China, and India [3]. In Indonesia, the rating system for green building is referred to as Greenship. Greenship is a rating system issued by a non-profit organization called Green Building Council Indonesia (GBCI). This system was prepared and compiled by GBC Indonesia by taking into account conditions, natural characteristics as well as regulations and standards that apply in Indonesia [4]. Greenship is structured by involving building sector actors who are experts in their fields, such as...
architects, the building industry, mechanical and electrical technicians, interior designers, landscape architects and others.

![Green Buildings Can Reduce...](image)

**Figure 1. Benefits of Green building [1].**

Virtual Reality (VR) as one of the most exciting technologies of the current decade, its potential is almost endless. Several studies conclude that VR allows researchers to conduct real-time analytical studies of the green building indicator, which is one of the concepts of sustainable architecture, can compare scenarios from the planning stage to the next design stage [5]. Virtual Reality (VR) is a computer-generated representation of an image or environment that can be interacted with using specialized software or electronic devices. VR has long been an important buzzword in the industrial world, especially when thinking about sustainable architecture VR has become an important topic for future engineers, this is especially true in modelling, visualizing, and interacting with complex information structures and concepts [6]. This paper presents the role of VR technology in the green building concept from several building research studies. The paper focuses on acquiring knowledge about the use of VR technology in simulating green building projects.

2. Methodology
To gain knowledge of the role of Virtual Reality (VR) in green building, this paper presents it through a literature study. Literature study research is considered as one of the research methods carried out by reviewing various existing literature, sourced from books and journals. The research begins by setting search keywords, then searching for data through a predetermined search engine application. The keywords defined are “green building concept”, “green building and virtual reality”, “the role of virtual reality in green building”, “the role of virtual reality in green architecture”, and “green building and immersive technology”. The period of the literature article set is between 2010 to 2021. The study of each literature article that is taken is then discussed descriptively so that it gets the conclusion.

3. Results and Discussion

3.1 Green Building Concept
In general, green building is the planning of buildings for a better life and to meet the needs of future generations, especially those related to natural, health, and social sustainability. Green building has become one of the topics that has been widely raised since a few years ago. This topic relates to the construction of houses, apartments, offices, shop houses, and other buildings with an environmentally friendly concept. According to the Green Building Council Indonesia (GBCI), the application of the green building concept can be seen from three perspectives, namely from environmental, economic, and social aspects. These aspects are embodied in the green building parameters, namely: Appropriate Site
Development, Energy Efficiency and Conservation, Water Conservation, Material Resources and Cycle, Indoor Health and Comfort, Building Environment Management [7].

From the green building aspect above, it can be concluded that the green building concept is a step to increase productivity, improve the quality of life and achieve a better environment, which is the goal of the Sustainable Development Goals, as shown in Figure 2 [8]. From several studies, VR allows architects and engineers to make decisions regarding sustainable architectural designs [5].

![World Green Building Council - Sustainable Development Goals](image)

Figure 2. Green building in Sustainable Development Goals [8].

3.2 The Role of Virtual Reality in Green Building Design.

Virtual Reality (VR) is a computer-generated simulation in which a person can interact with an artificial three-dimensional environment using an electronic device. VR brings sights, sounds, and other sensations through devices such as glasses, headsets, and sensor devices such as gloves or controllers. Nowadays, VR technology has developed rapidly, so that it is almost considered capable of creating the same atmosphere as the original [9].

In designing buildings, VR has allowed designers to imagine and test new spaces before committing to construction. Compared to static images or movies, through VR, users can travel around the virtual world to assess the advantages and disadvantages. VR can perform many types of simulation tests, such as weather, social, airflow, and so on, so we will know exactly how the building will behave [10].

In the design and manufacturing sectors, real-time photorealistic VR rendering capabilities can help reduce the number of physical prototypes required in the visual design process, thereby reducing material wastage, as is the case in creating building mockups. [11]. Making building mockups based on virtual reality does not create waste like traditional building mockups. When it is outdated and not needed, this virtual reality-based building mockup also doesn't need to be thrown away and become trash like traditional mockups. This in turn can reduce the carbon footprint generated due to the minimal amount of waste generated from digital-based content creation. Of course, this makes virtual reality-based building mockups more environmentally friendly while reducing overall waste processing costs.

Raimbaud stated, the use of Virtual Reality can provide many benefits for its users, and the use of Building Information Modelling (BIM) can improve the performance of users in Architectural Engineering and Construction (AEC). He gave an example; user evaluations have shown that BIM data with 3D building modelling is better than using 2D data in supporting user participation in architectural design studies. The design process, especially the interaction provided in a virtual environment may be
complicated, but to overcome these problems can use a methodology. This methodology is a user-centred design methodology, and it should be noted that it relies mainly on three components: 1) user task analysis, 2) expert evaluation and study of interaction techniques, and 3) user evaluation of prototype interaction techniques. [12]. Using the BIM-Game prototype with VR interaction, it can provide a collaborative environment and make collaborative decisions. As shown in Figure 3, users are involved in making collaborative decisions regarding the accessibility of the building. This study shows that VR can provide the benefits of collaboration between stakeholders.

![Figure 3. BIM game engine for collaborative design using different points of views in architectural studies][12]

Chen conducts research that integrates VR technology on user behaviour and feelings into Green building. Discusses how to open the VR scene experience to users from the aspect of scene perfection, with experience mode selection, feedback gathering and setting, and how to modify their schema design. Figure 4 shows the feedback process from users in the use of VR to get a "green performance" scheme. Comparative analysis of the applications was carried out and proposed that the Revit and Mars applications be used as the main software for BIM and VR. The application of technology application is carried out from four aspects, namely site, general layout, architectural form design and interior space design [13]. BIM and VR technologies allow users to test sustainable designs in virtual 3D for energy efficiency. With this technology, architects can run a performance analysis of the 3D model that has been created and see aspects of the architectural concept to make it more environmentally friendly. In this way, it can not only develop a perfect green project, but also lower the cost of building maintenance after completion.

![Figure 4. The use of VR technology to explore in real time][13]
Niu developed an innovative analytical approach using VR technology to assist building designers in identifying design patterns that can guide occupants to the most energy efficient behaviour, to close energy performance gaps due to occupant error [14]. Figure 5 shows, at first the architects determined the target behaviour of the “energy efficient” occupants, then they identified the design pattern that resulted from the behaviour of the occupants through the DwI process. DwI is an attempt to describe the many types of systems (products, services, interfaces, environments) that have been strategically designed with a view to influencing how people use them. This reflective approach can be beneficial for building designers, realizing that designing is not just a product, not just an experience, but actually designing behaviour on one level or another. Through VR experiments involving occupants, architects can observe occupant behaviour and evaluate occupant behaviour. Thus the design pattern can be obtained from the results of the occupants' behaviour.

![Design with Intent (DwI) Process](image)

**Figure 5.** Building energy design process involving occupants through DwI-VR integration [13]

VR can be used to analyse the energy requirements of a building [15]. When examining a building model, the architect can plan in optimizing the energy system of the building. This of course will reduce the cost of using equipment that is too excessive in a building. As shown in Figure 6, the architect can directly see the parts of the building and get energy data information on a building. From the data obtained, the architect can determine the energy devices needed in the building, as well as determine the position of the solar panels in the building to get maximum solar energy for electricity needs.
Figure 6. The use of VR and AR, shows energy information in buildings that can help architects make design decisions [15]

4. Conclusion
Virtual Reality has not only changed the way architects create designs, it has also given them the opportunity to enhance the green building aspects of those designs. There are several ways Virtual Reality can help make buildings more environmentally friendly. In the design and manufacturing sectors, the emergence of real-time photorealistic rendering capabilities in conjunction with Virtual Reality technology can help reduce the physical prototypes required in the visual design process, thereby reducing material waste. In the green building design process with Virtual Reality, the design process not only moves faster towards the construction stage, but also uses saving materials. Through virtual reality, architects can experiment to achieve green building designs, such as using different colors to see where sunlight naturally lands, experimenting with multiple light cycles, viewing their designs during different hours of the day. By experiencing the orientation of the building, the architect can adjust to reduce heating and cooling costs for the property or to optimize the building’s solar energy system.

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