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Digitalizing and Greening the Built Environment



Abstract: - The paper investigated issues of greening and digitalizing the built environment with a view to identifying applications of Building Information Modelling (BIM) in it and prospects of smart cities development. The paper adopted qualitative research method, with its design based on archival materials in the subject investigated as contained in the literatures reviewed on it as a mono-method. Google search engine was employed to scout through Google Scholar, Science Direct, among other relevant websites for open-access materials. Qualitative data obtained were subjected to content/thematic analyses. Findings revealed that digitalizing and greening the built environment have great prospects in smart cities development, one of which is the creation of sustainable environment resulting in reduction of carbon emissions from the built environment, lowering of global warming, increase of user participation in buildings and lowering the cost of building lifecycle. Although green building design strategies and digitalization have advanced, full adoption in the built environment particularly in developing nations is required, hence the need to take steps in the right direction. Digitalizing and greening the built environment can enhance the quality of life of people by increasing availability of green spaces, improving air quality, creating healthy living spaces, and reducing pollution levels. The study sensitizes architects, planners, and other designers in considering sustainability and digitalization from predesign phase (incorporating required or special features into the design of future cities, towns, and microenvironments) to postconstruction phase making the environment sustainable.

Keywords: Building information modelling, built environment, digitalization, energy conservation, green building, smart cities.

I. INTRODUCTION

The built environment refers to human made surroundings that enable human activities. It consists of buildings, neighborhoods, green spaces, cities, towns, and villages with services such as water and electricity. It is where people work and live so it should be aesthetically pleasing, easily accessible and functional with good roads. The demand we have on the built environment is becoming more rigorous as there is increased need for sustainable development with increase in population. Buildings account for around 39% of global carbon emissions (M. Adams, 2019). Green building design is a method of constructing that focuses on long-term sustainability and the effects of our design decisions on the environment. Green buildings aim to develop self-sufficient, long-lasting structures by conserving resources and reducing environmental effect. Overall improvements in the environmental friendliness of our built environment can be realized by improving the design of structures with this in mind.

The use of digital tools to adjust business models to improve revenue and value-producing prospects for organizations and businesses is known as digitalization. It is the process of transitioning to a digital business model.

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It benefits any industry in several ways such as fall in prices, improves sustainability, it makes life more comfortable and there are more choices.

The aim of this study was to investigate issues of greening and digitalizing the built environment with a view to identifying applications of Building Information Modelling (BIM) in it and prospects of smart cities development. The objectives of this study are to: examine the principles of greening the environment; itemize the green design strategies; describe principles of digitalization of the built environment; summarize application of BIM in the built environment; and evaluate prospects of smart cities. The justification of the study hinged on the fact that it is beneficial to all stakeholders if the findings are well understood and implemented by built environment professionals.

II. REVIEW OF LITERATURE

The relevant literature for this study is summarized in this chapter. It discusses the built environment, including its history, characteristics, and impact. It also goes over green buildings, their characteristics, goals, importance, and advantages. It will also discuss digitalization in the construction industry, how it aids in the achievement of sustainability in the built environment, and relevant case studies that implement digitalization and sustainability in the built environment.

2.1 *The Built Environment*

The term "built environment" encompasses all man-made constructions that support human endeavors. It encompasses every physical element present within a city or town, such as structures, streets, plazas, gardens, pathways, business signs, and various urban amenities (Micholas, 2014). The built environment is specifically crafted to meet the needs and desires of its inhabitants, encompassing elements like security, dignity, and the ability to express oneself. These demands can pertain to both physical and social aspects. On a global scale, the built environment plays a significant role in greenhouse gas emissions. In numerous developed nations, building energy consumption alone contributes to over 40% of carbon emissions (Wilkinson, 2007).

2.1.1 *History of Built Environment*

History is one of many perspectives on the world, offering a sense of what is deeply ingrained in culture and what is fleeting, thereby demonstrating relative value (Galvano, Arndt, & Hyser, 2008). The word "built environment" is new, but it has been around since the beginning of time because it encompasses all human creativity - past, present, and future aspirations. Design and planning for human, environmental, and technical demands intersect many disciplines of interest and research. (McClure & Bartuska, 2007).

Four connected features define the built environment. For starters, it is vast because it sets the stage for all human endeavors. Furthermore, the built environment is the result of human concepts and the achievement of human objectives aimed at fulfilling human necessities, aspirations, and principles. Additionally, it assists in coping with and safeguarding against the natural surroundings, while also acting as a means to modify or shape it to enhance our comfort and overall welfare. Finally, context defines and shapes each of its constituents, with each component and the whole contributing to the overall quality of natural and manmade environments, as well as human-environment relationships (Bartuska, 2007).

2.1.2 *Features of the Built Environment*

The built environment is designed to satisfy the demands of the residents. People desire a well-designed environment at a convenient spot with well-developed amenities, quick connectivity, and adequate roadways. They also want a house that is affordable, pleasant, low-maintenance, and well-insulated both sound and thermally. The built environment consists of some features which are;

- i. Transportation
- ii. Green spaces and parks
- iii. Residential buildings
- iv. Commercial buildings
- v. Land use

Transportation

This refers to the means by which people or things get to different places. It plays a vital role in a built environment. It includes sidewalks and roads. Pedestrians and drivers of vehicles can dependably visit all sections of an urban space due to roads. Road systems have long acted as the connector in cities, allowing people to move

quickly between different parts of a city. They transport people and goods throughout cities. They are also used for separating regions in a built environment and to serve as barriers. In addition, it helps street connectivity, this refers to the ease with which two points can be reached, which is closely related to street design aspects. It is distinguished for its numerous interconnecting streets (Saelens B.E., 2003). The main role of roads is to make places easily accessible and accessibility in this case refers to ease to which one can get to different places in the environment.

Green Spaces and Parks

These have a number of benefits to neighborhoods. A park protects nature, social life, and recreation for children, as well as providing relaxation for city dwellers (Polat, 2013). Building density and population density have both increased dramatically as a result of rapid urbanization. The amount of green space available in cities is dwindling, and inhabitants are yearning for more. As a result, the city has several naturally occurring and unplanned little green spaces that have been converted into parks. Public spaces are creative hotspots that facilitate interactions, information sharing, and a sense of location and belonging. They serve as gathering spots and catalysts for people, ideas, and resources. Parks' location and accessibility have a significant positive impact on the people around them. Green spaces can help to minimize air pollution, and even have an impact on city-wide temperatures by reducing the Heat-island effect (Brad P., 2021).

2.1.3 Impact of the Built Environment on the Climate

Cities already contain 50% of the world's population, and this number is anticipated to climb. Built environments have a significant impact on the climate in their immediate surroundings. The environment, as well as urban inhabitants, are already experiencing a number of challenges such as heat waves, water pollution, and other weather-related hazards (Wilby, 2007). The built environment plays a significant role in global carbon emissions, accounting for 39 percent of the total. These emissions can be attributed to two distinct factors: operational carbon and embodied carbon. Operational carbon stems from the energy used to heat, light, and cool existing buildings, while embodied carbon arises from the materials utilized in the construction of new buildings (Moncaster, 2021). Emissions from manufacturing of construction materials account for more than 11% of world emissions. (Why the Construction Industry Needs to Think About Climate Change, 2020)

Operational carbon is currently limited in most countries due to rigorous national construction regulations. Due to a combination of renewable energy and passive house design, zero-carbon new buildings are now possible. Reduced operating carbon is further aided by the use of renewable electricity. This can come from on-site renewables like rooftop photovoltaics or from the grid (Moncaster, 2021).

Embodied carbon, on the other hand, is still unregulated, despite increased industry efforts to assess impacts even in the absence of regulation. Operational carbon is currently limited in most countries due to rigorous national construction regulations.

However, it is recommended that each project be approached with the environment in mind. That is, in designing buildings, various tactics must be put in place or applied, and they are given below:

- i. Reducing the amount of energy used: Operational energy has by far the greatest impact on the climate over time for major structures. By reducing our energy demand now, we will be able to pick and choose which low- or zero-carbon utility supply sources to implement (Brower, 2022).
- ii. Creating intelligent buildings: New sensor and network technologies are assisting us in the development of higher-performance structures. In the future, our environments, structures, and urban areas will harness real-time data regarding occupant behavior, air quality, and temperature in order to enhance building efficiency and subsequently adapt in response to this information. The quantity of energy required to operate the built environment will be greatly reduced as a result of this responsiveness (Brower, 2022).
- iii. Combining form and performance: Building performance is now the primary design driver. We now approach every job with the intention of implementing cutting-edge solutions for conserving energy and water. Having said that, we still have a lot of space for improvement. Our buildings and towns will have to experiment with new climate responsive forms to achieve true resilience and continue moving toward a carbon-neutral society, and in many cases, the built environment will require significant changes (Brower, 2022).
- iv. Embodied carbon should be addressed: Another option to reduce carbon emissions from construction materials is to simply renovate and reuse existing structures. If done correctly, retrofitting existing structures can have a greater positive impact on the environment than focusing entirely on new building performance engineering. Clients can also alter the appearance and use of an existing structure. Significant

design interventions can give people a completely new personality or experience without having to start from scratch (Brower, 2022).

2.1.4 Design Process in Built Environment and Digital Tools

The design process is divided into three stages: brief, creation of a technical solution and implementation. The expansion of the urban landscape demands feedback. The architect turns the project's initial aims into design criteria, then tests a proposed design solution resulting in a cycle design process until the project brief is met. By speeding up the design and testing process, the adoption of digital technology in this phase considerably lowers feedback. Designers can test the performance of a large number of designs within a fraction of the time it takes to do so in the traditional design process. The process of digitally testing a proposal demands the use of a quantitative criterion to measure and compare the performance of the proposed solution (Somanath, 2021).

Recently, designers have been using 3D modeling tools or digital design environments to enhance Digital Design Process. Furthermore, computer-assisted proposal visualization can encourage stakeholder participation and collaboration. This form of three-dimensional modeling software is useful for assessing socio-spatial data and serving as a digital design environment in the built environment (Somanath, 2021).

III. METHODOLOGY

The research adopted interpretivist and realist philosophies which are qualitative in nature as well as inductive approach (Aduwo, Ejale & Ibem, 2022; Ediae, Egbudom & Abeng, 2022; Ekhaese & Solaja, 2022; Oloke, Sholanke, Akindele & Akinola, 2022); unlike Adewale and Fasae (2019), Adewale, Ibem, Amole, and Adeboye (2019), Tunji-Olayeni, Afolabi, Adewale, and Fagbenle (2018) that were mainly quantitative in nature based on cross sectional survey of selected samples. The research design was based on archival materials in the subject investigated as contained in the literatures reviewed on it as a mono-method. Since majority of these literatures spread over seven (7) years, the study is nothing short of longitudinal horizon. Google search engine was employed to scout through Google Scholar, Science Direct, among other relevant websites for open-access materials. Over a hundred and fifty (150) literatures were found on the theme, which were filtered through textual analysis to a manageable number of those that focussed on the subject of the study. Secondary data which are qualitative in nature were collected for the study, and these were subjected to meticulous examination and content analysis based on themes in line with the objectives.

IV. FINDINGS AND DISCUSSION

Over twenty (20) key literatures that focussed on the subject of study were content and thematically analysed in line with the study purpose. In this section, findings based on study objectives have been carefully outlined and discussed.

4.1 Principles of Greening the Environment

The built environment is a complex interconnected multi-scale system that includes cities, towns, and neighborhoods, with elements such as land use, design, transportation and utility infrastructure, and human behavior influencing energy performance and emissions. As stated earlier, green building design is a method of constructing that focuses on long-term sustainability and the effects of our design decisions on the environment. The built environment recycles old resources and uses low-carbon, low-impact, non-toxic materials. Renewable energy empowers it, it ensures sustainable water use, and promotes people's health and safety. Natural biodiversity, green spaces, and nature-based solutions help people feel more resilient, happy, and connected. It emphasizes shared and long-term mobility (Blueprint for a sustainable built environment, 2022).

4.1.1 Features of Green Building

It is vital to consider the passive design features of any green structure. Placement of the building on the site, the shape of the building, and architectural aspects of the building, such as positioning of window and shading features, are all instances of design. It's vital to maximize the positive effects of local temperature and sunlight while reducing the negative effects.

- i. The placement of the building on the site: The orientation and architectural aspects of a structure in relation to the sun's path have an impact on its performance and the comfort of its users. The designer must consider compromises, such as the fact that maximizing sunshine lowers lighting cost but raises cooling costs. Since the direction of the sun changes throughout the year, the best orientation must consider the net results of positive and negative influences across the entire year.

- ii. The massing and shape of the building: Long skinny buildings get more natural lighting, but have higher heating and cooling demands, whereas compact buildings get less natural lighting, but have lower heating and cooling demands.
- iii. The architectural characteristics of the building: Windows can provide daylighting, minimize dependency on electricity-intensive artificial lighting, and absorb solar radiation, which helps to heat the structure during the winter months. In order to be energy efficient, buildings should contain shading features that allow sunlight in when it is advantageous but block it when it is not.
- iv. Active measures are generally targeted at all power-driven equipment, such as heating, ventilation, and air-conditioning (HVAC) systems, artificial lighting, and dynamic glazing (Perez-Lombard, 2011). They also deal with all possible control or automation systems, such as a building management system and thermostat settings. Active choices have been shown in studies to offer a high potential for attaining energy efficiency (Perez-Lombard, 2011).

4.1.2 Importance of Green Buildings

Green buildings (Wienerberger, 2022) are vital in our cities for the following reasons.

- i. They reduce expenses spent on operating by increasing productivity and reducing energy and water consumption.
- ii. Due to better indoor air quality, there is improved productivity.
- iii. Environmental consequences, such as storm water runoff and the heating effect, are reduced.

On the contrary, the advantages of green building can be categorized into three distinct aspects: environmental, economic, and social.

Environment: Green buildings can benefit the environment by generating their own energy or consuming less water, energy, or natural resources. In comparison to other industries, the construction industry has the greatest potential for drastically reducing global greenhouse gas emissions (worldgbc, 2016).

Economic: Green design saves occupants or household's money on utility bills, reduces the life cycle cost and increases property value for building developers, and creates jobs. (worldgbc, 2016).

Social: Greening the environment has not only environmental and economic benefits, but also social benefits, with this aspect focusing on the health of its users. The performance of building users improves when gas emissions are reduced and indoor air quality is improved (worldgbc, 2016).

4.2 Green Design Strategies

When creating a structure, a balance between environmental friendliness, functionality, and comfort must be established. There is no best method to developing a green built environment, but there are a few guidelines to take.

- i. Sustainable site selection
- ii. Alternative forms of transportation promotion
- iii. Water efficient landscaping utilization
- iv. Wastewater reuse
- v. Rainwater harvesting
- vi. Onsite renewable energy utilization
- vii. Local materials utilization
- viii. Rapidly renewable materials utilization
- ix. System controls utilization
- x. Ventilation increase
- xi. Daylighting

In general, when creating a green building, the architect must take into account several factors. These include incorporating passive architectural design elements, selecting building envelope materials that minimize energy loss and contribute to lowering the carbon footprint, enhancing the effectiveness of active building systems, and employing innovative approaches to integrate renewable and sustainable energy and water resources whenever feasible, thereby decreasing dependence on external sources.

4.3 Principles of Digitalization of the Built Environment

It is the process of using technology and data digitalization to change the way people work, change the way customers and businesses engage and interact, and generate new revenue streams. Digitalization has the potential to reduce resource consumption and carbon emissions and to increase efficiency throughout the built-environment. It enables the development of new procedures and services. In the construction sector, it will continue to

revolutionize the way we build, share information, and make decisions. It can give a host of benefits for stakeholders if done effectively, including more transparency and the opportunity to develop more efficiently and sustainably. Digitalization enables rapid information sharing throughout the construction process, allowing businesses to test ideas, and solve complex problems in a fraction of the time required by earlier approaches. Digital solutions can give building occupants more control over environmental conditions during the operational phase, while owners and operators can save money by managing assets more efficiently (wbcasd, 2021).

4.4 Application of Building Information Modelling in the Built Environment

4.4.1 Utilization of Building Information Modelling in all Stages of Construction

CAD tools are improving their expressive and geometric capabilities to enable a design process in which the computer model may be utilized to realize the design throughout the whole design process.

Building Information Modelling (BIM) is widely regarded as one of the most impactful technologies that has proven to be incredibly beneficial to the building and architectural industries. Many chaotic circumstances were brought under control with the introduction of BIM. Over budgeting, redesigning, and other issues have all been reduced to a large extent because to the use of BIM during various stages of development. It is a process that has altered the building industry's basic ideas. Most design revisions take place during the planning and development stages, rather than during the building phase. This serves as a determining factor in lowering costs and decreasing durations. BIM is a thorough way of realistically constructing a structure via digital media that includes "a complete collection of the architectural data, 3D geometry, and components." This model can be used to manage a building from its conception stage to its post-construction facility management (Dave, 2018).

4.4.2 Application of BIM in Energy Conservation

BIM is a key tool for decreasing the environment's carbon emissions. BIM is the foundation of the construction industry's new "informed" mode of operation, triggered and targeted by digitization and ready to manage the "total energy content" of a project (Buildup, 2020).

The integrated information provided by the BIM model aids facility managers and owners in analyzing and comparing various energy options, allowing them to select the most environmentally friendly and cost-effective solution. They can establish the most cost-effective energy consumption plan by continuously monitoring a variety of building performance factors such as daylighting, comfort, water consumption, low- to zero-carbon technology, and the environmental impact of materials.

Potential, embedded, operational, and sustainable energy are the four phases of the energy life cycle in building.

- i. Potential energy: Energy savings are anticipated and targeted during the planning process. It's all about applying BIM technology to reduce the gap between expected and actual building performance. BIM may be used to model buildings and run numerous analyses in a sequential order, resulting in energy performance estimates that can be used to compare design options and help make a better final decision.
- ii. Embedded energy: BIM is widely acknowledged as a tool for visualizing a building's energy efficiency, construction sequence, and timetable so that sustainable construction materials and procedures can be used with little energy and material waste. The usage of BIM 4D and 5D tools i.e time scheduling simulation and quantification allows for more effective project management during the building phase. By merging a 3D BIM model with VR and AR technology, site work may be made more productive and faster. With BIM-based digital design and visualization, prefabrication may be used, planned, and delivered more effectively. Additionally, BIM product catalogs can justify and simplify the use of local materials. Various digital data inputs and outputs are combined into new digital construction workflows through digitalization (Buildup, 2020).
- iii. Operational energy: The energy savings achieved throughout the building operating phase are analyzed and maintained on a regular basis, with lessons learned being passed on to other designers for future projects. The fact that Building Information Modelling supports performance management in building operations by facilitating the interlinking of data environments demonstrates the value of using it. Appropriate energy management lowers energy use while protecting occupants' health, and comfort. In order to achieve energy sustainability, BIM is utilized to optimize existing operations. The usage of smart buildings is interwoven with the use of smart buildings. The digital model of the building's BIM is utilized to generate digital sensors and the meters platform (Buildup, 2020).
- iv. Sustainable energy: It is targeted during the maintenance stage. Energy for demolition or recycling is a necessary component of a building's life cycle energy and, while small in quantity, can nonetheless make

a major contribution to its overall environmental performance. For recycling or disposal, all materials, and goods, particularly those with strong insulating properties, may necessitate a significant amount of energy and carbon emissions (Buildup, 2020).

4.5 Prospects of Smart Cities

Traditional construction and built environment solutions are no longer sufficient as we strive for carbon neutrality and resource efficiency. We are heading toward a more adaptable, energy-efficient, and intelligent built environment. Future life will be carbon-free, and people will be able to live better lives because of it. "Smart building" is now widely regarded as a promising way to improve the built environment's adaptability and efficiency. Smart city components such as smart infrastructure, smart mobility, smart technologies, smart energies, smart healthcare, smart construction, smart governance and education, smart transportation, and smart citizens all rely on such structures (Karimi, 2020).

V. CONCLUSION

The purpose of this study is to elucidate green building features, importance and benefits of greening and digitalizing the built environment. Findings revealed that, incorporating the green design strategies and applying BIM in energy conservation would be beneficial to the built environment. Digitalizing and greening the built environment have great prospects in smart cities development, one of which is the creation of sustainable environment resulting in reduction of carbon emissions from the built environment, lowering of global warming, increase of user participation in buildings and lowering the cost of building lifecycle through active and passive methods.

The study sensitizes architects, planners and other designers in considering sustainability and digitalization from pre-design phase (incorporating required or special features into the design of future cities, towns and microenvironments) to postconstruction phase making the environment sustainable.

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