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SUSTAINABLE ARCHITECTURAL DESIGN PRINCIPLES AS A PANACEA TO ENERGY-EFFICIENT BUILDING

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ABSTRACT

This paper focuses on integrating sustainability as an architectural design principle that addresses the issue of energy efficiency in buildings. The design approach in the school of architecture and among practitioners are mostly based on form and function, but sustainability has in recent time introduced a shift that ensures that both the environment and the present and future generations can be sustained adequately without depleting available resources. In architectural practice, the three cores of sustainability; social, economic, and environmental factors are mostly ignored by architects while making decisions at the design stage. This topic will focus on efforts that will increase the overall energy efficiency of a building from the design stage to its lifecycle. In the training and practice of architecture, sustainability has not been prioritized. This study will evaluate and integrate sustainable architectural design principles needed to achieve energy-efficient buildings from the preliminary stage of architectural design. Data were collected through detailed literature reviews; a case study research strategy was adopted to ascertain the effectiveness and efficiency of building design with an emphasis on sustainable architectural design principles. The result reveals that buildings that were designed and built with a sustainable architectural design approach are more energy efficient and environmentally friendly. This paper, therefore, intends to identify the best architectural design principles for sustainability that can help architects navigate architectural practice toward a more current approach to achieving energy efficiency in buildings. This means the introduction of passive design strategies, design for deconstruction, adaptive reuse, and design for human comfort at different levels of the architectural design method. The study, therefore, recommends the need for architects and other allied professionals in the built environment to adopt architectural design principles with sustainable strategies as a tool for the achievement of energy-efficient buildings.

Keywords: Design principles, Sustainability, Energy efficient building.

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1.0 Introduction

Sustainability in architectural design is a purposeful design of the building and the environment by the architect and other allied professionals in the building industry with the aim of implementing the principles of social, economic, and ecological sustainability, in essence, the architectural design for sustainability should minimize environmental impact and building energy consumption (Wael, 2017). Lack of introduction of a sustainable approach as a design principle at the early stage of design would impact negatively the design output. (Wael 2017) cite (Burger 2008, Fasoulaki, 2008).

In this study, it is imperative to have in-depth knowledge of the link between architecture and sustainable development, since the connection between architecture and sustainability is the base for the achievement of an environment devoid of excessive consumption of natural resources. Every architectural design without the inclusion of sustainability contributes about 50% to exploitation of the natural resources. (Magarida and Miguel 2019) cited (Anink et al 1999, Edward et al 2004).

According to UNESCO and the International Union of Architects (UIA), Charter for Architectural Education…." Architectural design should integrate those things that influence the built environment and the way it is designed, planned, landscaped, and maintain (Wael 2017).

Architects must have to reduce through the sustainable architectural design principle the use of energy and carbon-intensive technologies following the 2015 Paris Climate Accord. To achieve this, it is imperative to change the present principle of architectural design towards sustainability. This implies that the practice of architecture and architectural education should be geared to cover the knowledge of climate and its effect on our built environment.

1.1 Passive Design

The passive design utilizes natural energy sources for cooling, heating, and ventilation for a comfortable ambient inside the buildings (Alfa et al, 2021) cited (Thomas 2012). Passive design is known for its simplicity, aesthetic appearance, and zero operational cost.

According to Alfa et al, (2021), passive design approaches if introduce into architectural design principles essential at the design stage of public buildings like the Ozuoba Medical Heath Center that requires cooling, refrigeration, and lighting will lead to a sustainable building with low energy consumption.

Passive design is achieved when the internal space remains thermally comfortable with the climate in the built area, through building orientation, and proper design of the building envelopes (floor, walls, windows, and roof) (McGee, 2013).

According to Barry: irrespective of the construction type and climatic variation of places, buildings should be designed to respond better to their immediate environment, by the inclusion of passive design strategies from the design stage as it allows for little or no energy for heating and cooling (Stephen et al, 2010).

1.2 Definition of terminologies

a) Passive architecture; passive architecture refers to a building capable of ensuring living comfort without a heating or cooling system (Romina Totaro, 2022)

b) Passive design 'Passive design is a design that works with the local climate to maintain a comfortable temperature in the home.

c) Energy Efficiency: Energy efficiency is defined as the optimization of energy consumption, with no sacrifice in lighting quality. It is a combination of thoughtful design and selection of appropriate lamp, luminaire, and control system selection, made in conjunction with informed choices of the illumination level required, integration, and awareness of the environment or space which is being lit. (Arup, 2021).

d) Panacea; An eco-friendly design architecture for wellness.

e) Sustainable architecture; defines a building designed and built to significantly reduce the damages inflicted on the health of its inhabitants and the environment (Spruce 2022)

1.3 Aim and Objectives

The study aims at highlighting existing architectural design principles in relation to sustainable principles that could enhance sustainability in the architectural practice and the achievement of energy efficiency in building.

1.4 Objective

i. The objectives involve integrating both architectural design and sustainable principles in design and construction.
ii. Using the integrating principles as a design tool used by the architects for the attainment of Energy efficient building design.

1.5 Research question

i. What are the various focus in integrating sustainability as an architectural design principle.
ii. How energy efficiency in the building can be addressed in line with sustainable strategies as a tool for the achievement of energy-efficient buildings.

2.0 Literature Review

The present condition and the need for effective sustainable solutions to the global issues on climate change have brought a lot of challenges to the architectural profession, with a call for transformation and adaptation (Magarida and Miguel 2019).

The architect needs to understand the principles of sustainability in a more detailed manner while creating and transforming space into a more energy-efficient building (Brophy and Lewis, 2011). In order to implement sustainability as a fundamental in the building lifecycle, sustainable principles should be integrated into the architectural design (Amado et al, 2015).

According to Margarida and Miguel, the principle of architectural design should be based on flexibility and inclusive planning that should have a link with the sustainable development objective.

The design stage which is the first decision-making phase of every building design has a lot of influence on the building's performance down to its lifecycle, the architectural design principle or concept used by the architect should be based on sustainability principles (Magarida and Migue, 2019). This is possible through the introduction and implementation of deconstruction, passive, adaptive strategies, and Design for Human Comfort as an architectural design principle, with the aim of using the architectural concepts above as a sustainable tool for energy reduction in buildings, looking at it from the design stage (Guy and farmer, 2011, Kanters et al 2014).

2.1 Design for Deconstruction,

Deconstruction according to Fernada et al (2015) is the act of putting into use demolished materials from a demolished building. This process of restoring demolished building materials serves as a strategy for preserving raw materials (Webster, 2007).

The difficulties associated with deconstructing a building are the hazards, economics, and assembly time, these problems can be overcome if planned for from the design stage of the building, if the projects are designed intentionally for deconstruction throughout its life cycle, and this architectural design principle is called design for deconstruction (Fernada et al., 2015).

Design for Deconstruction (DfD) is a means of achieving sustainability through waste reduction, resource conservation, and recovering of waste for reuse and recycling. It is therefore imperative that architects and other professionals in the built environment to introduced design for deconstruction from the design stage and as a design approach for sustainable design (Chris & Fionn, 2005).

2.3 Adaptive Reuse

Adaptive reuse is the process of changing a building's overall character with a focus on the function and other variations made to the building itself, through orientation and the relationship between spaces which can be an addition or demolition with the sole aim of preserving the building or site (Fiorani, 2017).According to Schmtid, adaptive reuse is a condition whereby a building maintains and performs the basic developmental requirements of the users and still undergoes a steady change in a perfect manner and retains maximum value in its lifecycle (Zahraa and Sana, 2020) cite Schmtid (2009).The act of recycling and reuse of building materials according to Rathmann study deals with the change in functional needs of the society from the building (Zahraa and Sana, 2020) cite Rathmann (1998). These adaptive reuse strategies can be fully achieved as a sustainable approach if integrated as part of architectural design principles from the design stage.

Adaptive reuse comes with a lot of economic benefits, it is super-efficient and effective in space provision, and both the structural elements and partition components can be put to use making it cost-effective and environmentally friendly. (Zahraa and Sana, 2020)

2.4 Design for Human Comfort

Buildings and the environment are designed for human comfort, these buildings run on energy for users' comfort. In order to achieve comfort there must be a balance between human comfort and the environment, the architect at the design phase should factor in the user's comfort as part of his architectural design principles for sustainability (Geun and Jeong, 2014).

Fundamentally, architecture is to protect man from external environmental impact, thus providing comfortable shelter, which can result in an increase in energy consumption in the building. But Geun and Jeong, argued that if a new comfort theory is introduced; the energy usage in the building can be reduced with better satisfaction of occupants' comfort (Geun and Jeong, 2014).

Vitruvius, architectural design principles can be used for better internal comfort by relating the building with the adjacent natural environment

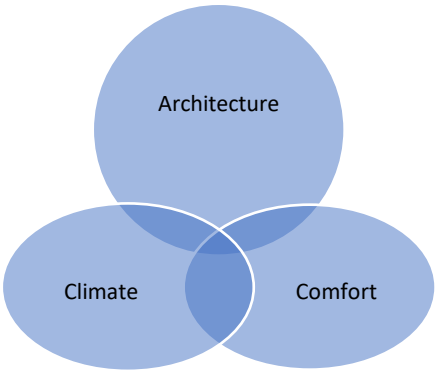

Figure 2.1 Vitruvian Model of Environment in Architecture

Sustainable building energy and comfort cannot be separated; therefore, the architect is expected to incorporate the five categories of sustainable site, energy & atmosphere, materials & resources, water & efficiency, indoor environmental quality, and innovation in design (Bauer et al, 2009). Innovation in design that can lead to sustainability can only occur if sustainable design techniques are integrated into architectural design principles.

2.5 Sustainable Architecture Design Approach

The concept of the Sustainable Architecture Design Approach has been introduced to combine concern for the well-being of the planet with continued growth and development. This requires awareness of the full short and long-term consequences of any transformation of the environment (Ajayi Oluwole, Soyebo Olugbenga, Joseph. J O, 2016).

There are five major elements of sustainable architecture design approaches,
Which are:

a) Sustainable Site Design; this is achievable through minimizing urban sprawl and needless destruction of valuable land and habitat, which are the usual consequences of inefficient low-density development. Encourage higher-density urban development, urban re-development and urban renewal, and brownfield development as a means to preserve valuable green space.

b) Water Conservation and Quality; Preserve the existing natural water cycle and design site and building improvements such that they closely follow the site's natural "pre-development" hydrological systems. Emphasis should be placed on retention of storm water and on-site infiltration and groundwater recharge using methods that closely follow natural systems. Minimize the unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and grey water.

c) Energy and Environment; Minimize adverse impacts on the environment (air, water, land, natural resources) through optimized building siting, optimized building design, material selection, and aggressive use of energy conservation measures. Maximize the use of renewable energy and other low-impact energy sources.

d) Indoor Environmental Quality Principles: Provide a healthy, comfortable, and productive indoor environment for building occupants and visitors. Provide a building design, which affords the best possible conditions in terms of indoor air quality,

ventilation, thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment

e) **Conservation of Materials and Resources.** Minimize the use of non-renewable construction materials and other resources such as energy and water through efficient engineering, design, planning, and construction and effective recycling of construction debris. Maximize the use of recycled content materials, modern resource-efficient engineered materials, and resource-efficient composite-type structural systems wherever possible.

3.0 Methodology

The study adopted the descriptive approach to present a case study that identifies the effectiveness of architectural design principles as a sustainable solution in architectural design. Related literature on both sustainable and architectural design principles where exhaustively reviewed.

3.1 Case Study and Criteria for Selection

After a careful study and observations, a purpose-built government community health center was adopted with the following criteria for the practical study:

I. Public buildings that have architectural features different from others,
II. Approved project that adopted the variables under study: passive design, deconstruction, adaptive reuse, and design for human comfort.
III. Building that is energy efficient.

3.2 Community Medical Health Centre

Location; Ozuoba Community, Obio/Akpor Local Government Area Rivers State
Project uses; Medical Health Center
Year completed; 2009

Ozuoba Community Health Center was built in 2009 by the Rivers State Government. The general concept of the building was sustainability, it was achieved from the design stage by the adoption and co-operation of passive, deconstruction, adaptive, and design for human comfort as a strategy for energy efficiency which makes the facility unique among the many health centers built across the state by the state government.

Figure 3.1 View from the Gate showing both the medical block and the staff quarters

Figure 3.2 View showing the reception/waiting area with natural lighten

Figure 3.3 View showing roof with solar panel

Figure 3.4 Courtyard Showing Wall finish with Poly-thane sandwich (metal sheet) panel with an insulating Poly-thane foam

4.0 Findings and Benefits from the Case Study

1. Passive Approach

- Natural ventilation was achieved through the introduction of large windows
- Daylighting was also achieved intentionally from the design, by the orientation and the large window opening
- The facility runs on about 70% solar energy which makes it efficient and sustainable.

The use of courtyard design as a passive approach enhances the ventilation and lightening

2. Deconstruction

- The choice of de-constructible building materials in this respect makes the process of maintenance and repairs very easy, without altering the other part or shutting down activities
- It will allow for future adaptability of the structure and the recycling of materials especially when after demolishing or remodeling
- The panels are designed to be in a uniform module, which will help in reducing unnecessary waste during production and reuse.

3. Adaptive Reuse

- Adaptive reuse contributes to and enhances the physical and technical use of the building.
- It helps in reducing energy demand and carbon emissions (reduce pollution).
- It makes maintenance of public buildings of this nature very easy.
- It is cost-effective
- It enhances and increases the lifespan of public buildings.
- Adaptive reuse helps in maintaining the functional value of the building

4. Human Comfort

- The construction method and materials (the building envelop) help in reducing the temperature, thereby improving the human comfort

- The sizes of opening which allowed for continuous airflow through the space makes humans comfortable
- The building utilizes a passive design approach as a stratagem for enhancing the relationship between comfort and external condition which help occupants to adapt to changing environmental conditions

4.1 Jempol Hospital, Negeri Sembilan

Location; Bandar Baru Serting, Jempol, Negeri Sembilan
Project uses; Medical Health Center
Year completed; 2004

The 929-bed CPMC system is one of the largest not-for-profit, tertiary teaching hospitals in the U.S., and the premier private, acute care enterprise in Northern California. The new, 13-story hospital, designed to accommodate 555 beds for adults and women/children, along with affiliated medical offices, specialty outpatient services, and emergency services and parking, will occupy a full city block.

Figure 4.1. Efficient use of clear glasses as daylight strategy in passive design Spaces Source (Envision Prince George's Community Action Team 2012)

4.2 Sufficient daylight

Figure 4.1 shows additional facility such as gymnasium at rehabilitation area is provided with careful consideration of natural daylight and access to the therapeutic garden. Sufficient daylight at waiting area (Figure 4.1) at Pharmacy Department which has also a direct view out to the courtyard gives a better environment during process of waiting.

Figure 4.2 Source (Envision Prince George's Community Action Team (2012)

Effective use of clear windows to clearly show exhibition while also serving for ventilation. Image Source: (Aaron, Mikel, & Olson) as cited in (Pintos, The Burke Museum, 2021) A large central atrium and "smart glass" skylight likewise foster a bright, daylight interior experience, without risking damage to sensitive artefacts. The project is LEED® Gold certified. The building's rational scheme holds the complexity of the Burke's activities and collections, both now and into the future (Owhor, Simeon Julius, Arc. Paul Uchenna, 2021).

4.3 University of Virginia Medical Center Replacement Hospital
Location; Bandar Baru Serting, Jempol, Negeri Sembilan
Project uses; University of Virginia Medical Center
Year completed;

Smith Group JJR has provided services to the University of Virginia Medical Center since 1978, including master planning and designing a new 610-bed tertiary care teaching replacement hospital, as well as a 28,000 sf children's outpatient center and a 7,000 sf outpatient cancer center. Ranked as one of America's Best Hospitals by U.S. News & World Report, the hospital offers state-of-the-art care in endocrinology, cancer, ENT, urology, neurology and neurosurgery, respiratory disorders, geriatrics, and kidney disease. Ongoing renovations and expansions in both hospital buildings have accommodated the hospital's new standards of patient-centered care and the most advanced technologies, including a Gamma Knife unit and neuro angiography suite.

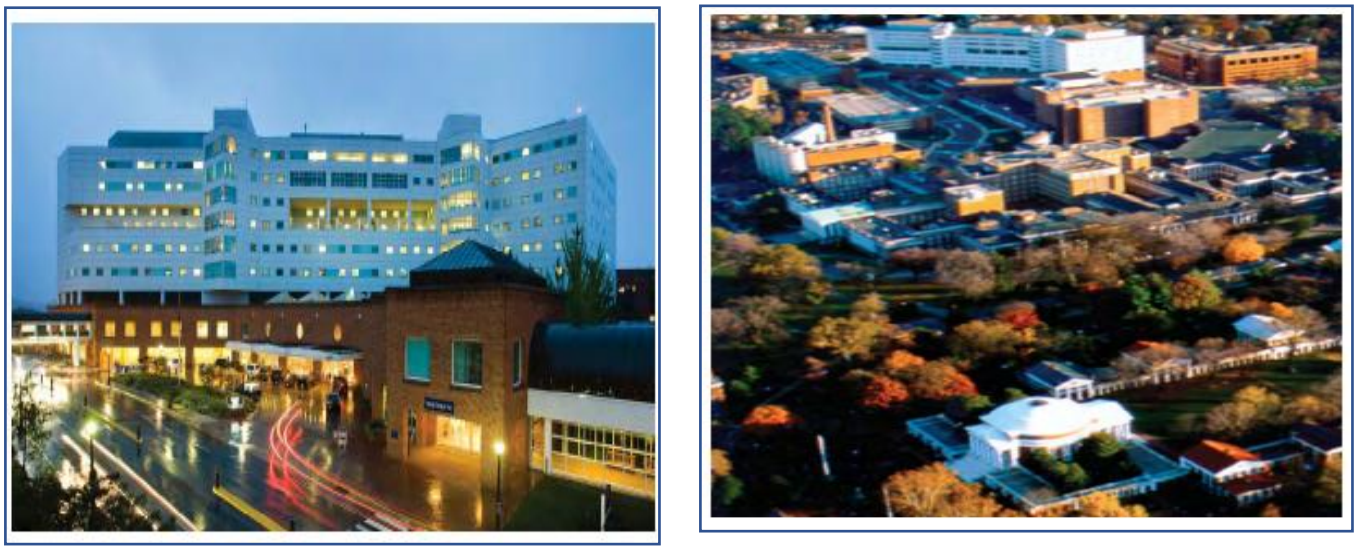

Figure 4.3 (source: Envision Prince George's Community Action Team 2012) shows a developed sense of a high-density community with the presence of several blocks of high-rise administrative and staff quarters. However, one has to note that the preference or requirement for either low-rise or high-rise structure in implementing the hospital project does not hinder the considerations on passive design but rather adds to the aesthetic of the building.

Figure 4.4 shows sufficient daylight in the waiting area of the hospital (Envision Prince George's Community Action Team 2012)

4.4 Natural ventilation

In Jempol Hospital, the waiting area at the specialist clinic is designed for natural ventilation with cross ventilation from the courtyard to the external space (Figure 4.4). Sufficient openings provide natural daylight penetrates into the space. Since the specialist clinic is facing west, the architect takes the opportunity to design an opening incorporated with sun shading devices, and louvers below the windows for natural cross ventilation.

Before employing energy-consuming mechanical air conditioning systems, it is important to consider natural ventilation. All space-conditioning systems involve some basic processes to

operate; energy collection, storage, distribution, and loss back to the environment. The proper size and location of all types of openings like doors windows and vents are employed as natural means of ventilating buildings. Adjustable openings ensure every space within the building adapts to various seasonal demands. The inlet and outlet of air are placed in either opposite directions or adjacent to each other. Wright never liked air-conditioning and preferred natural ways of ventilating the Usonian house through passive means. (David Gikaru 2017)

4.5 Daylighting

A good approach for excellent daylighting and glare control is separating view and light windows. Use high-transmission, clearer glazing in high-level windows, and lower-transmission glazing in view windows to control glare (O'Connor et al, 1997). Diffuse glazing on the interior face and glass blocks redirect the skylight to the deeper parts of the room, to a limited degree, from where the sky is not visible. (Ministry of environment new Zealand 2008) The same type of prisms can also be used to redirect sunlight to the ceiling, giving shading in the front of the room, and generally increase daylight levels by diffuse reflection from the ceiling (Hastings, 1994).

5.0 Conclusion

The achievement of a sustainable building and environment starts with a sustainable design approach used by the architect. Therefore, the role of the architect in the implementation of sustainability cannot be overemphasized. The professionals in the built environment especially the architect must double their effort toward mitigation and resilience, new techniques, and technology in the design of buildings that must support the sustainability movement. The architect in his approach to the built environment starts Principles of architectural design remains a takeoff point to every successful building design and achievement of energy-efficient building.

6.0 Recommendations

The study, therefore, recommends the following;

1. The integration of passive, design, design for deconstruction, adaptive reuse, and design for human comfort as part of architectural design principles that would result in energy-efficient buildings should be adopted in every design of buildings by architects.

2. The introduction of passive design such as the Ozuoba Medical Health Centre as a replacement for the active design approach would reduce the carbon footprint and energy consumption in the building, thereby eliminating excessive dependence on fossil fuel.

3. The adoption of deconstruction in public buildings or any other building type would increase project speed(time) and eliminate materials wastage, exhaustion and will allow for adaptive reuse

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