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Appraisal of Lighting Strategies for Achieving Environmental Sustainability in Selected Art Museums and Galleries in Nigeria

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Abstract Lighting in the display areas of art museums and galleries is a key facilitator of an effective design. However, this brings to the fore the issue of environmental sustainability. This study investigated the use of lighting strategies in three selected art museums and galleries in Nigeria to ascertain how effective they are in achieving energy conservation, towards attaining environmental sustainability in developing the built environment. The study adopted a qualitative research method that obtained primary data with the aid of an observation guide developed for the research. Results were content analysed and presented descriptively with plates and tables. The results indicated that both daylighting and artificial lighting strategies of several types were utilized. However, the daylighting strategies were used in the display areas as supportive measures and the use of artificial lighting techniques was found to be prominent. Using both strategies helped to effectively light the display areas and encouraged energy conservation, thereby encouraging environmental sustainability. The study underscored the importance of appreciably integrating daylighting strategies with artificial lighting techniques in the development of display areas of museums and galleries right from the design stage. It suggested the use of the combined lighting system so that the daylighting strategies are optimised to the level that can cause a significant reduction in the use of artificial lighting techniques to meaningfully conserve energy. This will in turn stimulate environmental sustainability, especially where artworks not affected by direct rays from the sun are exhibited.

Keywords Daylighting Strategies, Artificial Lighting Strategies, Art Galleries, Art Museums, Lighting, Energy Conservation, Environmental Sustainability, Nigeria

1. Introduction

Art museums and galleries have been established for a variety of reasons including, but not limited to, serving as an influence for economic growth, a medium to accommodate recreational activities and academic functions, a tool to attract tourism to a geographical location to boost civic pride and contribute to the good quality of life in the communities, in which they are located [1]-[3]. Art museums and galleries are recognized for their role in aiding the public to rediscover a shared educational foundation. They facilitate the cultivation of unity by encouraging the development of connections rather than fostering discord. This is achieved by offering insights through intellectual engagements or by highlighting historical oversights as manifestations of the past's presence [2], [4]. Art museums and galleries play a pivotal role in unravelling the essence of art. They transcend being mere showcases for artworks, evolving into dynamic

arenas fostering interaction, facilitating the acquisition of novel creative modalities, and promoting collaborative endeavours.

The notion of art is developed by how it is presented to a viewer; presentation also plays an important part in subject matter evaluation. The atmosphere of art galleries is primarily concerned with amplifying or glorifying the feelings and concepts expressed in each item of the area. The major goal of an exhibition or gallery is to tell the story of its development while motivating aspiring artists to discover/develop new skills [5], [6]. In art museums and galleries, artefacts, objects, and other exhibits are there interacting with us. To design art museums or galleries, environmental conditions are crucial factors to consider while planning spaces for users and their features. These specific environmental prerequisites that foster effective communication encompass favourable visual, thermal, acoustic, and air conditions [7]-[9].

However, among the environmental parameters to be considered and regulated, lighting stands out as a fundamental key requirement that varies with function and task [10]-[13]. As lighting centers as an enabler for a successful design, it raises the question of environmental sustainability. Lighting in museums is burdened with its specificity (intensity and colour) as it must convey the artwork's visual richness and emotional significance to the audience while conserving and maintaining its value and data for the future [1], [4], [14].

As humans exist further into the centuries, there is a gradual understanding that the psychological relationship between humans and the wider environment is very important [15]–[21]. Sustainable development is a broad term that refers to policies, initiatives, and projects that deliver benefits today without jeopardizing future environmental, social, and human health [22]–[26]. These policies are frequently referred to as "green" since they aim to reduce the environmental effect of growth. On the other hand, sustainable development advantages are felt across a broad range of human health and well-being, including decreases in pollution and environment-related illness, improved health outcomes, and reduced stress [24]. Sustainable development also promotes ethical production and manufacturing, tackling the industrial side of environmental degradation and waste, as well as encouraging several sectors and governments to make good decisions based on long-term implications rather than the simplest, cheapest solution [22], [27].

According to Okonkwo [28], one of the identified techniques available to developers and builders is “developing sites and designing buildings to reduce the consumption of energy and non-renewable materials and the production of waste, toxic emissions, and pollution”. In Nigeria today, the concept of sustainability in terms of reduced energy demand and consumption has become a national trend. In Corroboration to the above statement, Okonkwo [18] stated that the Urban Land Institute commissioned a publication to explain how developers might put the notion of sustainable development into reality, guided by its long-established principle of offering "responsible leadership in the use of land to enhance the total environment”. The concept entails an effective approach to increase building performance and lower the negative impact on the environment, thereby reducing carbon footprints and ozone layer depletion. About 40% of all energy consumed worldwide is utilized for heating and cooling, so integrating energy efficiency and renewable energy use in buildings is necessary for sustainable development in the building industry [29]-[32]. Narrowing the concept of sustainability, the issue of sustainability cannot be discussed without architectural lighting [33].

According to some studies, daylighting, and safe artificial lighting have been shown to improve building interior performance as well as help attain environmental sustainability. Therefore, it must be integrated into the design of buildings [15], [37], [38]. Such studies include *Built Architecture: The Role of Natural Light* [12]; *Assessment of Day Light Design Considerations in Kogi State Museum [20]; How lighting design impacts a building's performance?* [19]; *Lighting Design for Health and Sustainability: A Guide for Architects* [33]; *The Role of Artificial Lighting in Architectural Design: A Literature Review* [34]; *Light level, visual comfort and lighting energy savings potential in a green-certified high-rise building* [36]; *The Benefits of Daylighting in Your Building* [37]; *Natural Lighting Strategies and Benefits* [38]; *Inverse lighting design for interior buildings integrating natural and artificial sources.* [39].

Despite the importance of daylighting in buildings, it is observed that its usage constitutes a problem in certain building types, such as art museums and galleries. In Nigeria, the use of daylighting is less prominent in museum designs because the use of daylighting in museums results in high luminous outputs that contain large concentrations of ultraviolet rays. These rays eventually damage textiles and artefacts [14], [40], [41]. There is therefore a need to guide against the negative effects of the various available energy options while harnessing their potential to achieve reliable and sustainable lighting in the development of art museums and galleries [42].

The strategic application of daylighting can mitigate the problems associated with its use [11]–[13], [27], [31], [33], [36], [37]. In Nigeria, studies are found to have focused on museums and lighting include: *Assessment of Lighting Strategies and Their Influence on Users' Experience in Art Galleries* [10]; *Assessment of Daylight Design Considerations in Kogi State Museum* [41]; *Assessment of Lighting Strategies in Art Galleries: A Comparative Case Study of Selected Art Galleries in Lagos State* [43]; *Assessment of Daylighting Designs in the Selected Museums of Southwest Nigeria: A Focus on The Integrated Relevant Energy Efficiency Features* [44]; and *Design of the New National Museum, Lagos State, Nigeria: Using a Universal Design Approach* [45].

Despite the valuable contributions the aforementioned

studies made to knowledge, they were found not to have focused on the assessment of the use of both daylighting and artificial lighting strategies towards achieving energy conservation and environmental sustainability in the development of art gallery and museum buildings, particularly in Nigeria, which is the gap this study was conducted to fill. Therefore, the target of the study was to investigate lighting strategies in three selected art museums and galleries in Nigeria, with a view to ascertain how effective they are in achieving energy conservation, towards attaining environmental sustainability in the development of the built environment. To achieve this aim, two objectives were set: to identify the lighting strategies utilized in the display areas of the selected art museums and galleries; and to ascertain how effective they are in achieving energy conservation.

The scope of the study covered both natural and artificial lighting strategies. The study was divided into seven parts as follows: title section (topic, authors information, abstract and keywords; introduction (background to the study, research problem clarification, research questions, aim and objectives development, justification for the study and literature review), methodology, presentation of results with discussion of the findings, conclusion, acknowledgements, conflict of interest and references. The study provides valuable insight to designers, scholars and researchers on how various lighting strategies employed in display areas or exhibition spaces can be utilized to conserve energy and achieve environmental sustainability. The study is a valuable resource for designers, scholars, and researchers to consult on issues relating to energy conservation and effective lighting of exhibition spaces towards achieving environmental sustainability. The study also promotes the eleventh aim of the 17 sustainable development goals which targets the development of resilient, safe, and sustainable communities.

1.1. Categories of Lighting in Art Museums and Galleries

Architectural lighting employed in building designs is categorized into two broad headings based on their sources: daylighting or natural lighting and artificial lighting [41] as shown in Figure 1.

(a) Sun (b) Light bulb

Source: Christian Richters (2023)

Figure 1. Artificial and Daylighting Sources

1.2. Daylighting

Daylighting, also known as natural lighting, originates from the Sun [12]. The Sun is the main natural source of illumination on Earth which receives its energy through nuclear fusion [34], [14], [31]. Sunlight is important to all life forms but can only be utilized until nightfall. The use of sunlight in light areas in buildings contributes to a reduction in the quantity of energy required for such purposes via artificial ways, which reduces energy demand for lighting and greenhouse gas emissions [27], [34], [35], [38]. Daylight originates not solely through direct sunlight but additionally through the sky on overcast days.

The concept of "daylighting" pertains to the deliberate utilization of natural sunlight in and around structures. Placing daylight systems (redirection devices, tubular lights, exterior glazing; windows, glass blocks, skylights, panels, and openings) ensure that daylight effectively illuminates interior spaces during the day [38], [46], [47]. Therefore, it utilizes strategies that aim to efficiently bring daylight into a structure using proper space planning and daylight systems to reduce artificial lighting requirements and save energy, without compromising comfort and function [41], [44].

It can be exceedingly difficult when trying to fully utilize daylighting in art museums and galleries, to achieve environmental sustainability because many factors need to be considered. These include building use, sun orientation, opening sizes, number, and spacing, window-to-wall ratio, proper space planning, building geometry, proximity to the area of interest, location and type of opening aperture, sky-reflected components, and internally and externally reflected components [9], [31], [32], [48], [49]. These considerations determine daylight characteristics.

1.2.1. Daylighting Strategies

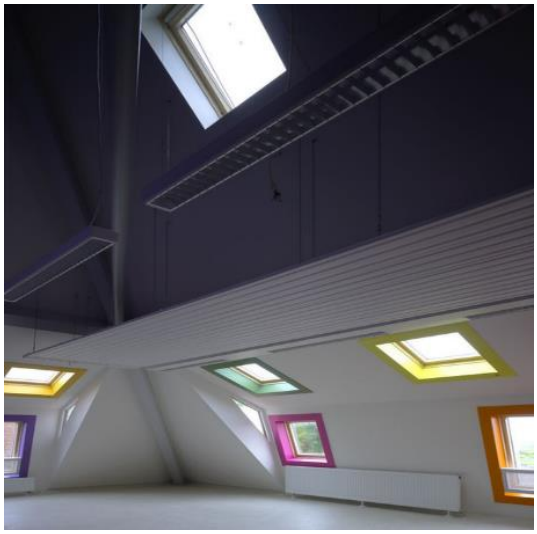
To optimize the efficacy of daylighting strategies and to maximize the utilization of natural light, it is imperative to meticulously observe the building considerations emphasized in paragraph 3 of section 1.2 [29]. Daylighting strategies vary in their degrees of effectiveness, influenced by factors such as the amount and quality of sunlight, seasonal variations, geographical location, and atmospheric conditions. An intricately crafted architectural design is essential to incorporate elements like admission, diffusion, shading, and reflection of daylight. The identified daylight strategy includes the following.

i. Direct Lighting

The most prevalent daylighting strategy approach is known as direct lighting. Controlled light exposure falls directly into the building and on non-light-sensitive artworks [50]. The strongest light occurs when the sun is at its highest position in the sky, while the 'golden' light is at its purest right before sunset. This colour shift is used in architecture [51]. This method has been utilized extensively in Egyptian architecture and is suited for open-

concept structures where the ceiling parallels the roof plane. They constitute a portion of the roof utilizing skylight and clerestory.

Proper daylighting system installation can be used to minimize visual discomfort and heat, and increase the major benefits of this daylighting strategy, even if it is thought to have the potential to cause excessive heat gain and glare. Glare may be reduced by using opaque windows, and double glazing should be used as frequently as possible. Additionally, the equal dispersion of light can be enhanced by installing a ceiling diffuser at the base of the skylight shaft as shown in Figure 2. When the display area is not being utilized by the public, curtains or blinds can be used to control this and make it dark. Figure 2 shows the use of direct lighting in a room.



Source: Christian Richters (2023)

Figure 2. Direct Lighting in a Room

ii. Sunspace

Sunspace is a resolute direct-gain room on the south side of the home that is designed using the building's orientation, opening measurements, and location. As shown in Figure 3, a common wall used in sun scape is a wall that separates a house from a sunroom; it contains adjustable windows and doors that may be opened and closed as desired to control the amount of light required. This tactic relies on diffused lighting, a theory in which gentle light is dispersed uniformly throughout the room from a remote source. Figure 3 is an illustration of sunspace in a room.

When there are little to no lighting limitations, the sunspace method implementation in temperate locations works effectively. This may be accomplished by using louvres or perforated blocks. This strategy approach effectively addresses the challenge of managing the intensity of natural illumination. Retractable awnings offer distinct advantages over alternative window light-diffusion methods like tinting, blinds, and stationary awnings. Furthermore, they contribute to a noteworthy reduction in heat gain.

Source: Rohin & Michelle (2011)

Figure 3. Sunspace in a Room

iii. Sun Tempering

Sun tempering is the practice of adding a modest number of windows on the south side with opaque clerestories to prevent direct sunlight from hitting artwork. The apertures in the south receive full daylight since the sun rises in the east, travels through the south, and sets in the west. As shown in Figure 4, this is a low-cost method for making effective use of daylight while reducing heat gains and glare. A fourth of the windows in a typical design face south. This is equivalent to around 14% of the home's total floor area. The proportion is increased to a maximum of around 7% on the south side in a sun-tempered design scheme [11], [31], [32], [40]. Figure 4 shows an illustration of sun tempering in a room.

Source: Reinberg ZT GmbH (2009)

Figure 4. Sun Tempering in A Building

iv. Combined System

Direct heat gain, sunspace, and sun tempering can function individually, but combining the two or three strategies will yield the best benefits. As shown in Figure 5, combining direct gain with a sunspace or sun tempering is very adequate in mitigating the lighting problems associated with daylighting. The systems must be effectively linked with one another and the building's

mechanical system, which necessitates a significant quantity of south-facing area and careful design considerations [40], [48]. Figure 5 shows a combined system utilized in a room.

Source: Marc Rosenbaum (2017)

Figure 5. Combined System (Direct lighting and sun spaced)

1.3. Artificial Lighting

Artificial lighting is referred to as man-made lighting features that employ technology to provide lighting for the improvement of vision and aesthetic purposes; to work, they need a manufactured light source. [52]. They can be manually regulated to provide the necessary level of light and direction, producing a variety of effects depending on the space's needs. [44]. When selecting artificial lighting, things to consider include the usage of the building, the structure's geometry, its closeness to the region of interest, and the internally reflected elements [4], [9].

Sources of artificial lighting include incandescent, fluorescent, and light-emitting diodes (LED) [34]. According to Sylvania [53], artificial lighting types include ambient lighting, decorative lighting, spotlighting, accent lighting, wall washing, dimming, floodlight and beam angles. All the previously mentioned artificial lighting types can be categorized under four strategies which are examined in the following section.

1.3.1. Artificial Lighting Strategies

The established guideline for the recommended illuminance level for delicate objects is within the range of 50 to 100 lux [54]. Therefore, to guarantee that displayed works are only lit while the users are present, timers, dimmer switches, energy-efficient lighting systems, and motion sensors should be used. [29], [55]. The identified types of artificial lighting strategies include:

i. Down Lighting

This frequently used artificial lighting strategy projects light downward from light sources on or recessed in the ceiling. A downlight is a light that is set or designed to cast light downwards on display artwork in a semi-controlled manner, focusing the light on that direction as shown in Figure 6. Most building types use this lighting technique since it is the easiest to disperse light. With the arrival of light emitting diode (LED) lighting, an incandescent downlight or spotlight's energy efficiency has increased by about 90%. LED lights or bulbs may now be adapted to replace fixtures with significant energy usage [11], [39], [53]. Figure 6 shows how down lighting was utilized in an art gallery.

Source: Yujileds (2023)

Figure 6. Down Lighting in an Art Gallery

ii. Up Lighting

A less common artificial lighting technique called up lighting is employed to reflect light down from the ceiling or walls. The diffused highlight draws attention to the object's natural texture and colour [46]. Figure 7 shows that this lighting strategy is used in object lighting situations that require ambient lighting levels with no glare. The reflecting coefficient of the surface completely dictates how this will work. Although uplighting can create diffused, silhouette-free, and glare-free light, it is regarded as an ineffective and expensive artificial lighting strategy [39]. Figure 7 shows an example of uplighting used in an art gallery.

Source: Chauvetprofessional.com (2015)

Figure 7. Up Lighting in a Museum

iii. Front Lighting

Front Lighting is widely used because of its important merits. As highlighted by Figure 8, although it tends to make the topic look flat because it generates apparent silhouettes behind exhibited artwork, it uniformly lights the thing and leaves an almost seamless replica of the object. When basic lighting is needed, this strategy is employed [11], [39], [50], [56]. For effective use of front lighting, diffusion is advised to avoid wastage and glare. Figure 8 shows how front lighting was used in an art gallery.

Source: Dr. Thomas Schielke, ERCO (2018)

Figure 8. Front Lighting in an Art Gallery

iv. Side Lighting

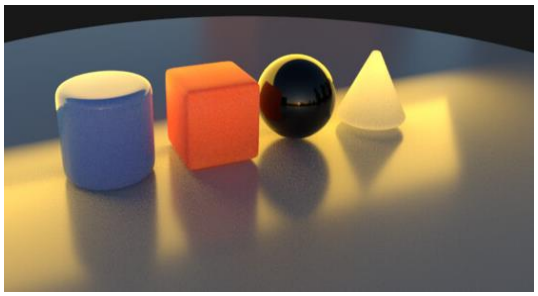
Using light at an approximately 45° or 90° angle as shown in Figure 9, this strategy illuminates one side of an item while darkening the other. Although side lighting is less common since it generates glare near the eyes, it significantly aids in defining the contour of the displayed works in three dimensions [50], [53], [56], [57] as shown in Figure 9.

Source: Simon (2022)

Figure 9. Side Lighting in a Museum

v. Backlighting

A strategy for illuminating an item with less light is called backlighting as shown in Figure 10. The main purpose of backlighting encircling or going through an object from behind is to emphasize. This adds depth to the displayed artwork, and a silhouette is produced by bright lighting. Additionally, it can be used to give off a grander appearance [11], [50], [56] as shown in Figure 10.



Source: Carlos Lemos (2022)

Figure 10. Backlighting in an Art Gallery

2. Materials and Methods

The target of the study was to investigate lighting strategies employed in selected art museums and galleries. To achieve this, a qualitative research approach was considered apt and adopted. An observation guide developed for the study was used to gather data. A digital camera was also used to gather images of the lighting strategies employed. Among all the art museums and galleries found in the study area, only three of them allowed the researchers full access to collect data. The three buildings that constitute the sample size and their locations are shown in Table 1.

Table 1. Selected Art Museums and Galleries in Nigeria

SN	Selected Museum and Galleries	Location
1	Discovery Museum	Wuse II, Abuja
2	Nike Art Gallery	Lekki, Lagos
3	Thought Pyramid Art Centre	Wuse II, Abuja

The observation guide developed for the study was divided into three (3) sections. The first section was used to gather data on the typical characteristics of the buildings. The second part was used to collect data on the lighting categories used in the buildings. The third section was used to gather information on the lighting strategies used in the art museums and galleries. The data were analyzed using content analysis and presented descriptively in themes with the aid of tables and plates for easy comprehension and clarity in the following sections.

3. Results and Discussion

The study investigated both natural and artificial lighting strategies employed in display areas of the three selected

art museums and galleries. The findings are presented in the following sub-sections.

3.1. Building Characteristics of the Selected Art Museums and Galleries

3.1.1. Discovery Museum

The Discovery Museum, also known as Art Tech District (ATD) is situated in Wuse II, Abuja. It is the first technology-focused theme museum in Nigeria. It features an impressive range of interactive, immersive, and enjoyable activities. The ATD creates a societal vision of Nigerian and international technology, art, science, and history all integrated into one creative area. The museum offers a wide range of educational activities, including the exploration of the facility, where visitors may participate in an interactive historical retelling utilizing the most up-to-date technology. Plate 1 shows a display area in the Discovery Museum [58].

Plate 1. A display area in the Discovery Museum

3.1.2. Nike Art Gallery

The Nike Art Gallery is located outside of the city of Lagos in the suburb of Lekki. It is a massive 5-storey structure covered in 8,000 distinct works of art. Access to the enormous structure, which is reputed to be the largest gallery in West Africa, is free. The gallery is used to frequently exhibit various well-known up-and-coming African artists. The gallery is well known for its adire, batik, indigo, drumming, beading, painting, carving and metal works. Plate 2 shows a display area in the Nike Art Gallery.

Plate 2. A display area in the Nike Art Gallery

3.1.3. Thought Pyramid Art Centre

The Thought Pyramid Art Centre is a spectacular art gallery located in Wuse II, Abuja. It has a roomy, open layout that holds many pieces of artwork for display across two floors. The collection, preservation, and research of modern and contemporary works of art from Africa and the African diaspora are the goals of the Thought Pyramid Art Center. Plate 3 shows a display area in the art museum. The building characteristics of the three art museums and galleries are displayed in Table 2.

Plate 3. A display area in the Thought Pyramid Art Gallery

Table 2. Building Characteristics

SN	Description	Art Museums and Galleries		
		Discovery Museum, Wuse II, Abuja	**Nike Art Gallery, Lekki, Lagos**	**Thought Pyramid Art Centre, Wuse II, Abuja**
1	Building Configuration	Rectangle	Rectangle	Rectangle
2	Building Storey	2-Storey Tall	5-Storey Tall	2-Storey Tall
3	Ceiling Construction Material	Wood	Wood and R. Conc. Slab	Wood
4	Walls Construction Material	Corrugated Wall Panels, Wood	Concrete Hollow Blocks	Concrete Hollow Blocks
5	Floor Construction Material	Metal panels	150mm R. Conc. Slab	150mm R. Conc. Slab
6	Interior Ceiling Finish	Aluminum and Wooden Finish	Matte Paint and Wood	Plaster of Paris
7	Interior Wall Finish	Wooden Finish	Matte Paint	Paint
8	Interior Floor Finish	Wooden Finish	Ceramic Floor Tiles	Ceramic Floor Tiles
9	Exhibition Type	Travel Type	Travel Type	Travel Type
10	Ceiling Interior Colour	Black, White, Green, and Cream	White and Brown	White
11	Wall Interior Colour	Green, White, Orange, Cream, Black and Brown	White	White
12	Floor Interior Colour	Brown	White	Cream

3.2. Lighting Categories in the Display Areas

Tables 3 and 4 are presentations of the lighting categories found in the display areas of the three art museums and galleries. Table 3 shows the daylighting systems, while Table 4 is a presentation of the artificial lighting types.

Table 3. Daylighting Systems in the Display Areas

SN	Natural Lighting Systems	Art Museums and Galleries		
		Discovery Museum, Wuse II, Abuja	**Nike Art Gallery, Lekki, Lagos**	**Thought Pyramid Art Centre, Wuse II, Abuja**
1	Windows	—	✓	✓
2	Skylights	—	—	—
3	Lay Light	—	—	—
4	Atrium	—	—	—
5	Translucent Walls	—	—	—
6	Light Tubes	—	—	—
7	Courtyards	—	—	—

Table 4. Artificial Lighting Types in the Display Areas

SN	Artificial Lighting systems	Art Museums and Galleries		
		Discovery Museum, Wuse II, Abuja	**Nike Art Gallery, Lekki, Lagos**	**Thought Pyramid Art Centre, Wuse II, Abuja**
1	Ambient Lighting	✓	—	—
2	Decorative Lighting	✓	—	✓
3	Spotlighting	✓	✓	✓
4	Accent Lighting	✓	—	✓
5	Wall Washing	✓	—	—
6	Dimming	✓	—	—
7	Floodlights	✓	—	✓
8	Beam Angles	✓	✓	✓

The data in Tables 3 and 4 indicate that the Discovery Museum made use of only artificial lighting without any form of natural lighting. But Nike Art Gallery majorly made use of artificial lighting which is supported by daylighting from windows in the display areas for metal works. Likewise, the Thought Pyramid Art Centre employed the artificial lighting supported by daylighting in major display areas with the aid of large windows. In the Nike Art Gallery where the use of artificial lighting is prominent, eco-friendly fluorescent lamps were the source of artificial lighting employed. The Discovery Museum which made use of only artificial lighting, employed diverse artificial lighting strategies that helped to minimize visual discomfort and highlight the displayed works to give them distinct identities.

3.3. Lighting Strategies in the Display Areas

Tables 5 and 6 show the lighting techniques identified in the three art museums and galleries. Table 5 shows the daylighting strategies, while Table 6 is a presentation of the artificial lighting strategies.

Table 5. Daylighting Strategies in the Display Areas

SN	Daylighting Strategies	Art Museums and Galleries		
		Discovery Museum, Wuse II, Abuja	Nike Art Gallery, Lekki, Lagos	Thought Pyramid Art Centre, Wuse II, Abuja
1	Direct Lighting	—	✓	✓
2	Sunspace	—	—	—
3	Sun Tempering	—	✓	✓
4	Combined System	—	✓	✓

Table 6. Artificial Lighting Strategies in the Display Areas

SN	Artificial Lighting Strategies	Art Museums and Galleries		
		Discovery Museum, Wuse II, Abuja	Nike Art Gallery, Lekki, Lagos	Thought Pyramid Art Centre, Wuse II, Abuja
1	Down Lighting	✓	✓	✓
2	Up Lighting	✓	—	—
3	Front Lighting	✓	—	—
4	Side Lighting	✓	—	—
5	Backlighting	✓	—	—

As earlier established, the data in Table 5 shows that no daylighting strategy was used in the Discovery Museum. The museum featured only artificial lighting strategies that are aesthetically pleasing. The strategies are down lighting, up lighting, front lighting, side lighting and backlighting as shown in Table 6. The use of diverse artificial lighting strategies helped to accentuate the displayed works. The kinds of lighting devices used are the manually controllable types as shown in Plates 4, 5 and 6.

In the Nike Art Gallery, the use of both natural and artificial lighting strategies was employed though the artificial strategy is more prominent. This makes the daylighting technique a supporting strategy as indicated in Tables 5 and 6 and shown in Plate 7. The direct and sun-tempering daylighting strategies were the two natural lighting techniques discovered in the gallery, which indicates that a combined daylighting system was utilized in the display areas as indicated in Table 5. The artificial lighting strategy employed is the down lighting type as shown in Plate 8. The use of both natural and artificial strategies was observed to be effective and energy-conserving.

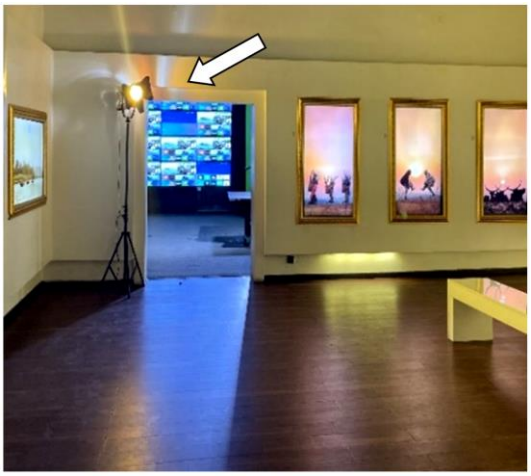


Plate 4. Front lighting in a display area of the Discovery Museum

Plate 5. Side Lighting in a Display Area of the Discovery Museum

Plate 6. Up Lighting in a Display Area of the Discovery Museum

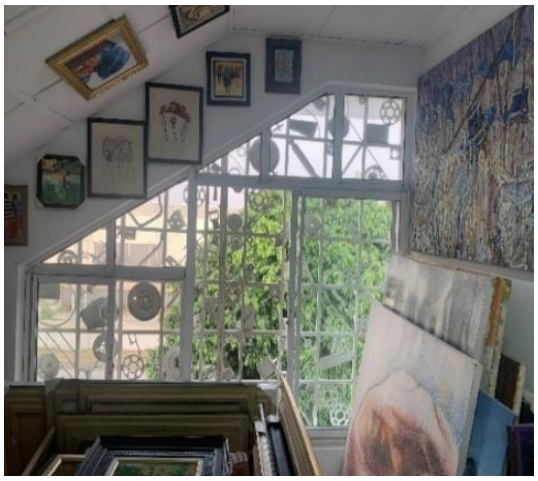


Plate 7. Direct Lighting in a Display Area of the Nike Art Gallery

Plate 8. Down Lighting in a Display Area of the Nike Art Gallery

In the Thought Pyramid Centre, both natural and artificial lighting strategies were also employed as indicated in Tables 5 and 6. For natural lighting, direct lighting and sun tempering strategies were the techniques utilized using large windows to admit sunlight during the

day. This helps to reduce the energy demand for lighting as the full potential of the natural lighting from the sun is utilized. The only artificial lighting strategy used in the gallery is the down lighting as shown in Plates 8, 9 and 10. In general, artificial lighting strategies in this gallery are prominent, however, the seamless use of daylighting techniques to support the artificial strategy is observed as an effective sustainable intervention.

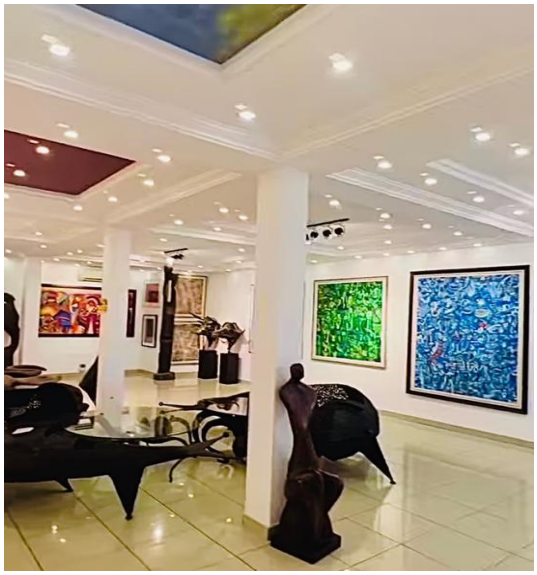


Plate 9. Down Lighting in a Display Area of the Thought Pyramid Centre

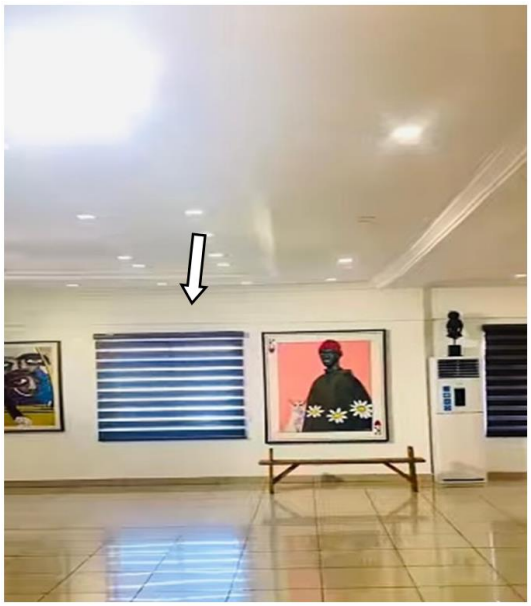


Plate 10. Direct and Down Lighting in a Display Area of the Thought Pyramid Centre

3.4. Discussion

The study investigated the lighting strategies employed in three selected art museums and galleries in Nigeria and found that artificial lighting strategies were mostly utilized in the display areas with daylighting techniques used in a few areas as supportive measures. Five artificial lighting strategies (down lighting; up lighting; front lighting; side lighting; backlighting) and four daylighting techniques (direct lighting; sunspace; sun tempering, and combined system) were identified in the display areas. The findings buttress the general belief that the utilization of daylighting strategy is a common concern in museum and gallery design as observed by Onuwe *et al.* [41] and Al-Sallal *et al.* [42].

Specifically, it was observed that in the Discovery Museum, only artificial lighting strategies were used in the display areas without any form of daylighting. This is considered not sustainable, due to the high demand of energy that will be required to power the lighting devices to always keep the artworks at a presentable level for visitors to the gallery. On the other hand, both the Nike Art Gallery and the Thought Pyramid Centre employed daylighting and artificial lighting in their display areas. However, the daylighting techniques are less prominent and were only used to support artificial lighting techniques. Nevertheless, the use of both strategies is considered necessary for achieving environmental sustainability regarding energy supply. In the Nike Art Gallery, the main artificial lighting technique used is the down lighting strategy that makes use of fluorescent lamps which require less power to operate. However, the almost complete dependency on artificial lighting for the display areas is most likely to eventually result in high energy demand and an increase in greenhouse gas emissions, which negates the target of environmental sustainability.

According to Udomiaye *et al.* [26], Nikoofam and Mobaraki [32], Wilson [33], Richardson [59], Womeldorf [60], Elijah [61] and, Altan *et al.* [62], the essence of environmental sustainability lies in enhancing human well-being while mitigating the repercussions on the Earth's essential ecosystems. To achieve environmental sustainability, the use of passive design is usually encouraged. The passive design makes optimal use of renewable energies such as daylight from the sun and ventilation generated naturally from the surroundings. Given the ease with which data can now be measured and recorded, the application of daylighting strategies and eco-friendly artificial lighting strategies is now feasible and highly desirable.

It is important to note that some artworks such as oil paintings, textiles, naturally occurring dyes, wood bone and Ivory, fur, and feathers are light sensitive and are prone to damage. Therefore, it is necessary to be meticulous in applying daylighting and artificial lighting strategies in the display areas of art museums and galleries. Also, as highlighted by Onuwe *et al.* [41], and Richardson [59], it is important to note that artificial lighting's high energy demand and negative impacts on displayed works and the environment are cumulative. The actual measure of light's influence is the total amount of exposure over an extended

period. Therefore, to achieve environmental sustainability in art museums and galleries, it is equally important that some lighting criteria are met. They include prolonged artwork shelf life, cost-effectiveness, reduced energy demand, and reduced energy waste.

The selected art museums and galleries typically utilized the two most common artificial light sources which are incandescent and fluorescent bulbs, both of which are inefficient energy sources. The Thought Pyramid Centre successfully combined the use of both day and artificial lighting strategies towards achieving environmental sustainability. From available studies by Asif ul Haq *et al*. [58], Al-Ashwal and Hassan [63], Asif ul Haq *et al* [64], and Yavuz *et al.* [65], 40% - 50% of the energy demand for lighting is reduced if artificial lighting is reduced or not used during peak sun hours.

In general, there exists an inadequacy in implementing sufficient measures in the majority of display spaces to ensure the optimal utilization of daylighting strategies though attempts were made to incorporate daylighting strategies. The prominent lighting strategies used are daylighting strategies (direct and sun tempering), and artificial lighting strategies (down lighting and front lighting). The findings indicate that the integration of a direct daylighting approach presents potential rewards, particularly when effectively synergized with artificial lighting strategies in display areas. Such contribution also contributes to diminishing reliance on artificial lighting systems, thereby aiding in the reduction of electricity consumption by up to 50%, thereby serving as a useful tool for achieving energy conservation and enhancing environmental sustainability in agreement with the positions of Singh [12], Maddox [14], Kunwar [37], One Green Planet [38], Fernández and Besuievsky [39], Mirrahimi *et al.* [49], Asif ul Haq *et al.*[58], Al-Ashwal and Hassan [63], and Yavuz *et al.* [65].

4. Conclusions and Recommendations

The study investigated the lighting strategies employed in the display areas of three selected museum and galleries in Nigeria, with a view to ascertain how effective they are in achieving energy conservation, towards attaining environmental sustainability in the development of the built environment. The findings indicated that though the display areas situated in the Discovery Art Museum utilized only artificial lighting strategies, those found in the Nike Art Gallery and Thought Pyramid Art Centre, made use of both daylighting and artificial lighting techniques. This goes to show that most of the display areas in the selected art museums and galleries made use of both daylighting and artificial lighting strategies in their exhibition areas. The adoption of an integrated lighting system contributes to the mitigation of artificial energy consumption within the display areas. thereby helping to contribute to improving the sustainability level of the energy supply of the buildings.

However, because the daylighting strategies were used just as support measures and not as the main lighting mediums, the contribution they made to the reduction of the artificial energy consumption of the display areas, is considered not significant enough to bring about a noticeable reduction in the energy consumption level of the selected art museums and galleries. Nevertheless, the idea of utilizing a combined lighting system should be encouraged in the design and development of display areas in art museums and galleries. It is recommended that in utilizing the combined lighting system, efforts should be made to increase the use of the daylighting strategies to the level that can cause a significant reduction in the use of artificial lighting in the display areas, especially where artworks not affected by sun rays from daylighting are exhibited. Also, with the identified artificial lighting strategies, the use of safe lightings such as eco-friendly fluorescent, light emitting diode (LED) and high-intensity discharge (HID) lamps should be a widespread practice and should be meticulously monitored by a lighting-controlled system (observers' sensors, photosensors and motion detectors) to encourage sustainability.

It is acknowledged that the few art museums and galleries used for this study constitute a limitation. The nature of the museum and galleries investigated also constitute a limitation. However, the limitations do not in any way diminish the contributions to knowledge of the study which include identifying the lighting strategies used in the display areas of the selected art museums and galleries; and provision of empirical evidence to support the extent to which the lighting strategies help to improve energy conservation and sustainability level.

Given the limitations of the study, similar studies should be conducted to investigate other types of museums and galleries. Studies on users' satisfaction levels with lighting strategies employed in exhibition spaces should also be conducted to pinpoint areas for improvement of users' experience.

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Conflict of Interest

The authors declare no conflict of interest.

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