



## HARNESSING THE USE OF DAY LIGHTING AS A MEANS FOR ENERGY SAVING TECHNIQUES IN ART MUSEUMS

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Adeniji, Philip A, and Imaah Ono Napoleon  
Department of Architecture  
Rivers State University, Nkpolu- Oroworukwo, Port Harcourt, Nigeria  
Email: [gentle619@gmail.com](mailto:gentle619@gmail.com)

### ABSTRACT

Museums are places of natural and human creativity as well as history. The aim of museums is to provide examples of each classification available for a field of knowledge. Museums employ two main strategies for its lighting which includes: daylighting and artificial lighting. This study was able to identify and discuss the different daylighting systems, and the existing museums which used daylighting were analysed properly to see how daylighting was harnessed in their respective internal spaces. The research methodology used for this research work includes case studies and extensive literature reviews. Deductions from these case studies showed the various natural lighting techniques used which include clerestory windows, luminous ceilings and cove luminaires. All of these played a major role in harnessing daylight in the museums studied. In the course of research, Lighting is significant in museum artifact display, as it helps with the interaction between the artifact and the human in a defined space. Daylighting, as it is significant to the artifact, if not properly controlled, can cause discomfort in the eyes of the observer, at the same time be destructive to the objects on display. Other methods used for introducing daylighting into the spaces include the use of diffuse lighting through Luminous ceilings, skylights, cove luminaires and also clerestory windows which help light reflects deeper into the exhibition halls. The design parameters and considerations indicate that buildings using these methods use less energy to lighten up their spaces, at the same time improving visibility and appreciation of artifacts.

**Keywords:** Museums, Artifact, Day lighting, Energy saving, Cove luminaires, Luminous.

### INTRODUCTION

Lighting is a major factor to consider when it comes to museum design as it is the only means which artifacts can be viewed well, either artificial or natural lighting. Designing museums and introducing daylighting into its interior spaces has been a necessity. From research, it is becoming clearer the use daylighting in museum designs without causing any visual interference to the museum visitors. The state of the economy has

been a major reason why most building owners would want to take on the challenge of using daylighting to light up their buildings. Research has shown that a good daylighting design can save up to 75% of the energy used for artificial lighting in a building (Kozlowski, 2019). More so, the demand for lighting comes during the peak hours of the day, thus a building with good daylighting effect would reduce the demand for artificial light thereby saving energy. According to (Hunt, 2009), Lighting is a critical component in a museum environment because the space enables visitors to see objects, experience new sights and react to the surrounding environment. Typically, environments have two sources of light; natural and artificial. For a museum, the role of light is an essential part of creating an atmosphere prime for phenomenological experience, while also preserving artifacts. This can be a challenge, a balancing act between preservation needs and the formation experiences that achieve the goal of the museum—a place to discover, explore and learn.

The word museum was defined by (Edward Porter Alexander, 2007), as an establishment that conserves an accumulation of antiques and different objects of creative, social, historical, of scientific significance: which make the curio for open review. According to (Babian, 2002), museum functions shift from organization to organization. Some prefer training over preservation, or vice versa. For instance, during the 1970s, the Canada Science and Technology Museum favoured training over method of conservation of items. Objects on display could be shown as perpetual or brief. Most extensive museums are situated in major urban communities all through the world. Be that as it may, neighbourhood museums exist in littler urban areas, towns and even in the wide open. Museums have contrasting focuses, going from serving researchers and specialists to serving the general populace. It was observed that as at 2010, the proceeding with increase in the digitization of data, together with the stretching limit of computerized data stockpiling, is making this conventional type of museums expand to accommodate virtual display and higher resolution images of their findings that benefactors can observe, consider, and investigate from wherever with the Internet. (Definitions and Translations, 2019)

This research is motivated by the need to cut down on energy consumed by buildings and due to the energy problem in the country over the years with much been spent and the outcome still remains poor, this paper is expected to look at various ways by which natural light can be maximized in the museum. This paper will also look at the concept of how daylighting can be used as an alternative method for energy saving devices in museum spaces without deteriorating effect on the artifacts which at the same time will not distort the objects on display.

### **Objectives**

To achieve the above-stated aim, these objectives are generated:

- To identify and discuss different daylighting systems.
- Case study of existing museums showing/discussing how Daylighting had been harnessed in their respective internal spaces.
- To adopt various means of Architectural designs, that will be used to introduce diffuse lights into the exhibition areas.

### **Statement of Architectural Problems**

The lighting system of a museum is a complex issue. The design will look at how to increase natural light and also how to decrease artificial light within the museum. These problems can be expanded into: The various lighting options that can be used to aid proper display of artifacts, through proper lighting effects on exhibited artifacts. Proper lighting methods and measure will enhance the resolution of these problems. This article adopts both primary and secondary method of research, which involves review of data that were already available elsewhere, and were collected for comparison and inference purposes. For this study, the case studies include Broad Art museum California and Modern Art museum of Fort Worth. The data were used for comparisons, inferences and projections for the study most especially in the area of daylighting, planning and space allocations.

### **LITERATURE REVIEW**

The most obvious vehicle for energy saving in buildings is in exploiting the most abundant source of light available to us –

daylight. "There is a growing acknowledgement that daylight produces positive effects, both physical and psychological" (Mardaljevic J., 2002,) According to (Gregg D. Ander, 2016) Daylighting is the bridge way of admitting natural light, direct sunlight and diffused light into a structure, to diminish the use of electric light and saving energy. With the need to amplify visual solace and utilize less vitality, daylighting is significantly considered. In architecture, daylighting alludes to the utilization of regular light, be it splendid daylight or muted cloudy light, to help the visual requests of the museum visitors.(Wymelenberg, 2014)

Research has shown according to (Reinhart, 2014) that the amount and quality of daylight in a space is proportional to the impact of direct light to diffuse light. Artificial lights were used as a supplementary to natural lights in buildings in 1940s. It tends to be seen that artificial lighting has changed the working environment by meeting the greater part of or the whole inhabitant's lighting necessity in a limited capacity to about 20 years. Starting late, energy and natural concerns have made natural lighting a rediscovered piece of structural lighting plan. Natural lighting is much of the time fused into structure as a design statement as well as energy saving means.(Chaudhary, 2014). It is observed that visibility and accessibility in a museum space depends on light levels. Light measurements in museum are controlled by the display type, gathering, stockpiling, and care. In the IESNA's required light dimensions, collection amassing is 53.81 Lux and collection gathering is 215 to 538 Lux. The sort of old rarities in the museum is a basic detail to develop the proportion of light measurement and light prologue to the exhibits. The general focus in a chronicled museum lighting design is to light individual artifacts with thought to the affectability of the objects and how museum visitors will see them. More sensitive objects require Lux going from 53 to 538, while sensitive objects have between 161 to 215 Lux. Less sensitive objects could have 322 to 538Lux(De Chiara, 2007).

### **Natural Lighting in Museum**

It is observed that light substantially affects the view of room and upon passionate reaction of visitors to the museum. Thus, lighting

is one of the components used in managing the space quality in a museum. It is likewise an essential component for the expression of a space.(Chaudhary, 2014). (Chaudhary, 2014), further stated that museum lighting is exceedingly hypothetical, because the nature of light is crucial. The necessities of lighting display shift with the capacity of the space, type, and size of the works and designs to be displayed. The kind of lighting utilized for two-dimensional and three-dimensional articles are unique. The best possible lighting framework is utilized by relying on the sensitivity of the material. Additionally, the lighting display has both the physiological and mental needs to be satisfied so it is ideal to mix both the sources (2D and 3D) to get alluring and helpful light.

“The primary goal of lighting design and installation is to create an optimum condition for viewing objects” as stated by (Shaw, 2001). Illuminating the object is the first basic requirement in museum lighting design. In this manner, it's critical to comprehend the general idea driving the exhibition before planning the lighting system for the museum. Emotional impacts can be made by the utilization of changing types of light, which can defeat the dull and repetitive museum conditions. The measure of light and its quality in a display ought to be in connection to the differences such as: glare, shading impacts, shade of light and luminance of the room.

### **Techniques for Natural Lighting**

#### **Luminous Ceiling**

The study reveals that the possibility of radiant ceiling comes from a craving to impersonate light. Luminous ceiling convey light, which is especially reasonable for painting displays – dominantly diffuse with an oval fenced in area, halfway directional with walled in areas of finished glass. The warmth that is created in any radiant ceiling should be disseminated or removed.(Armas, 2011). Research further shows that the light sources of choice are cylindrical fluorescent lights arranged according to the structured grid of the luminous ceiling. The extent of the luminous ceiling, its subdivision and the advances among ceiling and walls need to suit the extents of the room and the idea of the items showed.(Good lighting for museums galleries and exhibitions, 2000). (Armas, 2011), stated that

luminous ceilings imitating natural daylight need to deliver a high level of luminance: 500...1,000 cd/m<sup>2</sup>, ranging up to 2,000 cd/m<sup>2</sup> for very high-ceiling rooms. Luminous ceilings are especially suitable for interiors with 6-meter ceilings or higher. Where room heights are lower, their light can astonish, on the grounds that they possess a huge piece of the field of vision. Where the lighting is diminished for preservation reasons or to decrease glare, the luminous ceiling loses its sunlight quality and looks dark and oppressive. Therefore, the research has established there is a proportion between the room height and the amount of daylight in a space.

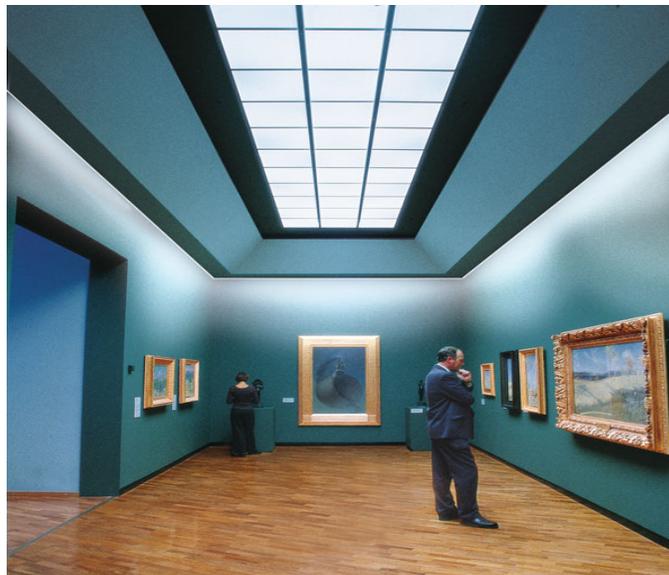


Figure 1: Luminous ceiling allowing daylight into a painting gallery.

### Cove Luminaires

(Armas, 2011), states that the diffuse light of luminaires introduced in the bending progress among walls and ceilings—the bay or coving – is another indirect lighting arrangement. The inlet luminaires most much of the time utilized in modern museum structures are models with housing, which themselves form the coving. The fundamental course of light with bay lighting is nearer to the level than with a luminous ceiling and compares generally to that of edge illuminating presences mounted in nonstop rows, the light is to a great extent without shadow.(Good lighting for museums galleries and exhibitions, 2000). Over the top luminance at the ceiling and on the upper

piece of walls, causes glare and meddles with spatial experience. This can happen in bays where no means are taken to give optical control. (Armas, 2011). Therefore, the research has established that the proportion of height for cove luminaires is less compared to that of luminous ceilings.



Figure 2: Cove luminaires used to bring diffuse light at Kumu art museum.

## Window

There are various ways today to arrange light and "lock out" direct sunshine even in room with lateral windows. Windows decline the proportion of wall space for shows. Undirected and unfiltered scene light through window can give reflections on display walls. (Chaudhary, 2014). Chaudhary further stated that from various perspectives, windows are the most problematic sunshine introducing building form. Regardless of whether illuminance is controlled, the outside view will constrain the eye to adjust to luminance a lot higher than the showed material.

## REFLECTED LIGHT TECHNIQUES

### ➤ Clerestory Windows

(Craven, 2018), states that clerestory windows can either be large window or series of small windows along the top of a building's wall, which are usually close to the roof line. She further stated that designers who love to maintain wall space, interior privacy and still maintain a well-lighted room often uses clerestory windows as they are used to naturally illuminate large spaces. According to (Wright, 1954), "The best

way to light a house is God's way – the natural way..." According to Wright, the best natural way, is to place clerestory windows along the southern exposure of a building, as the windows serves as a lantern to the house.



Fig. 3: Clerestory windows used to avoid glare in gallery

#### ➤ Light Shelves

According to (Darling, 2019), "A light shelf is an even reflective surface, at or above eye level, utilized both to latently channel common daylighting into an involved space and give shading". (Penny, 2017) further stated that, **interior light shelves** divide fenestration openings between the distinguishable segment and the part that lets in extra regular light, reflecting it upward and reflecting it off the ceiling to give sunlight a chance to infiltrate further into the space. Thus, the use of light shelves in museum interior spaces not only give more wall space for display, but also aid illumination of deep interior spaces.

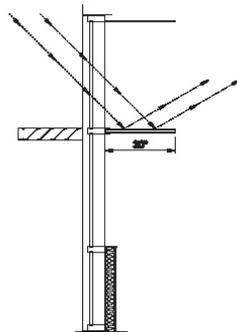


Fig.4: Light shelves used for optimal daylight absorption

## Findings and Discussion

Case studies were conducted on existing art museums and the results of such studies are analyzed chapter. The case studies emphasized different lighting techniques geared towards achieving optimal viewing in exhibition galleries.

## Selection of the Study Areas

For instance, the broad art museum California and the modern museum of Fort Worth were chosen as case studies based on the research topic as well as meeting the functional requirements of the spaces within a museum.

## Case Study 01: Broad art Museum, California



**Figure 5: Broad Art Museum Façade**

Source: <https://broadfoundation.org/los-angeles-new-contemporary-art-museum>

**Architect:** Ricardo Scofidio and Charles Renfro

**Location:** 221 South Grand Avenue, Los Angeles, CA 90012, United States

**Floor Area:** 11,148m<sup>2</sup>

**Construction:** September 2015

### **Background History**

According to (Eli and Edythe Broad Foundation, 2018), The Broad art was a long-time art collectors and philanthropists Eli and Edythe Broad. Its curated exhibitions are drawn from one of the world's most famous accumulations of contemporary art. Located across the street from Walt Disney Concert Hall, The Broad's museum is home to about 2,000 works of contemporary art housed inside the museum, (Eli and Edythe Broad Foundation, 2018).

### **The Building**

According to (Kiser, 2012) the broad museum was Dubbed "the veil and the vault," this design combines the two key projects of the structure which are: open show space and the capacity that will bolster The Broad Art Foundation's extensive lending activities. From the lobby, a –105-foot-long—escalator threads through a narrow-sloped tunnel. The "veil" would be a light-filtering exoskeleton, loosely wrapping the opaque vault, with public areas in between—which includes, atop the archive, a vast skylight gallery displaying selected works,(Architectural Records, 2018). The museum is designed to be flexible, whether the visitor ascends by escalator or the Jetson-like cylindrical glass elevator that rises like a rocket in its silo, all visitors will land at nearly the same spot. The overhead diagonal, glazed 9-foot-deep light scoop, slanted at 45 degrees is contoured for even, indirect illumination.

## Architectural Appraisal

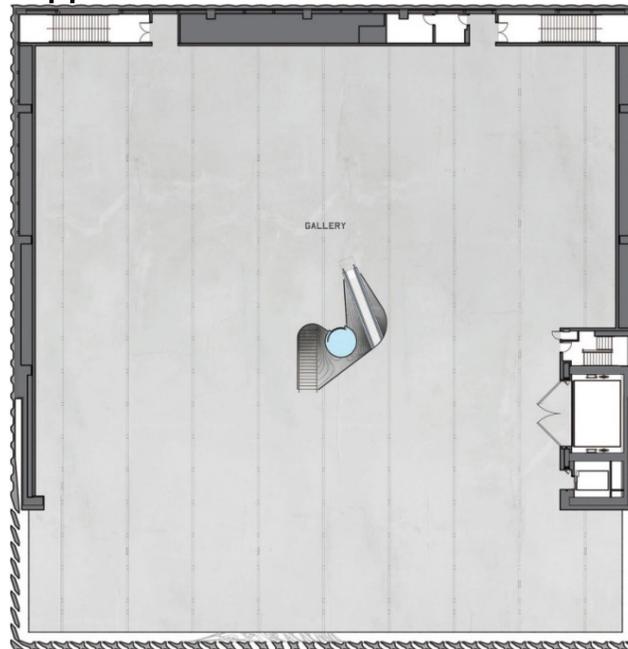


Figure 6: Third Floor Layout – Broad Art Museum

Source: <https://broadfoundation.org/los-angeles-new-contemporary-art-museum>

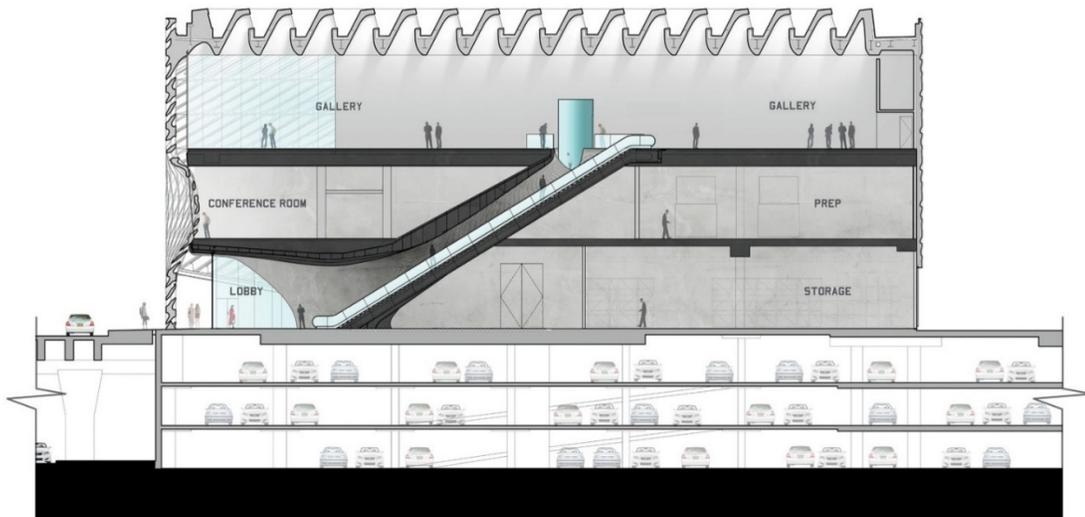


Figure 7: Cross Section – Showing how the gallery is lite from above

Source: <https://broadfoundation.org/los-angeles-new-contemporary-art-museum>



Figure 8: Gallery space – showing how diffuse light is introduced in the space  
SOURCE: <https://broadfoundation.org/los-angeles-new-contemporary-art-museum>

The advantages of Natural Lighting in this museum include;

- The museum uses natural lighting in its exhibition spaces as it can be seen from the materials used for construction and its design.
- The roofs skylight transfers diffuse light into the gallery space above which has no hazardous effect on the artifacts on display.
- Light intensity is controlled in the spaces with the honey comb shaped shell.
- The gallery space is dynamic as it can be tailored to any form required.

## Case Study 02: Modern Art Museum of Fort Worth



Figure 1: Perspective view. Modern Art Museum of Fort Worth

Source: <https://www.irvingtexas.com>

**Architect:** Tadao Ando

**Location:** 3200 Darnell Street Fort Worth, TX 76107

**Area:** 44354.4 sqm

**Building materials:** Concrete, steel aluminum, granite and glass

**Construction:** December 2002

### The Building

The works of the architect was exemplified through the simple geometry of the museum, and how it's incorporated into the natural environment. The Five long, flat-roofed pavilions appear to float atop the 1.5-acre reflective pond, which is a trade mark of Ando projects. The glass and water are very complimentary, as the still pond reflects the spaces just as glass reflects the water. (emmanuel, 2019). According to (Archdaily, 2019)"By using glass as a divider, physically there is an obstruction, an insurance all things considered, however outwardly, there is no limit between outside and inside. Light is reflected from the water through the glass which demonstrates an absence of limit and can make its quality felt on the divider." The Modern Art Museum of Fort Worth demonstrates the best level of accentuation on the limit; utilizing the materials to make an engineering that appears to drift on the lake that encompasses it. Light, likewise, ended up as key in the plan of the gallery, with spotlights on both diffused and reflected regular light. Cantilevered cast-solid rooftops bolster direct bay

windows and clerestory windows, which suit characteristic light. While the Five Y-shaped columns standing 40 feet high support the roof slabs, and have become an iconic element in the museum which accommodate more than 2,600 significant works of modern and contemporary international art in its gallery space, (emmanuel, 2019).

### Architectural Appraisal

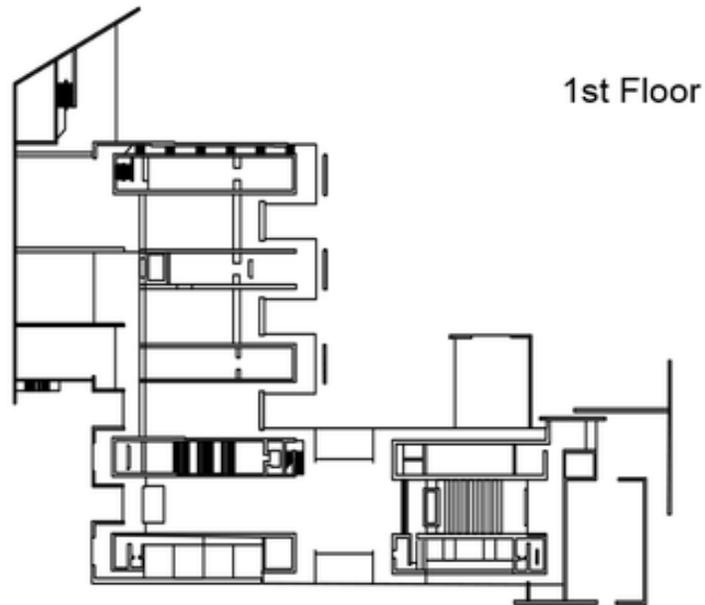


Figure 2: Floor Plans. Modern Art Museum of Fort Worth  
Source: <http://kemuelsarchistudio.blogspot.com>

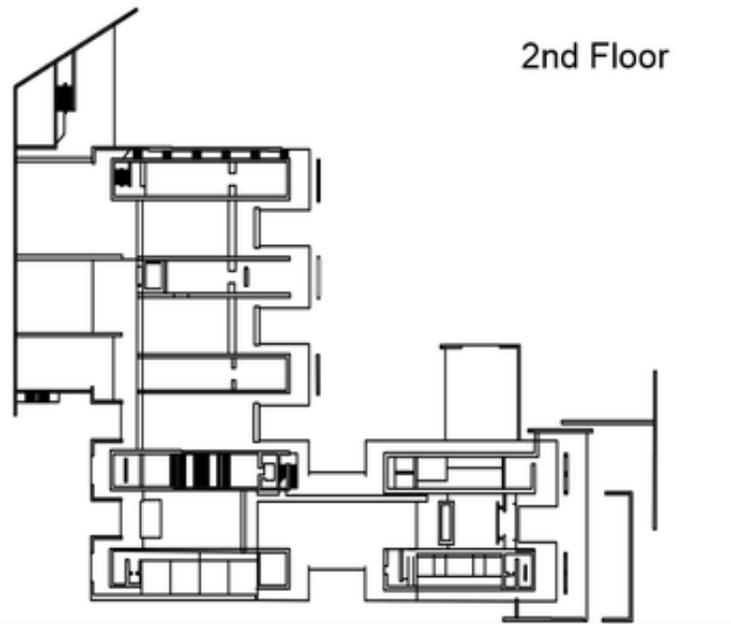


Figure 3: Floor plan. Modern Art Museum of Fort Worth  
Source: <http://kemuelsarchistudio.blogspot.com>

The advantages of Natural Lighting in this museum include;

- The still pond outside is used as a reflector to lighten the interior exhibition spaces.
- Clerestory windows are used in the museum which is a way of introducing more daylight into a space.
- The museum connects the exterior with the interior with the use of glass as its main boundary.
- The exhibition halls are well laid out and defined in a distinctive pattern.

All the museums studied solved one problem in so many ways and this makes each of them unique. The problem of lighting the galleries and exhibition halls were solved using various methods ranging from use of diffuse light to reflected lights, clerestory windows, skylights at angles that helps to distribute light evenly into the exhibition spaces and use of water as reflectors from the outside - inside the exhibition spaces.

## CONCLUSION AND RECOMMENDATION

The study was able to identify, discuss and subsequently the various ways of introducing daylight into the spaces without having any adverse effect on the artifacts. The analysis has shown

that problems associated with light use and control technique, as regards artifacts conservation and display are common concern in all museums. After much observation and discussions, it was revealed that measures should be put in place in considering the effective use of day lighting in museum particularly if it has not factor into consideration maximum daylight and minimum artificial light. Hence, with the use of daylighting in-view, it would be less expensive to achieve optimal lighting by retrofitting. These are issues that the article tried to tackle by suggesting the following recommendations.

- Efforts should be made by the Architect to ensure that day lighting design is achieved and integrated at all design stages and contribute to the design and construction process.
- To encourage architects to design museums with much considerations of daylight concept instead of shy away from it and looking for alternative artificial means.
- Relevant bodies or authorities should allow for museum designs as purpose made not as a make shift building or structure.
- Lighting is an important issue in building and this article has shown how energy usage in form of lighting the spaces can be minimized in building, by introducing natural lighting into the spaces.

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