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# Optimization Of Natural Light for Visual Comfort in The Design of a Museum in Sokoto

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***Abstract-*** ***This research studied the role of natural light in museum architecture, with a specific focus on Sokoto, considering its diverse heritage. The research aim was to optimize natural lighting for visual comfort in a museum design in Sokoto. The research adopted a methodology, combining qualitative and quantitative approaches, including case studies and climate-based daylight modeling (CBDM) simulations. Findings from case studies at Gidan Makama Museum in Kano and the Cyprian Ekwensi Centre for Arts and Culture revealed challenges in landscape, orientation, openings, materials, and daylight conditions. In conclusion, the research contributed to sustainable and visually comfortable museum design practices, providing valuable insights for architects and designers. The chosen intervention model not only serves as a practical guide for future design considerations but also reflects a tailored approach based on the specific findings of the research.***

***Keywords: Optimize, Simulations, Design, Museum, Visual***

## I. INTRODUCTION

In the Nigerian context, there have been some notable studies that provide insights into the potential benefits and challenges of incorporating natural light into museum design. One of such study is by Oluwaseun and Odunola, (2021), where they conducted a survey of the natural lighting conditions in the National Museum Lagos, using a light meter and a questionnaire to evaluate the quality and adequacy of the lighting.

The study found that while natural lighting was present in some areas of the museum, it was insufficient in others, leading to a reliance on artificial lighting that may have negative impacts on the preservation of artifacts and energy conservation. According to MacLeod et. al (2015), Museums provide opportunities for the public to engage with artifacts, to gain knowledge, and appreciate the diverse cultures and history of humanity.

For example, the history of museums can be traced back to ancient civilizations, where kings and emperors used to collect rare objects and artifacts as symbols of knowledge gain and understanding of their wealth and power (Jetkins, 2018).

Bilovus (2022) further discussed the important educational and cultural centers that preserve and communicate the history, art, science, and culture of humanity. Despite their significance, museums face many challenges, therefore the need arose to balance preservation with accessibility and visual comfort as published by Finkelstein et. al (2022).

In essence, lighting, whether artificial or natural, is a crucial consideration in museum architecture. According to Chidi et. al (2022), in museum architecture, lighting is a very important parameter because it is among the items that manage and control the visibility of artifacts and users‟ visual comfort without altering its actual physical properties. It is on this note that Kaya and Afacan (2018) reemphasized on the importance of the issue of illumination in the context of daylighting and visual

Museums provide elements that foster peaceful co-existence and crosscultural connections that go beyond the diversity of the people. This research

therefore treats the in-depth of natural light and visual comfort, in design of museums, with a specific focus on Sokoto, considering its diverse heritage.

Overall, further research is needed to examine the potential benefits and challenges of daylighting optimization in museum design in Sokoto, and to inform sustainable design practices in the city's cultural institutions. By incorporating natural light into museum design, museums can create more sustainable, comfortable, and informative exhibit spaces that showcase Nigeria's rich cultural heritage to the world.

## II. RESEARCH METHODOLOGY

### Design Strategy

The goal of this research is to enhance visual comfort through optimization of natural light in the design of a museum taking into account the quantity of natural light in a museum gallery and reducing the likelihood of glare.

The study employed both qualitative and quantitative research methods. Case studies and quasi-experimental (simulation) research methods were used to help achieve the study's goal and purpose.

### Case studies research design

Case study research scientifically investigates into a real-life phenomenon in-depth and within its environmental context. Such a case can be an individual, a group, an organization, an event, a problem, or an anomaly (Burawoy, 2009).

Case studies provide useful information about previously designed buildings of a similar nature and allow one to learn from both the successes and mistakes of others. In this instance, it entails examining the current facilities in order to establish a foundation for recognizing current issues and various approaches to implementing daylighting in the architecture of the Art Museum.

It also entails identifying the different ways that natural light is integrated into the design as well as the kinds of collections housed within the museum. According to Oluigbo (2010), cases must have certain inherent qualities related to the phenomenon being studied in order for them to be identified. As a result, the following factors were used to choose the museums for the study:

### Case studies selection criteria

i. Access to the facilities
ii. Climatic zone of the proposed site for the research
iii. Presence of daylight architectural elements in the building.

### Sampling

According to Veal (2006), the purpose of a case study is typically taken into consideration when choosing cases for analysis, these cases are chosen because they can offer insights into the research problem.

Purposive sampling was used for the case studies selection based on the availability of daylight architectural elements, climate zone, and facility access due to the nature of the research. Three case studies from the tropical wet and dry climate regions were selected for the study using a purposive sample. The selected case studies are;

I). The Gidan Makama Museum, Kano
ii). Cyprian Ekwensi Centre for Arts and Culture, Abuja

## III. METHOD OF DATA COLLECTION

### Simulation software

Ecotect Software was utilized for the simulation. A base case model was simulated in three different scenarios applying all necessary physical characteristics while focusing on how to optimize natural light and its efficiency. Mostly use by architects and building engineers to enhance their design advancements, the software is embedded to the main Autodesk CAD architecture, fully compatible with Autodesk REVIT.

Research Studies on many existing buildings have been performed to evaluate its building's performance. It is related to its environment, especially on dealing with solar heat, its nature for day-lighting, natural airflow for ventilation, and its energy consumption for man-made systems such as Air Conditioning and Lighting (Trisnawan, 2018).

Validation Study

Validation exercise was carried out in order to test the research instrument, the reliability of the results and to test the capability of the researcher to handle the tools. These results were compared and assessed using the Mean Bias Error calculation by Reinhart (2009) to ensure the reliability of the results.

Expected Findings

Some of the expected findings of this research includes optimization of natural light on visual comfort in museums and proposed design of a museum.

in summary, this research is expected to reveal the multifaceted nature of natural light, shedding light on its diverse components and characteristics. Furthermore, it will make clear the profound impact of natural light on visual comfort within museum settings. Lastly, the research will climax in design recommendations for a proposed museum in Sokoto, emphasizing the effective utilization of natural light to elevate the museum experience while ensuring sustainability and preservation.

These findings collectively offer valuable insights for optimizing natural lighting in museums, ultimately enhancing visitor satisfaction and the overall museum ambiance.

## IV. ANALYSIS, FINDINGS AND RESULTS

In relation to the three research objectives of this study, this chapter presents and goes into detail about the research analysis, discussions, and findings. Findings and results from three case studies were recorded. The Gidan Makama Museum, Kano and Cyprian Ekwensi Centre for Arts and Culture, Abuja are the Case studies which are located in the tropical wet and dry climate region.

In both cases, the study's research questions one and two were examined, and three base cases were created in order to address research question which will eventually give guidance on the approach to be used during the architectural design.

The simulated illuminances, which were measured as a result of the field study of the current daylight situation at the Cyprian Ekwensi Center for Arts Culture, were analyzed. Autodesk Ecotect simulation software was utilized to obtain the simulated outcomes. Descriptive statistics were subsequently used to analyze the data.

According to Reinhart (2009), the mean bias error (MBE) values for validation simulation data must fall between -15% and 15% in order for them to be considered reliable. The features of the area to be simulated and its condition at the time the study was conducted are presented in Figures 4.1, 4.2 and Table.

1. Location; Cyprian Ekwensi Center for Arts and Culture,
2. Latitude 9.0217°N
3. Longitude 7.2907°E
4. Orientation; the building orientation is facing towards south west direction as captured from google Earth
5. fenestration type; side windows of size 3000x1200mm and window head heights of 2500mm.
6. Size and shape; the Art gallery is rectangular in shape with size of 7000x12900mm.
7. A working Plane of 900mm was used and the sensor points were selected and

Validation of measured illuminance

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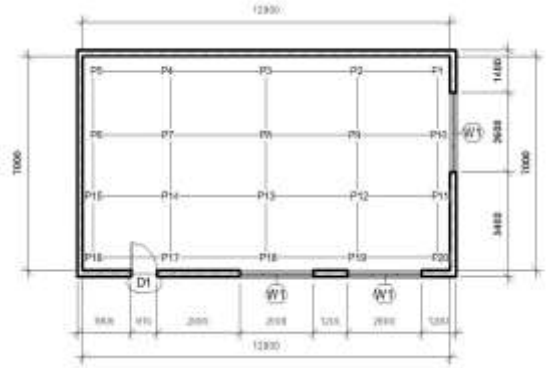

Figure 1: floor plan of art gallery showing sensor points

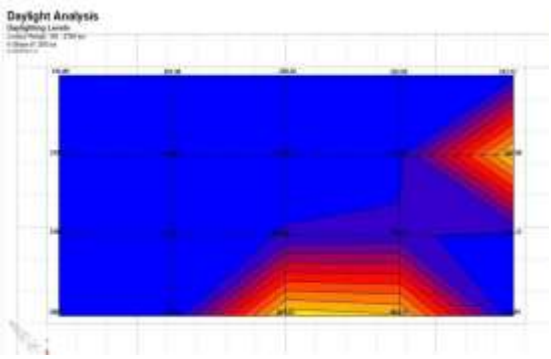


Figure 2: Simulated illuminances of Art gallery at Cyprian Ekwensi centre for arts and culture

Table 1: measured illuminance, simulated illumiance and their variance

| SENSOR POINTS | MEASURED LUX Xmea | SIMULATED LUX Xsim | DIFFERENCE (Xsim - Xmea) |
|---|---|---|---|
| P1 | 167 | 188.09 | 21.09 |
| P2 | 184 | 194.40 | 10.4 |
| P3 | 863 | 893.64 | 286.64 |
| P4 | 607 | 862.33 | -40.67 |
| P5 | 158 | 209.84 | 51.84 |
| P6 | 337 | 321.77 | -15.23 |
| P7 | 513 | 492.76 | -20.24 |
| P8 | 439 | 462.66 | 23.66 |
| P9 | 303 | 241.12 | -61.88 |
| P10 | 196 | 198.69 | 2.69 |
| P11 | 224 | 199.12 | -24.88 |
| P12 | 247 | 214.69 | -32.31 |
| P13 | 281 | 290.10 | 9.1 |
| P14 | 289 | 362.63 | 73.63 |
| P15 | 670 | 657.86 | 70.86 |
| P16 | 587 | 323.72 | -18.28 |
| P17 | 248 | 262.09 | 14.09 |
| P18 | 256 | 230.20 | -25.8 |
| P19 | 178 | 207.38 | 29.38 |
| P20 | 98 | 191.89 | 93.89 |
| AVERAGE ILLUMINANCE | 327.85 | 350.249 | **VARIANCE** |

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∑(Xsim-Xmea)

$\%MBE = \frac{100}{Xmea(av)\ N} \sum (Xsim - Xmea)$ where N is number of sensor points

The mean bias error (MBE) value which is 0.25% falls between -15% and 15%, as recommended by Reinhart (2009). This means the simulation is reliable and accurate, giving us confidence in the validity of the findings.


Figure 3: Chart showing Relationship Between measured and simulated illuminance

According to Chidi and Daminabo (2022), there are two main types of side-lighting openings which are windows and clerestories. Windows are a common and essential method for daylighting in various structures, offering light, views, and ventilation. In museum galleries, their historical use stems from the adaptation of museums into existing structures.

They stated that clerestories which are side openings placed at higher levels along walls are higher than eye level, they allow for deeper light penetration and reduce the likelihood of glare. The light distribution inside the space can be made consistent by combining clerestories facing opposite directions.

The average daylight intensity recorded was compared with provided standards for human visual comfort. Window to wall ratio of the intervention with the most suitable average intensity was adopted.

## V. FINDINGS FROM CASE STUDIES

In examining the dynamics of daylighting and visual comfort in museum spaces, the research focused on two distinctive cases: Gidan Makama Museum and the Cyprian Ekwensi Centre. Building orientation emerges as a critical factor influencing daylight access and glare control. Gidan Makama's building orientation neglects the potential benefits of maximizing daylight access and minimizing solar heating.

Despite the openings, improper consideration of orientation increases the risk of glare inside the building. The structure's shorter sides facing North and South, coupled with a slight orientation along the N/S direction, underscores the importance of careful orientation to control daylight effectively.

In contrast, the Cyprian Ekwensi Centre strategically orients its façade to the southwest, emphasizing a deliberate effort to admit natural lighting and facilitate ventilation into key areas such as the gallery and exhibition hall.
This southwest orientation aligns with a thoughtful approach to harnessing natural light, enhancing the overall lighting dynamics within the facility.

The choice of materials in museum architecture significantly influences visual comfort. Gidan Makama's architectural composition involves locally molded Tubali bricks, combining dry grass and red clay.

The red clay used for the interior finishing of art galleries results in low reflectance, causing an uneven distribution of daylight and interior darkness during the day. This adversely impacts the visual comfort of visitors. As for the second case study, which used modern construction materials, use of emulsion paint for the wall finishes as observed contributed to the low reflectivity of the walls, this made artefacts and other items on display not to be seen clearly thereby causing visual discomfort to users.

Openings play a crucial role in optimizing natural light conditions. Gidan Makama's interior primarily receives light through high-level windows made of timber, this contributes to varied natural light

conditions across galleries. The Cyprian Ekwensi Centre employs sliding windows ensuring the provision of brightness for users in some of the spaces.

Daylighting within museum spaces involves a complex interaction of architectural elements. Despite having a central courtyard design to maximize natural light, Gidan Makama museum encounters challenges with uneven daylight distribution, impacting visitor comfort in certain galleries.

There was an issue with the side lighting design in the gallery that received daylight, as one move away from the windows, there was a constant drop in light level. It appears that this building's daylight distribution is also impacted by the interior finishes. All of the galleries have average light levels between 3 and 603 lux. Comparing some of the galleries to the ISENA standard requirement for museum spaces, it is evident that some have good daylight design.

Some galleries have either too much or not enough natural light, which is uncomfortable for the eyes. Case study two observes natural lighting in exhibition room and art gallery. However, the art gallery experiences areas with low light intensity, potentially affecting visual comfort.

## VI. CONCLUSION

A simulation was carried out to optimised the visual comfort in the design of a museum in Sokoto. Two locations were used as case study namely, Gidan Makama Museum and the Cyprian Ekwensi Centre. Autodesk Ecotect simulation software was utilized to obtain the simulated outcomes.

The measured illuminance was compared against the simulated illuminance to obtained the optimal results.

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