

# Daylight Optimization in Reading Spaces in the Design of Architecture Library, Kaduna State University, Nigeria

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## Abstract

Daylight in a library is an intrinsic factor in teaching and learning spaces as daylight has been proven to stimulate the brain to stay active. However, too much daylight cause stress that affect assimilation. This study, therefore, examines and assesses the quality and quantity of daylight required for all learning spaces, according to International Energy Agency (IEA) using daylight elements to create variation in influx of lumen; with the purpose of combining manual and electronic study area. This case study is done Ahmadu Bello University, Zaria, Architecture Department Library using climate-based daylight modelling classification, in which Useful Daylight Illuminance (UDI) data are obtained from spaces with side lighting having daylight elements. Visual survey and quasi-experiment is done to test for the validity and reliability of the result, after which two daylight elements were introduced in the experiment and result taken intermediately. It is observed that the daylight performance metric of the Daylight Autonomy (DA) was influenced by the introduction of Daylight elements (DE) base on positioning and size of the windows and distance of the screen wall from the window opening. The combination of Centralised window (1100mm above floor level) and screen wall, 1200mm from the window opening resulted to 38.35% improvement in luminance. When centralised window (1100mm above floor level) was combined with screen wall at 900mm from the window opening, 36.76% improvement in interior luminance was recorded. The study shows that centralised window (1100mm above floor level) in combination with screen wall at 900mm is appropriate for redistributing light and improving luminance level in an interior space with other variable such as building orientation, window size, room reflectance, glazing type being the same. The readings from this research yielded a positive result and therefore were replicated in the design of the proposed faculty of architecture design in the Kaduna state University, Kaduna state.

**Keywords:** Daylight Autonomy, Daylight Elements, Daylight Illuminance Centralised Window, Daylight Performance.

## Introduction

Optimizing daylight in library reading spaces is crucial for user comfort and performance. Key design variables affecting daylight include window height and width coefficients, room height, glass transmittance, and orientation (Deng et al., 2022). A window-to-wall ratio (WWR) of 0.5 can provide effective daylighting up to 3% daylight factor within 4m of windows in deep interior spaces (Dahlan, 2005). Strategies for enhancing daylight in different library areas (e.g., private reading, group study, social spaces) should consider

their specific usage and daylight distribution requirements (Bakr & Nagy, 2020). In tropical regions, adding window openings, installing light shelves, and adjusting overhang length can optimize daylighting performance (Dianagri et al., 2021). Balanced daylight quality can be achieved with moderately large window height (0.7-0.8) and width (around 0.7) coefficients, glass transmittance (around 0.7), and moderately small room height (3.3-3.6 m) (Deng *et al.*, 2022).

Daylight is the holistic combination of the luminous characteristics of sunlight from direct solar radiation and skylight from diffused solar radiation (Knoop, Stephanie, Matsiak, Hobday, Wirz-Justice, Martiny, Kantermann, Aarts, Zemmouri, Appelt & Norton, 2019). In the tropical region, especially around the equator where there is abundance of sunlight, optimizing daylight means reducing the amount of daylight that goes into the building. As much as less daylight causes discomfort, more daylight also causes discomfort for building users, thereby rendering some functional spaces redundant. Japo and Abigail (2013) rendered it thus, "Daylight illumination brings about stresses when daylight is not properly and adequately harnessed. Indicators of stress from daylight illumination are visual distress, physical and mental fatigue. Circumstances for which daylight illumination can cause visual distress are glare, veiling reflection and flickering light source." Berkel (2013) suggested that, the aim of designing for optimal daylight is to get as much natural light as possible deep into the building while controlling heat and surface brightness within the users' fields of vision. While many devices encourage daylight to penetrate far into a building, other systems attempt to reduce daylight ingress.

When daylight is optimised, it reduces the amount of energy required to light up a space. According to (Mebarki, Djakab, Mokhtari, Amrane, & Derradji, 2021) energy efficiency in the building sector has become a major concern of energy and climate policies as it represents 40% [1] of global worldwide energy consumption. The space this research focuses on is the reading space in an academic library in a proposed faculty of architecture. In academic environments, libraries are where students, lecturers and the public, regardless of education or skill level, can have access to information (Bailey & Tierney, 2008). Beagle et al. (2006) also noted that the library of today and tomorrow must provide versatile spaces that support a wide range of users' learning and research activities while accommodating rapid advances in information technology (IT). Andy Priestner and Matt Borg (2016) rendered the idea thus; "Today's library services are incredibly complex. Long gone are the days when librarians were only questioning how to arrange their stock and have it circulate appropriately amongst their users. Now we also grapple with striking the right balance between print and electronic media, seamlessly serving both physical and remote users, actively embracing technology and research data, and delivering effective teaching and learning."

However, for a library to constantly meet the needs of its users there has to be provision for adequate daylighting for users engaging in research and studies. Considering that reading

and research are the main functions of use in libraries of all educational facilities, proper lighting becomes a crucial factor in the overall success of a library design. Therefore, daylight is essential for both energy saving and improvement of the quality of life in buildings where visual tasks are more divers (Ossama, Berta, Antonio, & Daniel, 2018). Depending on location and building typology, the parameters of direct and diffuse light ray lead to conclusions that have varying influence on orientation, massing, programme and envelope. It has also been researched that in a glazed fenestration, the practical depth of a day lighted zone is typically limited to 1.5 times the window head height (O' Connor, Lee, Rubinstein, & Selkowitz, 2007).

In a library design, it is important to consider the natural light experience, often referred as more satisfactory than artificial light (Oliveira & Guedes, 2006). However, library design in tropical climates like Nigeria need measures to control abundant natural light in to the interior's spaces. The primary application and effectiveness of daylight depends on different climatic conditions and varies at different time of the year. Some secondary factors that may affect daylight include building orientation, daylight devices, building depth etc. (Japo & Abigail, 2013). In order to optimize daylight, the primary factors would be analyzed while the secondary factors would be taken into consideration.

This thesis will focus on testing the performance of daylight in deep spaces considering the dependent variables as sensor points in deeper spaces; and independent variables as the size of window openings and the size of the space. The result of these experiments would be applied in the design of a proposed faculty of Architecture for Kaduna state university.

## Statement of the Problem

Library users need light for studies and research, however according to O' Connor, Lee, Rubinstein & Selkowitz, 2007) depending on the secondary factors affecting daylight into interior space, there is a limited amount of useable natural light that can penetrate into the building. Zeynep (2019) explained that occupants may prefer to sit near the window when they need more light to perform specific visual tasks, or they may want to sit away from daylight when it causes visual or thermal discomfort-these and other issues relating to the potential relationship between daylight and occupant behaviour remain to be further explored.

## Literature Review

Daylight is the total illumination provided by direct sunlight, skylight and the diffusely reflected sunlight which is absorbed and reflected over surfaces, both externally and internally (Salisu, 2015). Natural daylight was the only practical, generally available source until the mid-19th century, when gas lighting and kerosene fuelled oil lamps with efficient wick designs came to the market, predominantly in already industrialized countries (Shaw, 2010).

In the ancient traditional architecture, most human activities are carried out in its environment, thereby making surrounding environments big while living and sleeping spaces remained small. In those times, the openings in buildings were small because of the structural limitations of those times and the absence of artificial luminance (Brain, 2015).

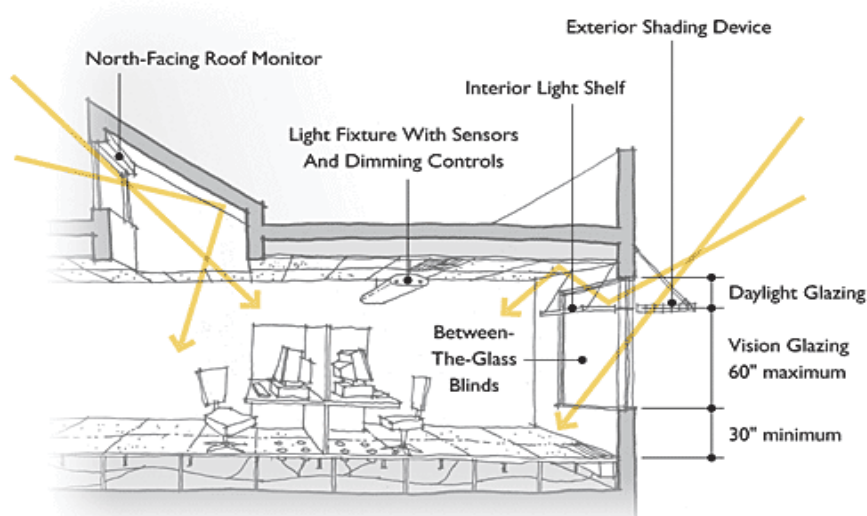
The issue connected to daylight ingress is heat, either excessive heat gains in tropical regions or heat loss in the temperate regions (Shaw, 2010). Consequently, for many institutional and commercial buildings, total energy costs can be reduced by as much as one-third through the optimal integration of daylight strategies (Gregg, 2014). Many studies have revealed that proper use of sustainable technology in lighting, such as the use of day lighting controls and low energy lighting, has a strong potential for reducing the demand for energy in commercial and industrial buildings (Busch, Du Pont and Chirarattananon, 2005).

According to Kahu (2012), daylight design refers to the consideration of key space design parameters that affect daylight performance, such as orientation and massing, size and placement of apertures, glazing and shading systems, and geometry and reflectance of interior surfaces. Berkel (2013) suggested that daylight in conjunction with other design elements are prior factors to be considered when formulating a design.

According to Berkel (2013) daylight design is synthesized in stages which are usually chronological arranged to achieve optimal daylight, these stages are conceptual design stage, design phase, construction planning and post-occupancy.

In a lecture note Abdullahi, (2015) stated that during construction installations are made for both natural and artificial lighting, before commissioning light controls must be calibrated to ensure they are operational in a turnkey procurement.

Daylight techniques and strategies are those factors considered in design stage that will help maximize the admittance of daylighting in the building. Figure 1 below shows various strategies that could be applied in a building and their effect in light admittance.



**Figure 1:** Daylight Strategies Source: (Hill, 2007)

There have been remarkable advances in knowledge sharing and research methods since the 1960s. Today, information is more accessible because of the emergence of the Internet and the prevalence of smart phones and tablet devices. The Internet not only reflects a change in the way researchers' access information but also poses a significant challenge to libraries, which must continue to be relevant in an age when information is so readily accessible. Not surprisingly, the proliferation of technology is having tangible effects on university libraries; there has been a sharp decline in the circulation of print sources, a reduction in the use of reference services, and falling gate counts (Gayton, 2008).

Advances in technology are threatening the existence of libraries as physical spaces, the traditional notion that libraries are "communal" spaces strictly to support quiet studious activities is also being called into question. One of the driving forces behind this reimagining of the library is a major shift in thinking about learning at the undergraduate level (Attalla & Connors, 2016).

The research gap reveals that reading spaces in a library should be designed with an open visibility to allow for natural light and fluid circulation, however, there is a level to which redirected light can travel into deep spaces. Ander (2014) suggested that in harvesting daylight for energy efficiency, the use of one or more daylight strategies is requisite to achieve maximum lighting in an interior space. Considering the fact that the amount of luminance required for reading and research is 300 lux at 0.8 meter from the ground according to Illuminating Engineering Society of North America (IESNA), several daylight elements, techniques and strategies should be employed to make light reach deeper spaces; these includes designing furniture arrangements in a way it does not obstruct the influx of daylight, but aid in redirecting light with its reflective surface.

## Research Methodology

This research is an experimental and quantitative research involving numeric measurement of daylight luminance. It also involves comparison of results from field survey and computer simulated environment to test its validity and reliability. Case study research design and experimental research design are considered to create a comparison between the daylight luminance measured in the field survey and the computer simulated environment as summarized in Table 1 below:

**Table 1:** Summary of case studies

Case Studies	Major Facility	Dominant Building Material	Use of daylight elements	Use of artificial lighting	Building Architectural feature and characteristics
Ahmadu Bello University, Zaria Architecture Library	The facility is a composite structure.	Glass, steel, concrete	Side lighting were used with adjustable and fixed louvered glass	Artificial light was not necessary in the day	The building adopts international style

**Source:** Researchers' Field Work (2024)

### Data Analysis

The data recorded from adjusting variables (daylight devices with light meter) are also compared with data with no variable to document the amount of changes observed represented from the Architecture departmental library of Ahmadu Bello University, Zaria to illustrate the extent of changes. In this test, the independent variables; sky condition, window opening are fixed while the dependent variables; daylight elements are adjusted to test for results. These results are recorded to score the extent of effect these elements have on the space. The window opening and screen wall was introduced at 1100mm and 350mm respectively above the floor level, the results were recorded the relationship between the measured illuminance visual analysis result and the simulated illuminance visual analysis result as shown below in Figure 1:

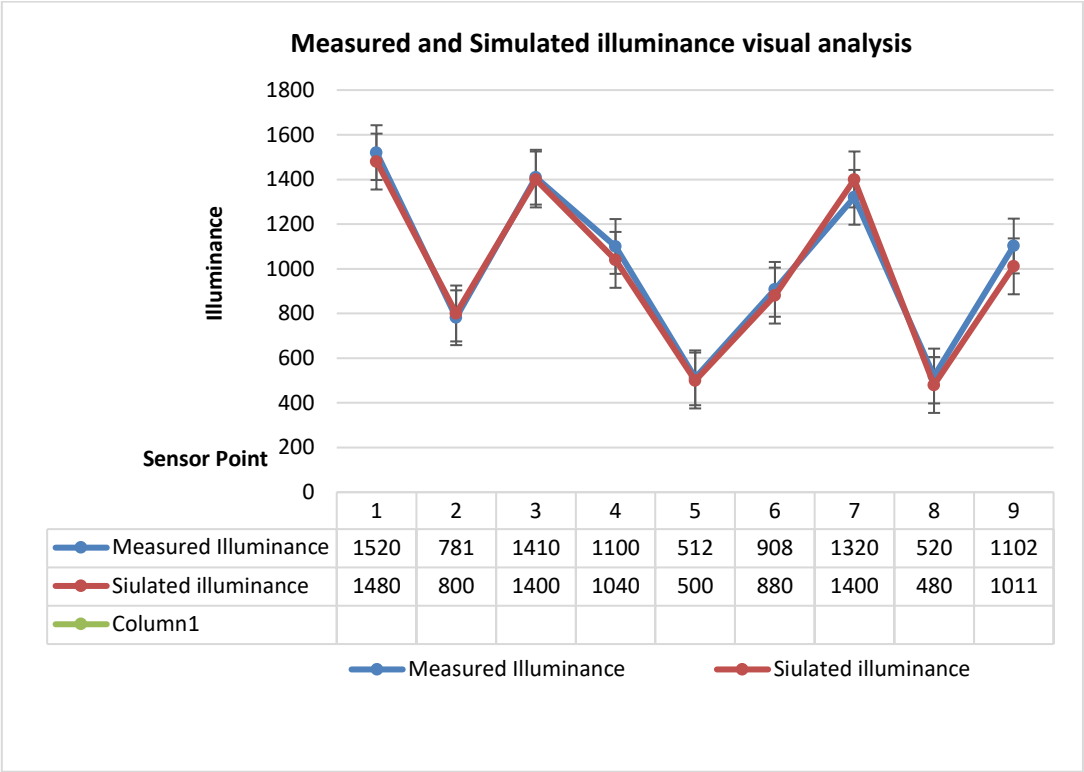


Figure 1 shows the relationship between the measured illuminance visual analysis result and the simulated illuminance visual analysis result

Summary of Findings

An interior space was modelled after an existing library in the department of Architecture, Ahmadu Bello Universities, with adequate side lighting. Records were taken at several points in the space to compare with the readings taken with a light metre in the field, for validity and reliability test. Afterwards, the elements were introduced and records taken. It was observed that the light points at the centre of the space increase by 0.66 times. Furthermore, when screen wall was introduced over the window, the light points were reduced by 0.1 times. The readings from this research yielded a positive result and therefore were replicated in the design of the proposed faculty of architecture. Therefore, the research objectives have been achieved.

Recommendations

Electronic teaching and learning are gradually becoming a requirement in the architectural education. To improve sociality amongst students, it would be necessary to merge the need of daylighting for both manual and electronic means of study in one space. Therefore, based on the results obtained from the research, the following recommendations were made;

- i. Window size & positioning and screen wall or other daylight elements should be used in maintaining the level of required luminance. Other devices are effective, however, for the delicate purpose of this research, these two elements are highly recommended.
- ii. In addition to the elements, it is recommended that daylighting design such as orientation and massing, size and placement of apertures, glazing, geometry and reflectance of interior surface be considered. These are design parameters that allow daylight influx; daylight elements only moderate daylight influx.

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