Assessment of Energy Efficiency Strategies of Public Libraries in Lagos, Nigeria

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ABSTRACT

Public libraries are social institutions that provide free, undiscriminated access to a wide range of knowledge, information, and resources to the communities they serve. These inclusive spaces serve as key facilities to foster literacy, facilitate lifelong learning, and uphold sustainable communities. With heavy reliance on public budgets and a responsibility to promote environmental stewardship and sustainability, energy efficiency is crucial to public libraries to lower operational costs as well as serve as beacons for environmentally conscious design. Lagos, being the world's fastest-growing city, was selected for this study because its rapid urbanization emphasizes the need for energy-efficient building designs. This paper seeks to investigate the adoption of energy-efficiency strategies by Public Libraries in Lagos, Nigeria to understand how the various strategies can be applied in the design process. Data were collected through carefully crafted observation guides and analysed using content analysis and the findings show that cross ventilation, window shading and the use of bright colours are some of the strategies commonly adopted by the public libraries. The study also recommends the consideration for building orientation, the thermal envelope as well as the use of active strategies such as occupancy sensors and lighting controls for future developments in Nigeria. The study is limited to its geographical context, Lagos state, Nigeria. Therefore, due to the contextual requirements of energy-efficient design, some principles discussed in this study may not be applicable to other geographical contexts.

Keywords: Energy efficiency, public library, design strategies, sustainability

1. INTRODUCTION

Libraries have traditionally been at the core of the communities they serve. They are welcoming spaces that provide irreplaceable resources, services, and participation to communities (Dedering, 2020). A public library is an institution established according to state laws or regulations with the purpose of catering to a community, district, or area. It offers an orderly collection of printed materials or other library resources, along with the required facilities, staff, and operational hours. And funded either entirely or partially with public taxes (ALA-APA, 2015). The public library also offers services such as informal childcare support for busy parents, language instruction for newcomers, and welcoming spaces for disadvantaged individuals, those without homes, and youth (Klinenberg, 2018). This inclusive aspect of the library positions it as a central force in fostering sustainable communities.

2. LITERATURE REVIEW

Public libraries have played an important role in information access throughout history. They are essential institutions for providing equitable access to knowledge and supporting sustainable communities. (Johnston & Audunson, 2019). Public libraries contribute significantly to the learning process, particularly since the nature of lifelong learning involves informal learning components, adaptable learning options, and a transition towards independent learning (Nielsen, 2014).

Public libraries, as repositories of indigenous knowledge, have a crucial function in serving their communities by promoting community literacy. (Chatterjee, Samanta, & Dey, 2020). This free access to knowledge, information and resources is an important responsibility of the public library to the community as it bridges the social, political, and economic barriers in a community. In the words of Robert Putnam, "People may go to the library looking mainly for information, but they find each other there." (Putnam, 2013). In a similar fashion to a large cinema hall or a megastore, libraries draw enormous crowds, opening commercial opportunities for a variety of nearby companies and organizations (Senville, 2011). Serving as places where numerous individuals gather, public libraries present opportunities for community involvement. Hence, it is crucial for them to prominently demonstrate their commitment to environmental sustainability and societal duty. This enhances the positive image associated with public libraries. (Sahavirta, 2020).

Sustainability includes several concerns, but none is as vital as energy efficiency (Lechner, 2015). Sustainable development as well as the green economy concepts are all focused on increasing energy efficiency (Soltangazinov, Smagulova, Amirova, Kashuk, Karimbergenova, Kadyrova & Zhaltyrova, 2020). Energy efficiency simply refers to utilizing the least amount of energy possible to produce the best results. In a nutshell, it is the process of getting rid of energy waste. (Erebor, Ibem, Ezema, 2021a). Through environmentally friendly site selection, building design, construction, operation, and maintenance, it aims to boost resource efficiency while minimizing its detrimental effects on human health and the environment throughout the structure's lifespan. (Gupta & Chakraborty, 2021) It must be well established that energy efficiency is by far the most significant design choice, as it is the easiest, quickest, and least expensive strategy to tackle global warming (Lechner, 2015).

The need for energy efficiency is a worldwide campaign. It is an essential part of the worldwide effort to lower carbon dioxide emissions, with the goal of reducing primary energy consumption to between 11% and 20% by 2030 and between 30% and 41% by 2050 (Erebor, Ibem, Ezema, 2021b). Buildings are a critical aspect of our transition to an energy-efficient future. They account for one-third of the world's greenhouse gas emissions and roughly 40% of the world's energy usage (UNEP, 2023). Stimoniaris (2014) particularly highlights the adoption of energy efficiency in public buildings as the first step towards sustainable development.

Public libraries present a unique opportunity to demonstrate environmental stewardship and serve as beacons of energy-efficient design. In their role as a community organisation, they have an obligation to minimise negative environmental impact (Mavily & Vasudevan, 2019). Gisolfi (2011) stresses on the role of public libraries as community leaders in sustainable practice. The library has a leading role in promoting sustainable ways of transforming the community with the future in mind (Mangemba, 2014).

Although energy efficiency principles are relevant to all building projects, public libraries are of special importance. They have a long lifespan and frequently have a low maintenance budget. They serve as significant symbols for the communities they represent and, as such, serve as an indication of the values upheld by those communities, which should include the prudent use of natural resources (McCabe & Kennedy, 2011).

Designing buildings with energy efficiency in mind can result in significant energy savings, with up to 30-50% reductions in energy consumption compared to conventional buildings (World Green Building Council, 2019). The choices taken during the initial phases of the design process hold significant significance in determining the energy efficiency of buildings. Incorrect choices and design shortcomings pertaining to factors like the general layout, shape, façade transparency or orientation can lead to a substantial rise in operational energy consumption (Raji, Tenpierik, & Dobbelsteen, 2017). By prioritizing energy-efficient design choices, public buildings can effectively minimize energy waste and environmental

impact, thus promoting sustainability and resource conservation. The rapid temperature increase seen in urban centres like Lagos, coupled with the heightened threat of global warming and climate change, underscore the heightened significance of energy-efficient constructions like never before. (Geissler, Österreicher, & Macharm, 2018). This study aims to explore the utilization of energy-efficient techniques in the architectural planning of public libraries in Lagos to gain insights into the applicability of these methods for potential integration into the design of public libraries. This study will focus on exploring energy-efficient design techniques in Lagos, Nigeria. Since the requirements for energy efficiency vary depending on climate, some of the strategies discussed in this paper may not be applicable to other climates.

A successful energy-efficient design requires an understanding of the integrated design process for designing energy-efficient buildings. There are no definitive universal procedures for designing energy-efficient buildings, but the design process follows a distinct pattern that requires an awareness of the goal during every stage of the project. Jordan & Hamilton (2019) conducted research that emphasized diverse approaches, categorizing them into four groups which are effective site planning, optimal architectural design, passive tactics, and active techniques.

2.1. Efficient Site Design

2.1.1. *Site Selection and Building Orientation*

Site layout and building orientation are critical considerations at the start of any development. A site that allows for an east–west orientation, free from physical and legal constraints that restrict the installation of energy-efficient equipment, and ample space for vegetation are some of the most important factors to consider when selecting a site that optimises energy efficiency (Lechner, 2015).

2.1.2. *Building Form*

An elongated rectangle is recommended for the tropical climate because it offers a very high potential for daylighting and cross-ventilation. Attention should be paid to voids and protrusions as well. While the overall massing of a building might be simple, when there are voids or protrusions within the thermal enclosure, the total surface area increases quickly. and a larger surface area implies more space for heat to escape (Lechner, 2015).

2.1.3. *Building Plan*

The east-west orientation is encouraged in the building plan to allow for maximum sunlight. The sun is almost always overhead and constant in the tropics therefore, the adoption of an open floor design can encourage maximum daylight and ventilation (Lechner, 2015).

2.2. Efficient Building Design

2.2.1. Ventilation

Optimising the building for natural ventilation significantly influences the choice of architectural layout. Opting for a narrow plan depth and adopting an aerodynamic building shape, such as a circle or ellipse, can aid in facilitating natural ventilation. (Raji, Tenpierik, & Dobbelsteen, 2017). The size, configuration and number of openings all influence the natural ventilation performance of a building (Sacht & Lukiantchuki, 2017). A better natural ventilation performance can be achieved with cross ventilation (Gao & Lee, 2011).

2.2.2. Daylighting

Significant reductions in artificial lighting and energy consumption can be accomplished by optimizing the utilisation of natural daylight (Gherri, 2013). The summary of design decisions that influence daylighting include the use of lofty ceilings and windows, as well as the use of skylights (Lechner, 2015). The window-to-wall ratio has a significant impact on the daylighting

performance of buildings (Ayoosu, Lim, Leng, & Idowu, 2021). The Nigerian National Building Energy Efficiency Code recommends a window-to-wall ratio of less than 20 percent for any building orientation.

2.2.3. Shading

The incorporation of sun control and shading systems holds significant importance within numerous energy-efficient architectural approaches. Buildings that utilize passive solar heating or maximize natural illumination frequently rely on skilfully engineered mechanisms for sun control and shading. (Prowler, 2016).

2.2.4. Colours and Materials

White is by far the best colour for energy efficiency because of its exceptionally high solar reflectance and great infrared emissivity, resulting in an extraordinarily high solar reflective index (SRI). Since ventilation is a significant source of heat gain and loss, use furniture, construction supplies, and cleaning products with low volatile organic compounds to reduce ventilation requirements (Lechner, 2015).

2.3. Passive Strategies

2.3.1. Thermal Envelope

Avoiding heat is the first step to achieving thermal comfort in hot climates, and this depends largely on the thermal envelope (Lechner, 2015). Hor & Rahmat (2018) stated that the choice of building facades and design elements play a role in shaping the energy requirements of buildings. The thermal envelopes of energy-efficient structures serve as more than just partitions between indoor and outdoor spaces. They function as integrated building systems that adapt to the external surroundings, actively ensuring comfortable indoor environments and significantly lowering overall energy usage in the buildings (Hailu, 2021).

2.3.2. Air Barriers

The use of air barriers as a passive strategy applies to air-conditioned buildings. The loss through infiltration may be reduced to 30% of the overall building heat loss with the use of high-quality weather-stripping on windows and doors and good, tight construction methods (Lechner, 2015).

2.3.3. Other Passive Strategies

Some of these strategies include elevating living spaces and the use of solar chimneys to catch maximum wind.

2.4. Active Strategies

2.4.1. Electric Lighting

The performance of the lighting fixture and the aesthetics of the space are additional factors to consider in lighting efficiency in addition to lamp efficacy. (Lechner, 2015).

2.4.2. Mechanical Equipment.

The use of building management systems to optimise the use of heating and cooling systems, elevators and lighting can greatly influence the energy efficiency of a building (Mendoza-Pitti, Calderón-Gómez, Lombardo, Gomez-Pulido, & Castillo-Sequera, 2021).

Public libraries consume substantial amounts of energy due to their size and diverse activities (Munguia, Esquer, Guzman, Herrera, Gutierrez-Ruelas & Velazquez, 2020) therefore, prioritizing energy efficiency is vital to reduce energy consumption, minimize carbon footprint, and contribute to global climate change mitigation efforts. By embracing

energy-efficient practices, public libraries demonstrate environmental responsibility and inspire their communities to adopt sustainable behaviours (Wang, Liu, & Yang, 2018)

Implementing energy efficiency in public libraries offers significant advantages. It leads to substantial cost savings by reducing energy bills and operational expenses. Adopting energy efficient practices, such as efficient lighting systems, building insulation, and HVAC system optimization, can substantially decrease the operational cost of the building (Audunson, Aabø, Blomgren, Evjen, & Jochumsen, 2019). These savings can be reinvested to enhance library services, resources, and community programs. Additionally, energy efficiency improves the environmental performance of public libraries by reducing greenhouse gas emissions and conserving natural resources (Warty & Mehendale, 2021).

3. METHODOLOGY

A qualitative research approach is used in this study since the goal of this research is to describe a phenomenon. This research approach required energy efficiency features to be identified, evaluated, and described for clarity and ease of understanding. The study is a multiple case study research and data was gathered from the selected case studies. Three public libraries were selected from the twelve available public libraries in Lagos State (Lagos State Library Board, 2016) because of their ease of accessibility. The selected public libraries were the Ikeja Secretariat Library, Herbert Macaulay Library, and Isolo Public Library.

A well-crafted observation guide was developed based on the relevant energy efficiency features identified in the reviewed literature. Data collection from the public libraries that constitute the sample size was done using the observation guide. The observation guide was divided into four sections which are, efficient site design, efficient building design, and passive and active design strategies. Each of the selected buildings was observed to identify the presence or absence of the strategies addressed in the observation guide. Field data were collected between December 2022 and January 2023. To analyse the data, the energy efficiency strategies were rated on a scale of 0-3, 0 meaning absent, 1, 2 and 3 being low, medium high levels of implementation respectively. The results were content analysed and presented with textual descriptions and supported by photographic evidence.

4. RESULTS AND DISCUSSION

The three selected public libraries were observed for presence and absence of the energy-efficiency design features studied in the literature**.** The first was the Illupeju public library. Situated along Johnson Street, Ilupeju, Lagos, Nigeria, the facility was designed to encourage a reading culture in the community. It is open to the public and provides a variety of services including access to books, magazines, newspapers, and other print materials.

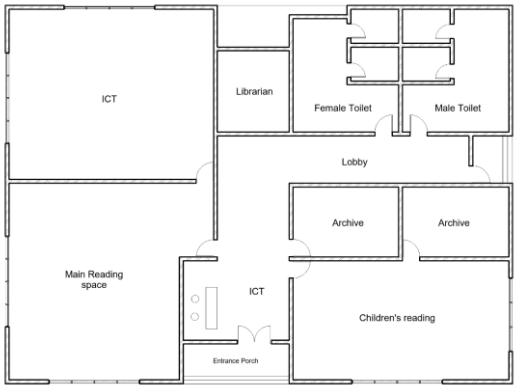

Figure 1: Sketched floor plan of the Ilupeju public library

Figure 2: The Illupeju public library

Figure 3: The librarian's desk at the Ilupeju public library

Figure 4: The general reading space in the Ilupeju public library

The second public library studied was the Isolo Public Library. Commissioned by Brigadier General Buba Marwa and registered under the Lagos State Library Board, the Isolo Public Library is a community library located along Holy Saviour's College Road, Isolo, Lagos, Nigeria. It serves the community by providing access to books, educational resources, and other learning materials and has a user capacity of about 150 people.

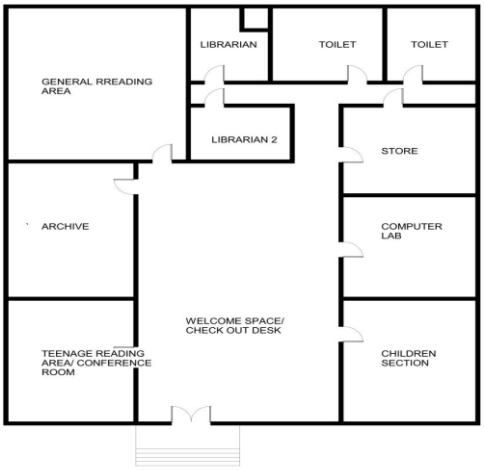

Figure 5: Sketched Floor Plan of the Isolo public Library

Figure 6: The Isolo public Library

Figure 7: Site Vegetation at the Isolo public Library

Figure 8: General Reading Space in the Isolo public Library

The third public library studied was the Henry Carr public Library. The facility is located along Adebisi Awoshoga Street, Dopemu, Lagos, Nigeria and was built by the famous Henry Rawlingson Carr to provide access to books and educational resources to the community. The library has a personal selection of 18,000 books by Henry and it consists of a general reding space which can seat about 200 readers.

Figure 10: The Henry Carr public library

Figure 11: The Main reading space

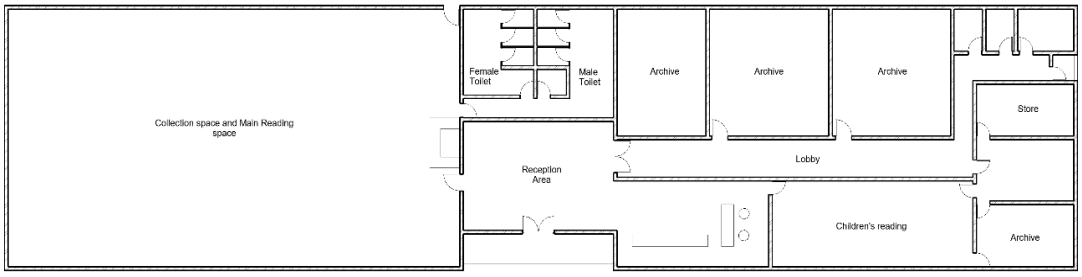

Figure 12: Sketched Floor Plan of the Henry Carr Public Library

Table 1: Adoption of Energy Efficiency Strategies by the Selected Public Libraries

S/N	Variables	Comments		
		Illupeju Public Library	**Isolo Public Library**	**Henry Carr Public Library**
Site Design	Site Selection & Building Orientation	Minimal vegetation on the site and although the site favours an east-west orientation, the building does not maximise this.	Presence of vegetation on the site and although the site favours an east-west orientation, the building does not maximise this.	Minimal vegetated areas on the site. Its longer side is oriented along the north-south axis
	Building Form	Compact and relatively square geometry	Compact and relatively square geometry	Elongated rectangular form
	Building Plan	Does not adopt an open floor plan	Does not adopt an open floor plan	The general reading space adopts an open floor plan
Building Design	Ventilation	Cross ventilation is utilised in all necessary spaces except the reception	Cross ventilation is neglected in the computer lab and librarian offices	Cross ventilation is utilised only in the general reading space
	Daylighting	Large windows permit adequate daylight in the reading spaces	Numerous windows permit adequate daylight in the reading spaces	High headroom in the reading spaces and the numerous windows permit adequate daylight.
	Shading	Horizontal slats shade the front elevation windows	Roof cantilever and vertical wall fins offer window and wall shading	Roof cantilever and vertical wall fins offer window and wall shading
	Colours and Materials	Bright yellow and white finishes on the building interior and exterior	Bright white and grey finish reflect light around the building interior and exterior	Bright yellow and white finishes on the building exterior and interiors
Passive Strategies	Thermal Envelope	Single skin of concrete masonry units and glass windows form the building envelope	Single skin of concrete masonry units and glass windows form the building envelope	Single skin of concrete masonry units and glass windows form the building envelope
	Air Barrier	Not identified	Not identified	Not identified
	Other passive Systems	Wing wall on the front elevation used as shading device	Not identified	Not identified
Active Strategies	Electric Lighting	Presence of LED (Light Emitting Diode) Fixtures and manual light controls	Presence of LED (Light Emitting Diode) Fixtures and manual light controls	Presence of LED (Light Emitting Diode) Fixtures and manual light controls
	Mechanical Equipment	Presence of ceiling fans	Presence of ceiling fans	Presence of ceiling fans

4.1. Efficient Site Design

4.1.1. *Site Selection and Building Orientation*

The three public library sites favoured a building orientation in the east-west direction. Lechner (2015) explains that an elongated rectangle with its long axis running in the east-west is recommended for maximum solar access and cross ventilation of the building. The three public libraries however do not take this into account therefore this criterion is poorly implemented.

4.1.1. *Building Form*

The form of the Henry Carr public library is an elongated rectangle geometry which favours natural ventilation. The other two public libraries however did not take geometry into consideration as they have a relatively square geometry.

4.1.2. *Building Plan*

The Henry Carr public library adopts the open floor plan in its reading spaces while the other two libraries are compartmentalised. The open floor plan implies adequate daylighting and natural ventilation in the space.

4.2. Efficient Building Design

4.2.1. *Ventilation*

The three public libraries all promote cross ventilation in the reading spaces, but some other vital spaces are neglected such as the children's reading in the Ilupeju public library and the computer lab in the Isolo public Library.

4.2.2. *Daylighting*

The three public libraries all have adequate daylight in the reading spaces, but the lighting in other interior spaces can be improved with the use of skylights and clerestory windows.

4.2.3. *Shading*

All three public libraries provided window shading in form of cantilevers or fins. This strategy is highly beneficial as it helps to reduce solar radiation in the interior spaces. (Shahdan, Ahmad, & Hussin, 2018).

4.2.4. *Colours and Materials*

All three public libraries made use of bright colours and particularly the Isolo public library as it utilises a highly reflective white gloss finish on its interior walls and white and grey interior furniture which help to bounce light around the space.

4.3. Passive Strategies

4.3.1. *Thermal Envelope*

The public libraries consist of a single skin of concrete masonry units and single glazed glass. Nearly half of the heat loss and gain on a building envelope occurs in windows (Akram, Hasannuzaman, Cuce, & Cuce, 2023). This can be combated by using double-glazed or triple-glazed glass to maintain indoor temperatures (Bangre, Surwade, & Kamal, 2023).

4.3.2. *Air Barriers*

None of the public libraries made use of an air barrier. In the form of weather-stripped doors or windows or ventilated cavity walls.

4.3.3. *Other passive strategies*

The Illupeju public library makes use of wing walls to further shade the building windows from the harsh overhead sun.

4.4. Active Strategies

4.4.1. *Electric Lighting*

All three public libraries made use of LEDs (Light Emitting Diodes) lighting fixtures which typically offers more energy savings when compared with fluorescent bulbs. These lights had controls that could easily be spotted, but none of the libraries utilised occupancy sensor technology or automated lighting controls which Garg & Bansal (2000) explain would typically offer more energy savings than the manual methods.

4.4.2. *Mechanical Equipment*

All three public libraries utilise ceiling fans with individual controls but other mechanical equipment such as carbon dioxide sensors were not identified. Desk fans were also not identified in any of the public libraries.

5. CONCLUSION

In the design of public libraries, consideration for energy efficiency should be made at the conceptual stages of the project to ensure an environmentally responsible building as well as avoid any subsequent costs that would be incurred in an attempt to superimpose energy

efficiency on an already inefficient design. A procedural design pattern was developed to integrate these strategies in the design process which include efficient building design, efficient site design, passive and active design strategies. When implemented properly from the beginning of the library design project, it offers significant operational cost savings for an institution that demands cost efficiency since it is funded by public taxes.

The study investigated the level of adoption of energy efficiency strategies in the design of selected public libraries in Lagos. The selected libraries were the Illupeju public library, Isolo public Library and the Henry Carr public library. The results shed light on some of the common strategies adopted by these public libraries, some of these strategies include cross ventilation in the general reading spaces, window shading to reduce solar radiation, as well as the use of bright colours and glossy materials in the space which reflect light around the interior spaces.

While the selected public libraries have employed some of these strategies in their design, there is a considerably large room for improvement regarding integrating energy efficiency in the design process for public libraries in Lagos. Some of the strategies to consider in the subsequent design of public libraries in Lagos include the east-west orientation of the library buildings to maximise thermal comfort and natural ventilation, the use of open floor plans to further ensure natural ventilation in the library spaces. The use of skylight and clerestory windows should be considered as well as they help to bring in daylight to the deeper parts of the space Attention should be paid to the thermal envelope to reduce heat gain in the building and the use of automation to ensure efficiency in the use of energy demanding equipment such as lights and fans.

Energy efficiency is particularly important to public libraries because as institutions that play a vital role in promoting education and community engagement, they can serve as models for energy-efficient building practices thus inspiring other institutions and individuals to follow suit, creating a more environmentally conscious community. This conforms with the research of Hauke & Werner (2013) which explains that libraries play a crucial role in not just spreading knowledge about environmental sustainability, but also in setting a positive example to emulate. Fulfilled environmental responsibility, affordable cost of construction, reduced carbon footprints, and economic benefits are some of the benefits of promoting energy efficiency in public libraries (Putnam, 2013).

In a bid to create more sustainable developments in Nigeria, energy efficiency is a principal concern and should be a significant consideration from the project conceptualisation stages. Thus, this study recommends that the design of public libraries, as well as other public buildings in Lagos should embrace the design procedure towards achieving energy efficiency and implement as many strategies possible including those that have been identified as the least adopted.

ACKNOWLEDGEMENTS

The authors appreciate Covenant University for providing a platform as well as the resources required to conduct this study. The authors would also like to thank the librarians of the chosen public libraries for allowing the data collection to take place in the library buildings. The researchers whose works were studied during the process of obtaining a background literature are also acknowledged.

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