USE OF DAYLIGHTING STRATEGIES FOR LIGHTING ENERGY COST REDUCTION IN A METROPOLITAN LIBRARY DESIGN

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DECLARATION

I, Emmanuel Ebenehi ADAJI hereby declare that the work in this thesis titled 'USE OF DAYLIGHTING STRATEGIES FOR LIGHTING ENERGY COST REDUCTION IN A METROPOLITAN LIBRARY DESIGN' was performed by me in the Department of Architecture Ahmadu Bello University. The information derived from the literature has been duly acknowledged in the text and a list of reference provided. No part of this project thesis was previously presented for another degree at this or any other institution.

ADAJI Emmanuel Ebenehi …….....

(Student) Signature/Date

CERTIFICATION

The thesis titled "USE OF DAYLIGHTING STRATEGIES FOR LIGHTING ENERGY COST REDUCTION IN A METROPOLITAN LIBRARY DESIGN**"** meets the regulations governing the award of degree of Master of Science (M.Sc) of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to God Almighty, for His grace and guidance.

To my Dear Wife and our lovely Princess HADASSAH for patiently understanding.

Lastly, to the loving Memory of my Son Bishop Ojima-Ojo and my wonderful parents.

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The success of this work was therefore largely depended on God for his unflinching love and mercies that saw me through these years and the opportunities provided in many spheres by my parents, teachers, scholars, friends and well-wishers through finances, guidance, advices, information and moral support. I remain forever grateful.

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ABSTRACT

The study focuses on the provision of adequate daylight in buildings to reduce over dependence on electrical energy for the artificial lighting. The lack of careful light design in a building therefore renders it close to useless as the supposed use becomes difficult in the absence of light at activity areas. Three libraries were studied using Building information modeling (BIM) - *Autodesk* Revit 2014, *Autodesk Ecotect 2011* to design for daylight in library and to analyze Daylight Illuminance level, Daylight Factor (DF) and daylight autonomy. The major factor considered in this study is the level of illumination on the work plane in the interior of the building, the area of the windows and the area floor of the spaces. The Strategies for admitting daylight were investigated to discover how building design can intelligently adopt the most energy efficient Daylighting for the library. The data collected were presented using tables, figures, graphs and plates. Findings illustrate that two libraries studied had low natural lighting which were below 500 lux, Dark zones in the building are apparent during power outages. The third case had a good average illumination value of 500 lux at most reading areas.

Some recommendations from the research includes remodeling sections of the building to allow for natural lighting and installation of roller shade blinds which can be easily controlled for optimum light penetration. Also design for buildings should go beyond provision of spaces for activity, but must adequately consider energy efficiency and the science of usability as part of the whole process in a buildings existence. The use of advanced building materials (smart materials) should be encouraged to achieve needed reading environment. These edifices should also serve as venues for plays, recreational purposes, conferencing, educational and commercial activities.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Philip (2004) noted that from the earliest caves, daylight from various opening informed the lives of the inhabitants of the difference between night and day; but as dwellings became more refined, the initial crude openings in caves transformed to windows which became means of letting in air, heat, cold and light to see and function well in various activities areas. Throughout history, daylight has been a primary source of lighting in buildings, supplemented originally with burned fuels and more recently with electrical energy (Philip, 2004). Before daylight was supplemented or replaced with electric light in the late 19th-century, consideration of good daylight strategies was essential (Kroelinger, 2005). The history of architecture is synonymous with the history of the use of windows as the vehicle for the introduction of daylight, and ultimately to the wondrous interiors of the mediaeval cathedral, the Baroque churches or the many private buildings of the eighteenth century (Philip, 2004). The use of daylight has been a primary source of lighting in buildings, but was supplemented with electrical energy (Dordai, 2002). According to Philip (2004) Libraries, before the start of light technology were characterized by volumes and planes illuminated with daylight, non-glare lighting in reading spaces. Dean (2005) further noted that any Building Design that takes adequate thought for daylight is considered a good design, due to the ambience of quiet contemplation and visual comfort created. This is why a properly lit work place promotes psychological sensations of comfort and enables quick understanding, with increase in productivity.

The use of Daylight came with problems in terms of glare and solar heat gain and so it became easier to shut it out of buildings and replace it with electric lighting, which was

cheap and easy to control then. Bennett (2008) in her study said that cost of energy nowadays and the diminishing resources necessary to generate energy have resurrected the need for daylight in our buildings and the sun once again can be revered as a source of life and energy **(**Bennett, 2008).

But energy shortages in recent times have also become a major concern on the use of non-renewable energy sources. In 2005, the worldwide annual use of electric light was 133 petalumen-hours (Plmh) with an average of 20 megalumen-hours (Mlmh) per person, and this consumes about 19 percent of total global electricity use (IEA 2006). On the other hand, two billion people in the world are still living without access to electricity (Mills 2002).

The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment **(**Philip, 2002). This study examine ways to effectively use Daylight in Library building design and provide opportunity to significantly reduce the operational cost due to the over-dependence on electricity for lighting, during daily functioning of this intellectual data bank.

1.2 STATEMENT OF PROBLEM

Lighting is an enormous and speedily rising source of energy demand. It is an extensive energy user, and a key constituent of the service expenditures in buildings **(**Bennett, 2008). Heschong (2000) stated that there is a greater dependency on non-natural source of light for illumination in most libraries, classrooms, and office building to operate despite attendant increase in electricity tariffs, and short fall in supply. Boyer et al

(1994) opined that operational cost could rise in buildings when daylight system is poorly designed, as consumption of electricity for artificial lighting during the daytime will inadvertently add up to other energy needs.

This study tends towards minimizing the over dependence on artificial lighting (which is expensive to supply), in library buildings through carefully thought out daylighting design strategies in the admittance of useful Daylight for the purpose of energy savings and to enhance visual task and reading.

1.3 AIM OF STUDY

The aim of the study is to evaluate illuminance level using Daylighting strategies for lighting operational cost reduction in the design of library buildings with a view to enhancing visual task and reading.

1.4 OBJCTIVES OF STUDY

The following objectives are necessary to achieve the aim

i. Evaluate the cost of lighting system in the Library
ii. Investigate illuminance levels for visual task and reading in library buildings.
iii. Investigate the adequacy of Daylighting system to enhance visual task and reading in library buildings.
iv. Evaluate operational cost savings for lighting from the use of Daylighting strategies in library building.

1.5 RESEARCH QUESTION

In carrying out the research the following questions were considered;

i. What is the cost of lighting system used in Library?

ii. What is the Illuminance level in library building for visual task and reading?

iii. What are the problems of integrated Daylighting design for lighting in buildings?

iv. How can the adoption of Daylight strategies enhance visual task and reading in Library buildings?

v. What is the operational cost savings for lighting using Daylighting in Library building?

1.6 SIGNIFICANCE OF STUDY

This study seeks to provide ways of improving natural light levels to enhance visual task and reading in Library buildings, reducing dependency on power generated for artificial lighting and ultimately the reduction in cost of energy required to power lighting systems in Public buildings in Nigeria, which is also replicable in the West Africa Sub Region.

1.7 JUSTIFICATION OF THE STUDY

The challenge of providing light energy in buildings, cost more through the life of the building and can be cut down significantly by design that allow a great percentage of Natural light into the work space as demonstrated for offices by Bodart and De Herde (2002). Daylight when directed properly into the building leads to decrease in cost for lighting. The architect as the initiator of building design is therefore saddled with the duty of harnessing useful daylight to the built environment effectively through integrated Design process.

1.8 LIMITATION OF STUDY

The artificial lighting may not be switched off at the reading area during the period of measurement or observation because it will disturb the normal functions of the library. Acquiring the required data for meaningful simulation was a task of varying difficulty.

1.9 SCOPE OF THE STUDY

The study was focused on the design of a six floor Metropolitan Library in Kaduna State. The building consists of Six (6) floors with, but not limited to the following spaces;

i. Reading area
ii. Acquisition room
iii. Holding room
iv. Reference Section
v. Reserved Book area
vi. Periodicals Area
vii. E-Library
viii. Administrative offices and other ancillary buildings.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The use of Daylight came with problems in terms of glare and solar heat gain and so it became easier to shut it out of buildings and replace it with electric lighting, which was cheap and easy to control then. But the cost of energy nowadays and the diminishing resources necessary to generate energy have resurrected the need for daylight in buildings and the sun once again can be revered as a source of life and energy **(**Bennett, 2008). According to Philips (2013), the use of daylight started when natural light entered the early man's caves through various openings. Philips (2013) further noted that the reason for renewed interest in daylight design was due to the high cost of fossil fuels coupled with the realization that sources of electricity had a finite life and that daylight related more to the human spirit, and the quality of life. Yilmaz (2010) also observed that up to the mid-20th century almost all schools and workplaces used daylight as their primary source of lighting, the advent of inexpensive energy and the proliferation of fluorescent lights in the 1950s and 1960s made daylight an illumination source almost irrelevant.

The US Department of Energy, (DOE 2006) said Lighting is a substantial energy consumer, and a major component of the service costs in many buildings. Increasing energy efficiency can bring opportunities to limit the rate of increase of electric power consumption, to reduce the need for capital intensive supply investments, and to mitigate climate change (DOE 2006).

According to Stern (2006) the Energy efficiency measures for buildings are approaches through which the energy consumption of a building can be reduced while maintaining

or improving the level of comfort in the building. They can typically be categorized into:

i. reducing heating demand
ii. Reducing cooling demand
iii. Reducing the energy requirements for ventilation
iv. Reducing energy use for lighting
v. Reducing energy used for heating water
vi. Reducing electricity consumption of office equipment and appliances
vii. Good housekeeping and people solutions.

2.2 LIGHT SOURCES AND COST OF LIGHTING IN BUILDINGS

In Table2.1 the sources of lighting in buildings- Artificial light and Natural light - are compared to understand the importance of each form of lighting, noting the advantages and disadvantages.

2.2.1 Impact of Light energy Sources

2.2.1.1 Artificial source:

According to an International Energy Agency (IEA 2006) study, global grid-based electric lighting consumed about 2650 TWh of electricity in 2005, the equivalent of 19% of total global electricity consumption. Based on the latest electric tariff rate by the Nigerian Energy Regulatory Commission (NERC), the national electricity provider, the tariff rate for the low voltage commercial building C2 is 20.26 per kWh. *If this light energy is supplied by electric light fixtures, then there is a consumption of electric energy at a certain rate to supply a given level of light.* The unit of electric power is the *watt*. The measure of the efficiency of a light source is the ratio of the amount of light

energy put out by the source for every watt of electric power consumed. This ratio, known as the *efficacy* of the source, provides a useful comparison of different sources of light (Philips, 2004).

Lighting systems have the largest potential of any known appliance to reduce United States energy use (Desroches and Garbesi 2011). Philip (2013) opined that the reduction in the use of energy in buildings has been identified as a major objective, of which electrical energy for lighting is a significant factor.

2.2.1.2 Natural light sources:

According to the U.S. Department of Energy (DOE 2006), using daylight to illuminate the interior of school buildings to reduce or eliminate the use of electric lights can save as much as 25%-40% of building energy costs and recent studies by keith (2003), Philips (2013), Herbert (2005), Lisa (2002), Heschong Mahone Group (1999) have shown that students achieve significantly higher test scores in classrooms that are day lit than in those that are not, making daylighting one of the best building-related investments. Philips (2013) also revealed that Energy savings can be maximized by utilizing daylighting, especially when it comes to lighting design for buildings that are mainly occupied during the day, such as class rooms, libraries and offices. Bennett, (2008) noted that the central concern associated with daylight is the heat gain that can result when natural light is brought into a home. During the heating season, the heat gain from natural light can become challenging and add up to energy. Where over-heating may be a problem, passive cooling and ventilation features will be required. The key elements of passive cooling are:

i. Minimizing solar gain when it is not wanted (through window design and shading)
ii. Taking advantage of natural ventilation flow to provide cooling
iii. Using insulation to prevent heat gain
iv. Using thermal mass to absorb day-time heat, keeping the building cool (at night, ventilation can be used to remove any unwanted heat).

The electromagnetic radiation from natural light, coming directly from the sun, can harm the human body (Bennett, 2008). It is a known cause of skin cancer due to over-exposure and also fading of carpet and drying out of furniture does occur when too much daylight is admitted in an uncontrolled manner. Fading of carpet and drying out of furniture occurred in the past when sunlight was allowed to enter the building directly, or too much daylight was admitted in a controlled manner. These issues can be avoided with good daylight design (Bennett, 2008).

Glare is another challenge with daylight, this refers to excessive brightness contrast within the field of view, and it is an aspect of lighting that can cause discomfort to occupants. The human eye can function quite well if extreme levels of brightness are present in the same field of view. Good daylight design can control this effect. There are two categories, the disability glare and the discomfort glare.

i. Disability glare is defined as the effect of stray light in the eye whereby visibility and visual performance are reduced. An example of disability glare is the sensation that a person experiences on a sunny day surrounded by snow. The overall luminance levels of that environment are too great and bright for the eyes.

ii. Discomfort glare is defined as glare that produces discomfort and it does not necessarily influence visual performance or visibility.

Clearly daylight is not cost free, and factors such as the control of sunlight, heat gain and loss, the association of windows with ventilation and the question of whether the windows should open or the building be sealed, are all problems which need to be addressed; but these need to be equated with the human desire for association with the natural environment, as well as the possible savings in electricity and cost (Dean, 2005).

Table 2.1: A Comparison of the Different Light Sources in Building.

Natural	Artificial
1. They are self-generated, mainly the sun is the primary source	Man-made, depends on other energy sources(Fuel based)
2. Renewable and benefits the environment	Non-renewable and source of greenhouse gases.
3. Can be controlled in architectural space	Can also be controlled in architectural space
4. Has a broad spectrum of colors and wavelength	Has limited spectrum of colors, making it less versatile
5. propagate through walls and roof apertures	Transmitted through electrical bulbs, tubes.
6. Add up to the heat loading in buildings and causes glare	Also generate heat and can cause glare
7. Benefits occupants psychology, and health	Has little or no benefit
8. Limited to day time and varies in brightness at different seasons. Natural daylight illumination can vary from 5,000 lx in a heavily overcast sky to over 40,000 lx in direct sunlight.	May be available when needed through the day, and no variation
9. Supply is free and in abundance & the light source efficiency is high	light source efficiency is low with cost of production & supply very high

Source: Dean (2005)

When daylight is designed, it becomes a powerful element in a building. Artificial lighting impacts the mood of a space and lighting fixtures are more than mere luminaries, but speak to the architectural expression of a building. The properties of natural and artificial light are investigated to discover how building design can intelligently incorporate both **(**Bennett, 2008).

2.2.2 Light in Architectural Spaces:

Fadeyi and Taha (2010) investigated Occupants' feedback on adequacy of lighting in a factory office in Dubai. The writers investigated through observation and distribution of 22 questionnaires to members of staff, out of a total number of 36 in the office. The study focused on artificial lighting and natural lighting in the studio and at individual workstations. A three point rating scale of "excellent", "average" and "poor" was used. Simple percentages were used to draw conclusions.

Poor lighting distribution and illumination were observed. Furthermore the integration between lighting distribution and furniture layout were questioned. The results show that occupants that rated the lighting in the office to be "excellent" were seated close to the windows which have a view of outside. Araloyin (2010) investigated the influence of environment on workers' productivity in Obafemi Awolowo University, Ife. The researcher using a 4 point rating scale in an interview of 253 workers out of a total academic staff strength of 1561 discovered that 66% of workers interviewed opined that the lighting condition of the offices are considered as "less adequate" and "not adequate".

Light is needed to function effectively. Light is said to be a creative medium, its most basic function is to enable us to see. Our visual acuity relies on the quantity of light and its spectral distribution. Light is thus the physical phenomenon most responsible for humans' perception of the world (Yilmaz, 2004). In Fig 2.1 Light is also the visible energy and can be considered as a wave or a particle since it maintains properties of both, but in this discussion light is considered to be a wave and thus obeys the properties of a wave.

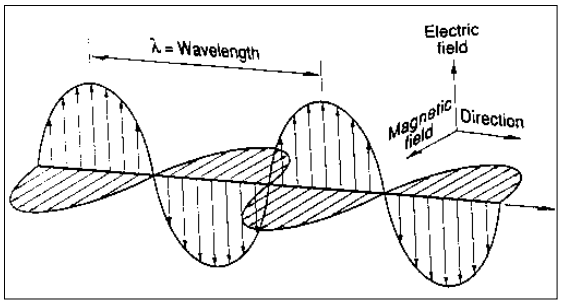


Figure 2.1: Light wave propagation. Source: (Bhusal, 2008).

2.2.3 Characteristics Light Energy:

The ability of light to travel in straight line between two points is a known characteristic. Light is reflected absorbed, transmitted and when it strikes a plane. (Addington and Schodek, 2005).

According to Stein (2006), the sun's energy can be broken down and categorized by wavelength and frequency. The light that enables vision is defined as visually evaluated radiant energy and makes up a very small portion of the wave energy spectrum. Figure 2.2 shows that the light energy of this portion of the spectrum ranges in frequencies of 380 -780 hertz (Hz). The color spectrum: violet (380 Hz), indigo, blue, green, yellow, orange, and red (780 Hz). A green blade of grass absorbs red and blue light but reflects green light which is why it appears green in color to the eyes (Stein, 2006).

2.2.4 Interactions of light with Materials in architecture.

According to Baker (2002), materials are a necessity of architecture and to create dynamic buildings it is necessary to understand the impact that light can have on materials and their design into a building. Buildings are done with light just as with materials, the difference is that materials are tangible while light is emotional (Baker, 2002).

In Figure 2.3 and Figure 2.4 respectively, light interacts with materials in three ways: reflection, absorption, and transmittance. When light hits the surface of a material it can be reflected or absorbed. In a perfect world white would have a reflectance of one and black would have a reflectance of zero and the opposite would be true considering absorption. In the real world all materials reflect and absorb light.

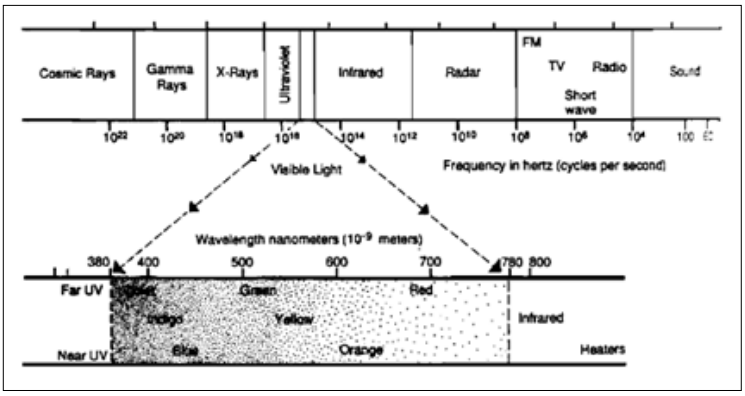


Figure 2.2: Solar energy spectrum and visible spectrum. Source: Stein 2006.

However Baker (2002) agreed that light can also be transmitted only through transparent or translucent materials such as glass. Baker (2002) also noted that, in transparent materials light is also reflected and absorbed but the absorption takes place within the material and the amount of absorption is dependent on the thickness of the material. Figure 2.3 shows that even though a light source is directly hitting a surface it is either reflected or transmitted as an evenly distributed hemisphere of light. Just as

materials can both absorb and reflect light, they can also have both specula and diffuse properties. A surface treatment such as a varnish or gloss applied to secularly off the surface treatment but some light will also transmit through the varnish and reflect diffusely off the material surface. Partial light-scattering can influence specula properties by smoothing out the reflected or transmitted light, making it appear fuzzy and out of focus. This can be accomplished through surface treatments such as sand-blasting glass or brushing aluminum. White Black Brushed anodized aluminum Sanded glass (Baker 2002).

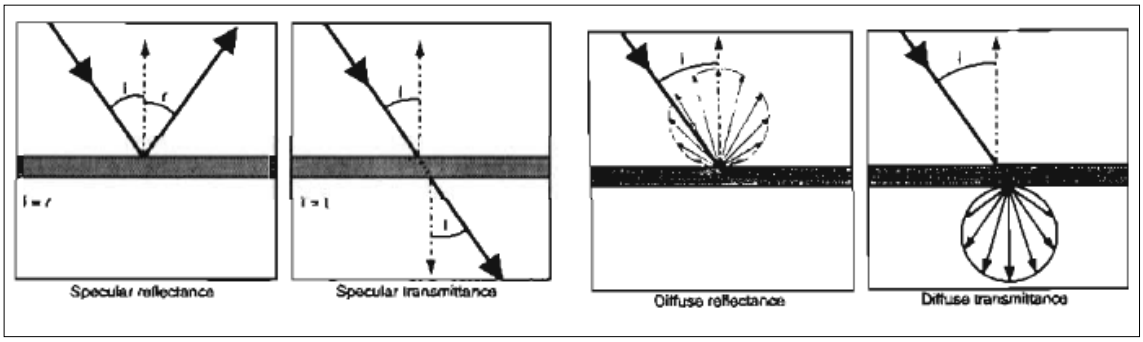


Figure 2.3: reflectance and transmittance. Source: Baker, (2002).

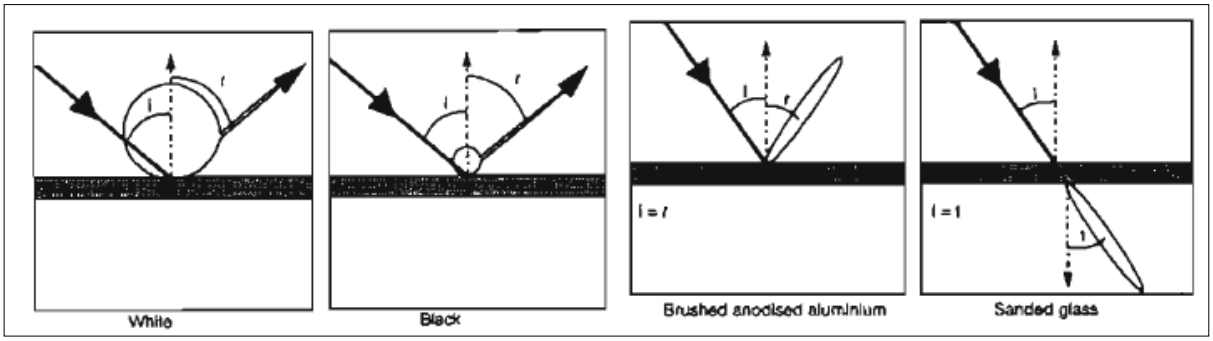


Figure 2.4: Examples of partial light-scattering. Source: Baker, (2002).

2.3 DAYLIGHT AND DAYLIGHTING STRATEGIES

Ander (2012) defined Daylighting as the controlled admission of natural light, direct sunlight and diffuse skylight into a building to reduce electric lighting and saving energy. By providing a direct link to the dynamic and perpetually evolving patterns of

outdoor illumination, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs (Ander, 2012). Michaelidou (2012) further noted that Daylighting can significantly improve life-cycle cost, increase user productivity, reduce emissions, and reduce operating cost. Day-lighting can save considerable money which is utilized for purchasing ballasts, fixtures and controls for artificial lighting (electricity) and increases user comfort and satisfaction, leading to improved performance. Daylight also reduces emission of greenhouse gases (GHGS), slows fossil fuel depletion and total energy costs by one third, than that of artificial lighting.

Daylight is a full-spectrum source of light to which human vision is adapted. Recent studies by have shown that proper daylighting of a building can increase productivity, decrease sick time and even increase sales. Daylighting has two general benefits: it can improve the quality of light in a space and reduce the amount of electrical lighting required.

2.3.1 Daylight Design Criteria in buildings

In a study by Sandanasamy et al (2013), it was noted that the climate, geographic location, building type and client preferences will influence the design of daylighting in buildings. Sandanasamy et al (2013), put forward the following guidelines in designing a building for the penetration of maximum daylight:

1. Avoiding direct sunlight and skylight unless needed for thermal comfort;
2. Bouncing of daylight to create indirect daylight;
3. Bringing daylight from above to obtain deeper penetration;
4. Filtering of daylight into buildings;
5. Using of sustainable design principles ;

i. Energy : the usage of renewable energy source (Sun, Wind or water).

ii. Minimize the consumption of artifical light.

iii. Land Use: It is not a 'commodity', it is the base of life.

iv. Local Material: Renewable local materials have to be used.

6. Maximizing ceiling height to gain better light distribution;
7. Providing separate view glass from daylight glass;
8. Determining whether daylight is primary or supplementary in lighting design ;
9. Adopting combined external and internal controls;
10. Proper planning of building geometry and interior space;
11. Creating low contrast between window frame and adjacent walls to reduce glare and improve vision;
12. Integrating artificial lighting with day-lighting through control systems.

2.3.2 Daylight Strategies

According to Bennett (2008) all Daylighting strategies make use of the luminance distribution from the sun, sky, buildings, and ground. Daylight strategies depend on the availability of natural light, which is determined by the latitude of the building site and the conditions immediately surrounding the building, e.g., the presence of obstructions. Daylighting strategies are also affected by climate; thus, the identification of seasonal, prevailing climate conditions, particularly ambient temperatures and sunshine probability, is a basic step in daylight design. Studying both climate and daylight availability at a construction site is key to understanding the operating conditions of the building's facade. According to Lechner (2001) Daylight strategies depend on:

i) The availability of natural light (based on latitude of the building site and surrounding conditions of the building);

ii) Climate;

iii) Orientation of buildings.

2.3.2.1 Daylight Accessibility

Bennett (2008) also noted that for effective and efficient daylight design, there must be enough of the day light. The daylight availability is mainly influenced by the luminance levels and patterns of the sky conditions as shown in Figure 2.5 to 2.7 below under these different sky conditions Light level varies. Peter (2010) revealed that the Overcast skies **i**n Figure 2.5 produce even diffuse light over the sky dome. Light coming from over head, is three times brighter in overcast skies than light coming from the horizon. This is so because the cloud density is thinnest directly above, in zenith, and gets denser as the clouds compact towards the horizon. When ignoring the direct sun rays, the overcast sky is actually brighter than a clear sky because of the amount of reflected light off the clouds. The illumination from an overcast sky is therefore fairly constant throughout the day and is strongest in its zenith (Brown, 2001).

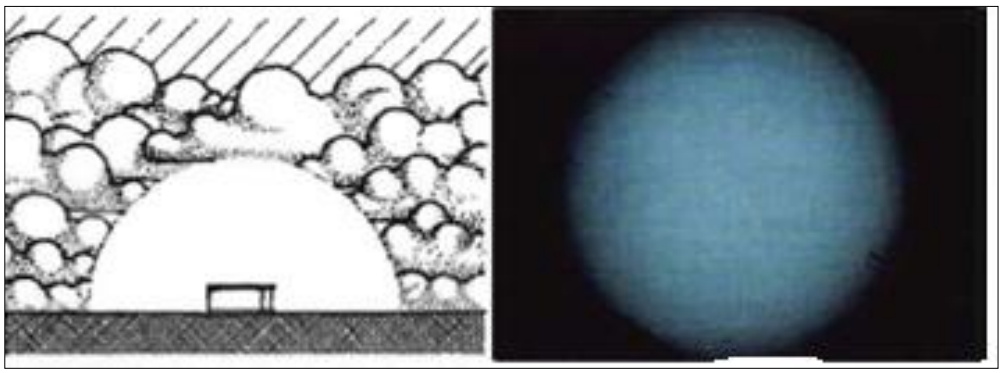


Figure 2.5: Overcast sky conditions. Source: Brown (2001)

Brown (2001) said Clear skies are opposite of overcast skies, and are three times brighter at the Horizons then they are in zenith as shown in Figure 2.6. Brown (2001) however said this is because only a certain amount of sunlight can come from above but

it accumulates as it approaches the horizon. However, Lechner (2001) noted that due to the sun's strong rays the amount of illumination varies depending on the position of the sun in the sky and for better daylight design the use of side lighting techniques that emphasize the vertical light for clear sky conditions and top lighting techniques which take advantage of the horizontal lighting for the overcast sky, is most preferred.

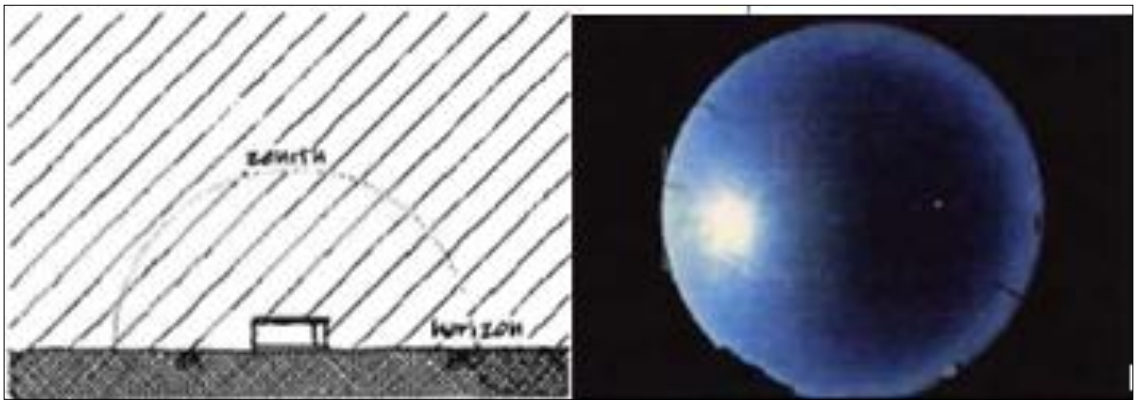


Figure 2.6: Clear of sky conditions. Source: Brown (2001)

The partly cloudy sky in Figure 2.7 is the most common type of sky condition. This condition is the most variant because it is classified as an overcast sky with sunny spots to a clear sky with a few small clouds. Since the sun position can be determined, illumination levels vary throughout the day.

Clear skies with clouds will be very bright due to the direct rays and the reflectance off the clouds. Overcast skies with sunny spots will vary in illumination levels across the sky dome due to the dispersed cloud cover. It is important in daylight design to know what type of sky condition is prominent to your site. Sky conditions can vary between the seasons and if so, multiple types of sky conditions must be accounted for in the design.

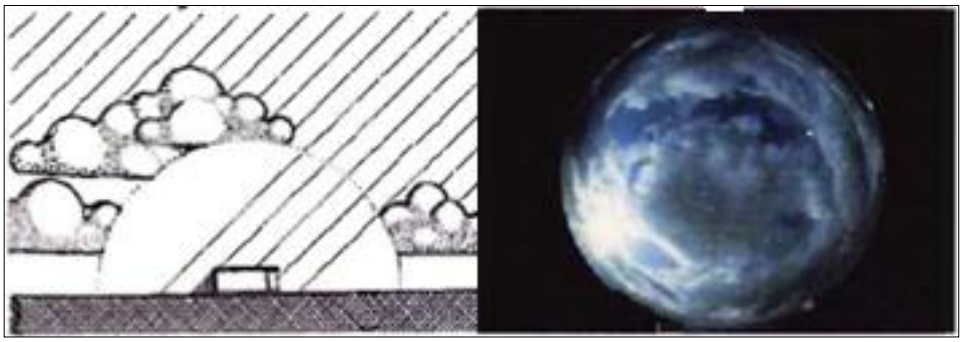


Figure 2.7: Partly cloudy sky conditions. Source: Brown (2001)

2.3.2.2 Building Depth in Relation to Natural Light Inflow;

In Figure 2.8 Reinhart, (2009) noted that the amount of sunlight reflected about an interior is determined by the size and shape of apertures in the spatial envelope – as they relate to the proportions of a room.

Reinhart, (2009) further stated that the extent daylight will penetrate deep into a room depends on the height of the top of the window from the floor level. When planning for good daylighting, it is proper to consider the illumination provided by the sky rather than direct sunlight, which is often undesirable. (Reinhart, 2009)

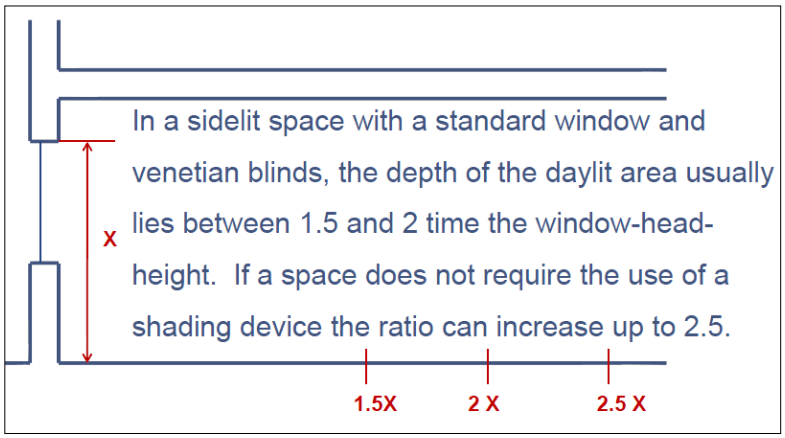


Figure 2.8: Daylight distribution and room depth Source: Reinhart, (2009)

2.3.2.3 Daylighting System for Light energy efficiency

Plate I below shows how natural lighting was integrated in the construction of early great structure like the Roman Pantheon with its dome-top *oculus*.



Plate I: The roof lighting of the roman pantheon. Source; (Yilmaz, 2004)

Dudek (2014) noted that Daylighting systems harvest the available daylight and distribute it inside the room and grouped into two general categories; the top-lighting systems and the side-lighting systems. Top-lighting systems distribute the available daylight inside the room from the ceiling or the roof of the room and side-lighting systems distribute the available daylight from the sides of the room. Side (Wall) Lighting are mostly opening through walls to harvest useful daylight and includes; windows of various shapes, sizes, treatments and composition of shadings.

a. Windows

The levels of light in a room with side windows are higher near the window and lower away from the window. The height of the window in a space can affect the depth of illumination with daylight. For example in a case of a classroom with a low ceiling and grade depth could experience a gloomy feeling due to the disparity in light levels between the back of the room and the peripheral area near the window. In such case an

effective strategy for the illumination of a classroom can be achieved by making the depth as much as 2 ½ times the height of the window above the working area (Dudek, 2014).

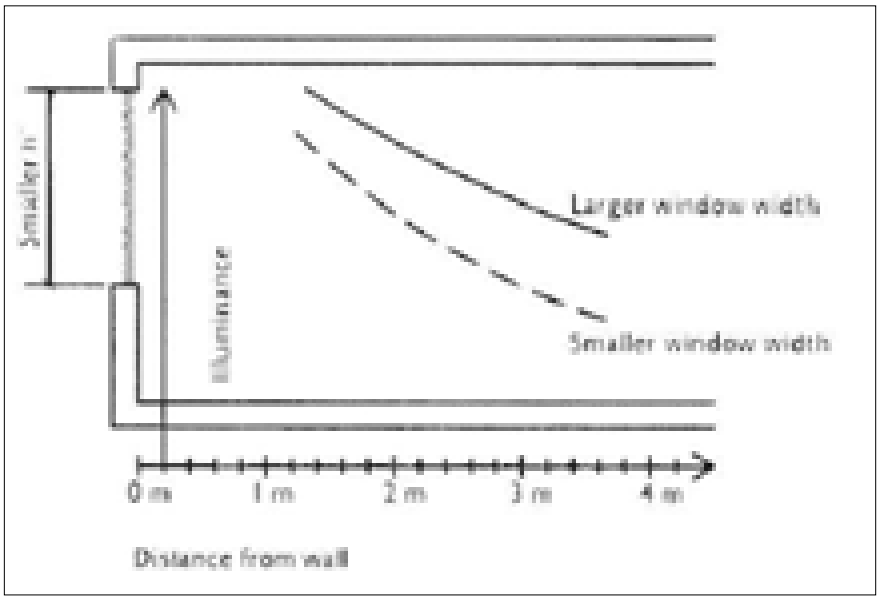


Figure 2.9: Cross-Section of smaller openings Source: Dudek (2014)

In the Cross-Section of opening shown in Figure 2.9, a narrow window allows narrow daylight distribution in the space; the affected area depends on the height of the window. Also, in the Cross-Section of opening shown in Figure 2.10 a large window allows a wider daylight distribution in the space; again the affected area depends on the height of the window.

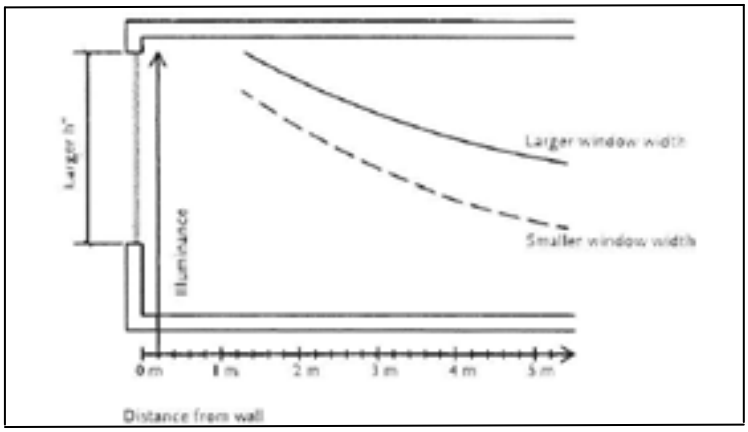


Figure 2.10: Cross-Section of Larger opening Source: Dudek (2014)

For example, a classroom with a ceiling height of 3.5 meters, which is the usual for a classroom, and desk height 0.75 meter, if the top of the window is 2 meters above desk height, the area that is adequately daylit is approximately up to (2 x 2.5 meters) 5 meters deep from the wall.

b. Light shelves;

Michaelidou, (2012) emphasized that in designing a room with side windows, an architect should give attention in order not to create areas near the windows that are going to be "very brightly lit" with areas at the back of the room that are poorly lit. Light shelves could prove a good solution for this problem. Figure 2.11 describe how light shelf is designed in such a way that the clerestory portion above the light shelf catches sunlight or diffuses daylight reflecting it towards the back of the room away from the window. In Figure 2.12 the protruding portion of the light shelf, in the case of a combined or exterior light shelf, acts also as a shading device and prevents sunlight from falling directly on the work plane. Moreover it prevents glare and minimizes the brightness near the window, making the light levels in the room uniform. The clerestory portion of the window should be made of clear glass for maximum daylight harvesting,

while the lower portion below the shelf (referred to as the view window) be tinted to reduce glare. Michaelidou, (2012) further noted that the light shelve as in Figure 2.13, can solve problems at once if it extends past the face of the building.



Figure 2.11: Daylight distribution with light-shelf Source: Autodesk.com (2011)

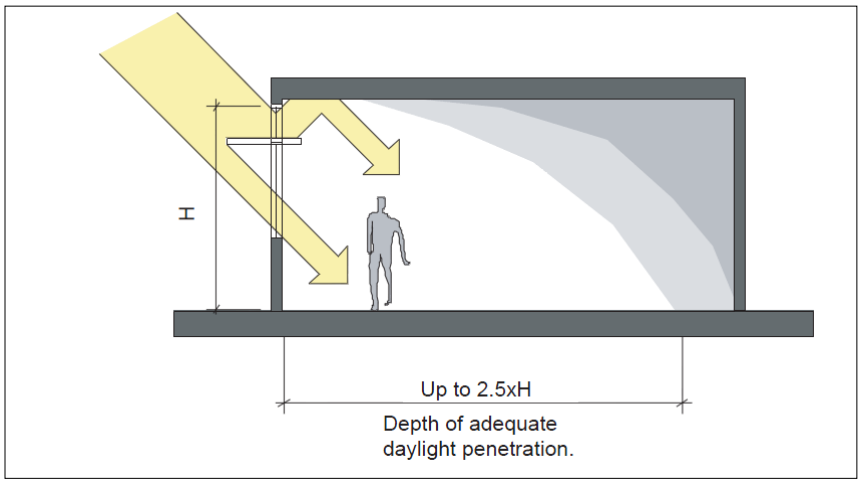


Figure 2.12: Cross-Section of Light Shelve principle. Source: Keith (2003)

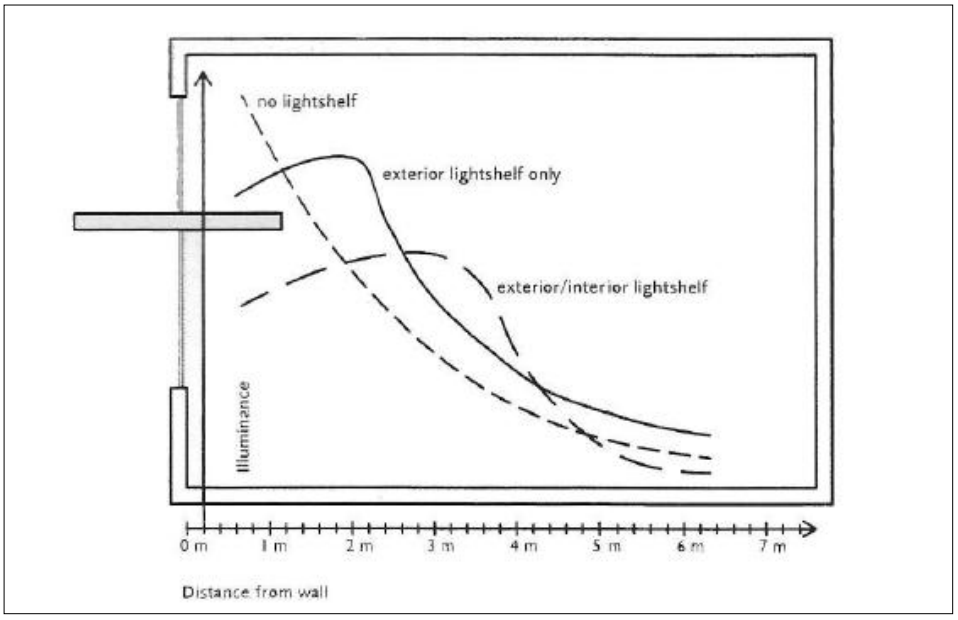


Figure 2.13: Daylight distributions. Source: Dudek (2014)

c. Clerestory windows

Dudek, (2007) defined it as mostly high-level openings on walls and have the ability to distribute natural light deep in to the room providing a balanced light distribution in to the space. The relationship between illumination from side window and clearstory depends on their size, height and position. The example in Figure 2.14 is a typical narrow window arrangement for clerestories; the recommended depth from the plane of the clearstory to the opposite wall is about equal to the distance from the mounting height of the clearstory above the work plane level. For wider clearstories the depth could be one and a half the mounting height. To obtain adequate and more uniform daylight distribution, the height of the clerestory window should be about one half the side wall window heights. Moreover not only does the height of the clerestory windows affect the depth of the daylight distribution in the space, but also the width (Dudek, 2007).

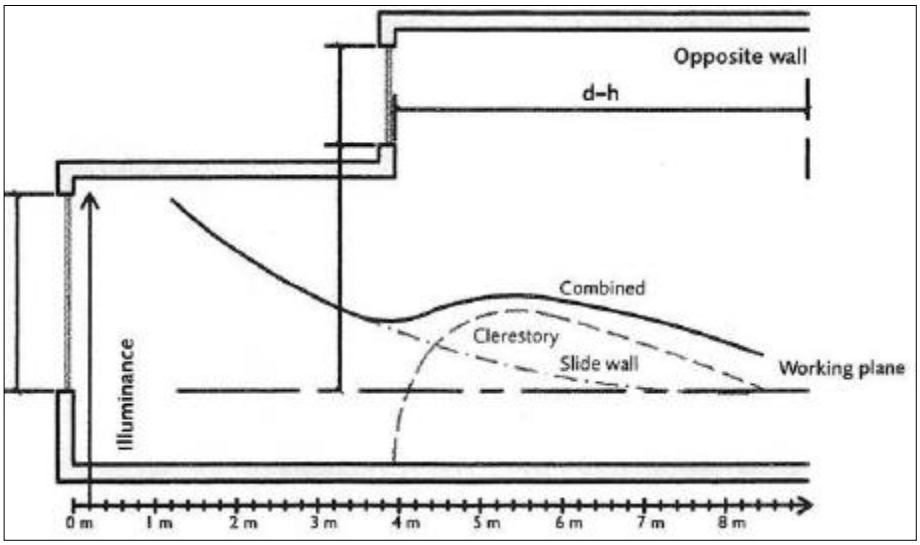


Figure 2.14: Clerestory window Source: Dudek (2014)

2. Roof or top-lighting; the roof component of the building envelope to provide the controlled use of the sun and daylight to offset much of the normally high internal lighting load. In Figure 2.15, there are a variety of methods of introducing diffuse, low-glare daylight from the roof level, including skylights and roof monitors. Roof monitors in Figure 2.16 are another good daylight strategy for a large room when uniform light distribution is desired is the roof monitor. Roof monitors bring in light from above from two opposite directions Henceforth directionality of light is minimized and uniformity is maximized. Roof monitors can be designed to allow sunlight in winter if desired and block it in the summer when not desired (Dudek, 2014).

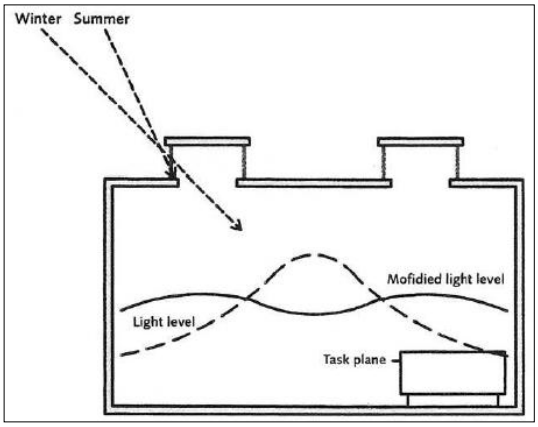


Figure 2.15: cross-sections of roof light Source; Dudek (2014)

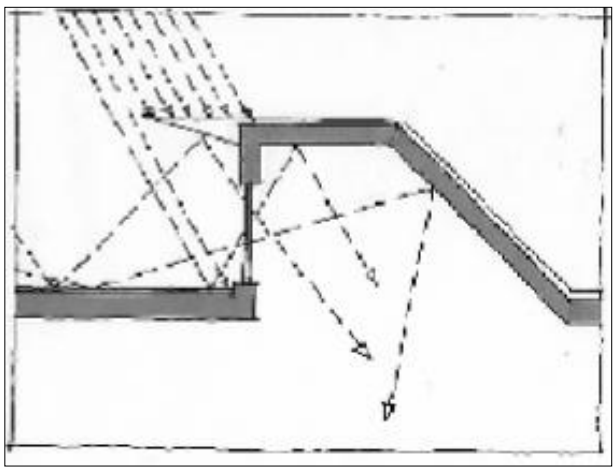


Figure 2.16: Detail of roof light Source; Dudek (2014)

a. Light Tube; Figure 2.17 shows light tube (also known as a solar tube or tubular skylight) as a tube that brings light from the roof to a room inside the house. One end of the tube has a clear dome that is mounted on the roof to allow in sunlight from any angle. The sunlight is directed down the tube, as in Figure 2.17 which is lined with highly reflective material that carries the sunlight to a diffuser mounted at the ceiling. In Figure 2.17 and Figure 2.18 the diffuser distributes the light inside the room. Light tubes can save energy by replacing electric lights for daytime light in rooms that do not have windows. Energy savings can be lost however if the tube is not air sealed and insulated (Dickson, 2014).

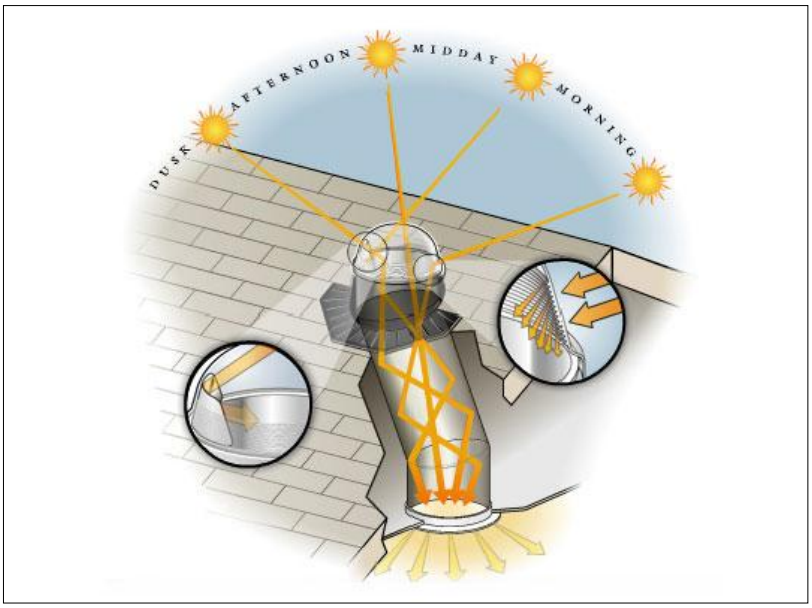


Figure 2.17: Light tube Source: Dulley (2006)

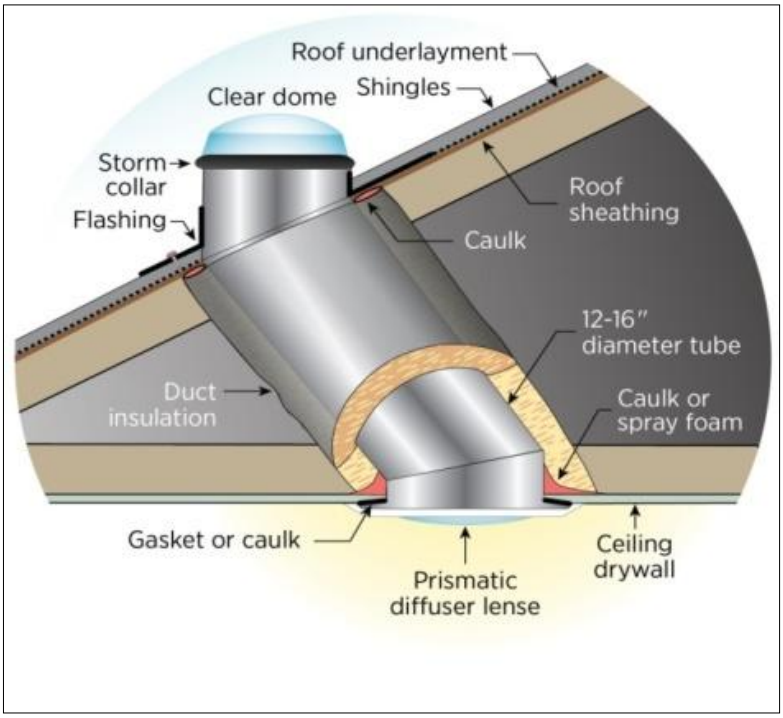


Figure 2.18: Cross-section of light tubes Source: Dulley (2006)

Light tubes can represent a significant amount of surface area that is exposed to unconditioned attics. The metal or flexible tube needs to be air sealed at both ends and along all seams and it should be insulated.

b. Anidolic duct: according to Michaelidou (2012), Anidolic daylighting systems (ADS), is typically a facade-integrated collector system as shown in Figure 2.19 with an adjacent horizontal-mirror light duct inside the building, are particularly interesting because they perform well in both sunny and overcast sky conditions. Anidolic systems are designed in such to collect the incident sunlight that falls on an entry aperture and concentrate it on a smaller exit aperture where the receiver is placed. The receiver is a light reflecting material controlling beam output through well-defined beam spread as shown in Figure 2.20. The protruding portion of the system in Figure 2.21 acts as a solar collector and concentrator. It collects large amounts of sunlight through the entry aperture and concentrates it onto a smaller area where the diffuser or distributor is located near the exit aperture. The distributor spreads daylight over a larger area further away from the side wall window (Michaelidou, 2012).

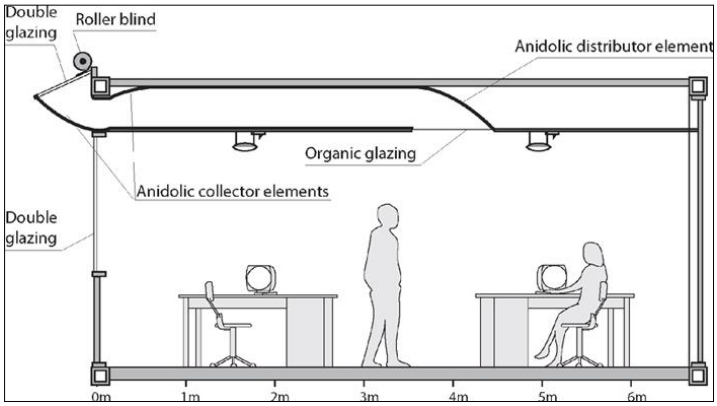


Figure 2.19: Section of Anidolic duct in a room Source; Dudek (2014)

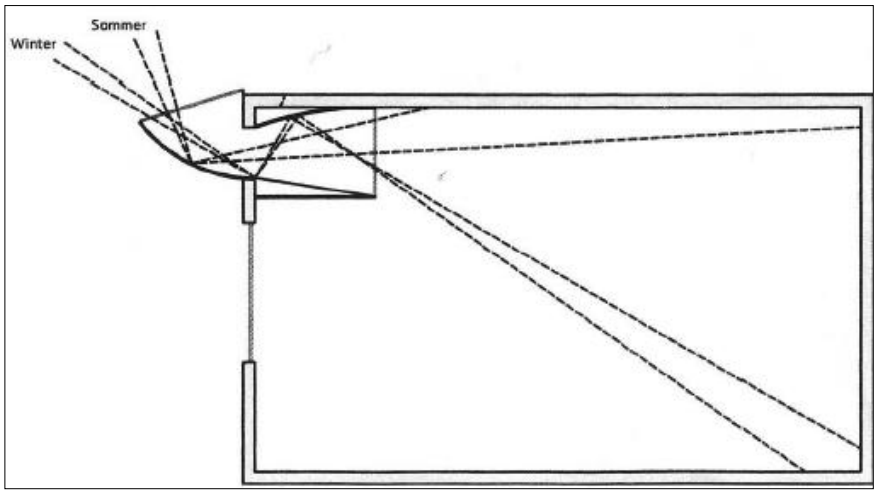


Figure 2.20: Anidolic duct in a room Source; Dudek (2014)

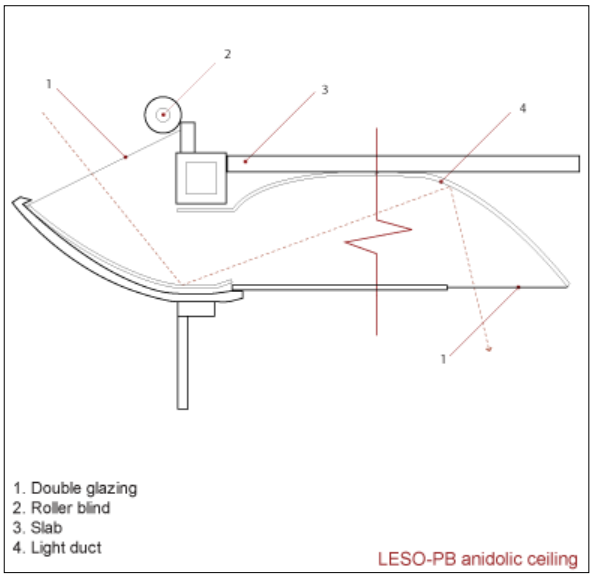


Figure 2.21: Anidolic beam Collector and distributor Source; Michaelidou (2012)

2.3.3 Daylighting Design and Green Building Codes

The U.S. Green Building Council (USGBC, 2012) developed the Leadership in Energy and Environmental Design (LEED) rating system. Under the Indoor Environmental Quality Credit 8.1, which has four options, one option is to achieve daylight illuminance levels of a minimum of 25 fc (270 lux) and a maximum of 500 fc (5,400 lux) in a clear sky condition on September 21 at 9 a.m. and 3 p.m. Under Credit 8.2, LEED requires a

direct line of sight to the outdoor environment via vision glazing between 30 and 90 inches (0.8 and 2.3 meters) above the finished floor for the building occupants in 90% of all regularly occupied areas (USGBC, 2012).

The British rating system Building Research Establishment Environmental assessment Method (BREEAM) in the UK, the Chartered Institution of Building Services Engineers (CIBSE) established Lighting Guide 10 (LG10-1999) Average daylight factor fewer than 2% – Not adequately lit – artificial lighting will be required. Average daylight factor between 2% and 5% – Adequately lit, but artificial lighting may be in use for part of the time. Average daylight factor over 5% – Well lit – artificial lighting generally not required except at dawn and dusk, but glare and solar gain may cause problems (CIBSE, 2012). The Pearl Rating System, it was created by the Abu Dhabi Urban Planning Council's Estidama, Demonstrate a minimum daylight illuminance of 250 lux on the working plane (762 mm from finished floor level) for a percentage of the occupied area, as follows: 1 credit point: 50% of the occupied area 2 credit points: 75% of the occupied area (Etidama, 2010).

2.3.4 Intelligent and smart material technology for daylighting.

In order to make buildings more energy-efficient, an extensive set of "energy-saving building components" has been developed that contributes to minimizing the energy need of buildings, that helps buildings to access renewable energy sources, and that helps buildings to utilize fossil fuels as efficiently as possible (Addington and Schodek, 2005). Examples of such energy saving building components are advanced glazing systems, thermal insulation layers, photovoltaic etc.

Smart materials and systems are divided in two classes, according to their behaviors until energy stimulus from surrounding environment:

Type 1 materials are those that have capability to change their properties - chemical, Mechanical, electrical, magnetic or thermal, including thermo-chromic, magneto-rheological, thermo-tropic, shape memory alloys. The energy input to a material affects the internal energy of the material by altering the material's microstructure and the input results in a property change of the material.

Type 2 materials are those that have capability to transform the energy from one form to another, including photovoltaic, thermoelectric, piezoelectric, photo-luminescent and electrostrictive. The energy input to a material changes the energy state of the material composition, but does not alter the material, it stays the same, but the energy undergoes a change (Addington 2002).

2.3.5 Smart glass or switchable glass

According to Addington and Schodek (2005) they are glass or glazing whose light transmission properties are altered when voltage, light or heat is applied. The glass changes from translucent to transparent, changing from blocking some (or all) wavelengths of light to letting light pass through. The technology includes electro chromic, photochromic, thermo chromic, liquid crystal devices, suspended particles, and micro-blinds. Architectural products made with these technology helps to:

i. Eliminate blinds and shades
ii. Preserve daytime and nighttime views
iii. Allow people to enjoy shading on-demand
iv. Minimize glare

v. Reduce heating and cooling requirements

vi. Maximize daylighting

vii. Protect interior furnishings and artwork from fading

2.3.6 The smart window

The term ‘smart window’ according to Begemann (2006) is been applied to any system that purports to have an interactive or switchable surface, regardless of whether that surface is a real or virtual window, interior or exterior. ‘Smart’ windows will typically possess one or more of the following functions:

i. Control of optical transmittance. A shift in the transparency (the optical density) of the material may be used to manage the incident solar radiation, particularly in the visual and near ultraviolet wavelengths. The window would vary from high density (opaque or translucent) for the prevention of direct sun penetration and its associated glare to low density (transparent) as incident light loses intensity.

ii. Control of thermal transmittance. This is a similar function to that above, but the wavelengths of interest extend into the near infrared region of the spectrum. Heat transmission by radiation can be minimized when appropriate (summer) and maximized for other conditions.

iii. Control of thermal absorption. Transparency and conductivity tend to correlate with each other, but are relatively independent of the incident radiation.

iv. Control of view. The use of switchable materials to control view is currently the fastest growing application of smart materials in a building. Interior panels and partitions that switch from transparent to translucent allow light

to transmit, but are able to moderate the view by altering the specularity of the material. Exterior store fronts can reveal merchandise in windows selectively, perhaps only when the store is open. A specular material will transmit intact images, whereas a diffuse material will obscure the image. (Begemann, et al 2006).

2.3.7 U Values

The 'U' value of a double glazing window is the measure of its ability to transfer heat – so double glazing windows with the lowest U value are the most efficient insulators against heat loss or gain in a room.

2.4 DAYLIGHT IN LIBRARY BUILDING

2.4.1 Introduction

A library is simply an institution of books collection and other informational materials made available to people for reading, study or reference. However, library collections have almost always contained availability of materials (sources, resources and services) (Halsey, et al, 2009). One can imagine the level of discomfort that would be experienced having to study during the daytime in an environment such as this. Studies have shown that enormous body heat is being generated when reading (human metabolic activity) (ASHRAE Fundamentals 2005). Libraries in Africa traced their origin to the desire of European colonist to have access to the information resources of their home countries. As a result, the Libraries were established typically to provide access only to specialized groups of European descendants and to elite Africans not to the general public (Halsey, et al, 2009).

Libraries today are accessible to the general public. In many situations, they are either over crowded, misused or an uncomfortable study environment and this is either due to poor design (sick building syndrome) or harsh climatic influences (ineffective thermal control systems). The use of natural light has conventionally been an enviable building feature and a characteristic of good design. Daylight can provide a welcome and dynamic contribution to the human experience in buildings and, as demonstrated in recent studies on schools and retail sales environments, can impact human performance (Heshong MahoneGroup, 1999). Dean (2005) noted that a library building must be adequately illuminated for the user to see a particular task, usually reading a book or the text on a computer screen. Also illustrated in Figure.2.22, the first requirement is then for enough light energy, or *lumens*, distributed over the area of the page or the screen so that the information can be readable, meaning, the light density or intensity on the reading surface must be a minimum amount; the unit of light density or *illumination* is the *foot-candle*. Dean (2005) also noted that;

"Well-designed daylighting should be a design objective for any library project because of the obvious benefits."

2.4.2 Illumination levels for Libraries

Light level or illuminance is the total luminous flux incident on a surface, per unit area. (Engineering toolbox, 2011).

A similar definition by Illuminating Engineering Society of North America, (IESNA, 2000) as cited in National Renewable Energy Laboratory (2005) states that illuminance is defined as the area density of the luminous flux incident at a point on a surface this is illustrated in Figure 2.22.

Illuminance is a measurement of radiation as sensed by the human eye. Every human eye senses radiation slightly differently, but a standard spectral response curve is defined by the Commission International de Éclair age (CIE, International Commission on Illumination as cited in National Renewable Energy Laboratory, Op cit). The lux is used to measure the adequacy of lighting for a task (Wulfinghoff, 1999).The metric unit of illuminance is lux (in the metric SI system) which is the number of lumens per square meter (IESNA, op cit). Another unit is the foot candle (ftcd, fc, fcd), which is the number of lumens per square foot. Thus;

1 lux = 1 lumen / sq meter = 0.0001 phot = 0.0929 foot candle (ftcd, fcd)

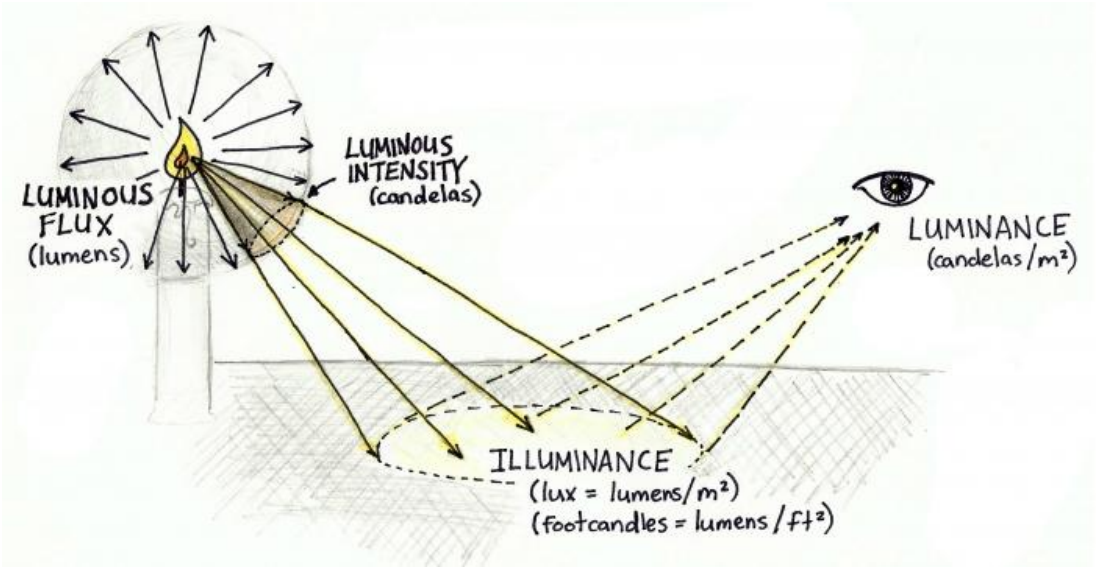


Figure 2.22: Light measurement Source; Autodesk, 2014

The outdoor light level is approximately*10, 000 lux* on a clear day (see Table 2.2).

Inside the building, at the areas closest to windows, the light level may be reduced to approximately *1,000 lux*. In the middle area it may be as low as *25 - 50lux*. Additional lighting equipment is often necessary to compensate the low levels. (Engineering toolbox.com, 2011). The recommended office lighting levels in the 1930s

were around 269 lux, the 1960 recommended practice for office lighting guidelines advised illuminance levels of between 1076 – 1615 lux (Oldfield, Trabucco, & Wood, 2009). Today the light level is more common in the range *500 - 1000 lux* - depending on activity. For precision and detailed works, the light level may even approach *1500 - 2000 lux* (Table 2.2)

Table 2.2: Common light levels for outdoor at day and night.

	Illumination	
	(ftcd)	*(lux)*
Sunlight	10,000	107,527
Full daylight	1,000	107,527
Overcast day	100	1,075
Very dark day	10	107
Twilight	1	10.8
Deep twilight	.1	1.08
Full moon	.01	.108
Quarter moon	.001	.0108
Star light	.0001	.0011
Overcast light	.00001	.0001

Source: www.engineeringtoolbox.com (2011)

Table 2.3: Recommended light level in different work spaces.

Activity	Illumination *(lux, Lumen/m^2)*
Public areas with dark surroundings	20-50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 -150
Warehouses, Homes, Theaters, Archives	150
Easy office work, classes	250

Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500 (46.45152 ftcd)
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical works	1000
Detailed Drawing Work, Very Detailed Mechanical	1500-2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000-5000
Performance of very prolonged and exacting visual tasks	5000-10000
Performance of very special visual tasks of extremely low contrast and small size	10000-20000

Source: www.engineeringtoolbox.com (2011)

The illuminating Engineering Society (IES) is an independent organization of professionals that sets light level guidelines which serve as the recognized standards for light in building Spaces. The following table provides the illumination levels recommended for library spaces.

Table 2.4: IES Recommended light Levels for Libraries (Foot-candles)

space	recommended illuminance(Foot-Candle Level)
Active (occupied) book stack	See table foot-not a below
Inactive book stacks	30
Book repair and binding	30
Cataloguing	30
Circulation desk and reference desk	30
Computer areas	30
Audio listening areas	30
Reading (Normal size and contrast: newsprint, magazines, keyboards)	30
Reading (very small size and low contrast :fine detail items, small prints)	50

- For book stacks, use vertical foot-candle levels. See the discussion immediately

below.

- At 30 inches above the finished floor level.
- Although this is the IES standard, lighting designers typically prefer 40-50 foot Candles at these desks.
- This should not be used as an excuse to light the whole library to 50 foot candles, just because there is always some low contrast tasks interspersed throughout the library. The higher light level would apply only in specific areas, such as collections of phone books.

Source: Dean (2005)

2.4.3 Book Stack Illumination

According to Dean (2005), book stacks must be lit evenly across the stack face so that titles and call numbers can be easily found and read. The lighting level should be a minimum of 6 foot-candles measured vertically on the face of the book spine at a height of 12 inches above the floor, and a maximum of 35 foot-candles at any height, so that no more than a 6:1 ratio results across the entire vertical face of the book stack. Daylight should be introduced above and behind the patron so that book titles are illuminated without glare (Figure 2.13) and (Figure 2.14) for an example in a built project.

2.5 LIGHTING COST CALCULATIONS AND FACTORS AFFECTING LIGHT MEASUREMENT

Despite numerous attempts to create the metrics of lighting, lighting quality is still dependent on some numerous factors involving space, finishes and the kind activities

(James et al, 2001). However, Stork and Mathers (2009) have categorized lighting calculation into three broad categories which includes the following:

1. Manual calculation methods
2. Three dimensional modeling
3. Visualization

More so, in order that these calculations are done appropriately, some parameters have to be considered which could serve as factors to ensuring a successful lighting calculation. This is particular to a research by Diego et al (2009) indicating some common simulation errors caused by the omission of some details. The details include the following:

i. Accurate dimension of rooms
ii. Accurate dimensions of openings
iii. Thickness of walls
iv. Optical properties of material surfaces.

However, a publication by Christophe (2013) pointed out some elements needed for the calculation of daylight factor. This elements are grouped into two (2).

A. Building data
    i. building geometry
    ii. optical property of material
    iii. status of artificial lighting
    iv. status of shading devices
    v. surrounding landscape
    vi. Ground reflectance

B. Sky condition

i. date and time

ii. geographical site

iii. irradiance data

iv. Sky luminous distribution.

2.5.1 **Daylighting Simulations**

Technology, according to Koutamanis (2004) has been an obvious solution to the increasing complexity of the built environment. There are available computational methods and techniques that aim at a more coherent approach by supporting integration of (day) lighting into architectural designing. It proposes that the two main courses of further action are the improvement and updating building regulations, and the combination of quantitative knowledge of good, existing daylight designs with advanced simulation-based analyses of early design proposals. Improvements in daylighting design and the integration of daylighting in design solutions depend primarily on design guidance based on the coordinated development and thorough understanding of usable measures such as the Daylight Factor, the Daylight autonomy. Lighting designers use this metrics like daylight factor and daylight autonomy to help them optimize and communicate the quantity and quality of daylight within a space. This is important because the availability of daylight can change a lot throughout the day based on sky conditions. A major prerequisite to both simulation and design guidance are robust and detailed geometrical 3D models that accommodate both the input and the output of design actions and transactions (Koutamanis, 2004).

Daylight Autonomy (DA) is the percentage of working hours when lighting needs are met by daylight alone. It is measured by comparing daylight illuminance on a work plane to the minimum requirement over time. This is a very popular metric and can tell you how often lights need to be on to meet specific illumination requirements.

The art and science of usability

Daylighting software is an important component towards creating accurate simulations for sustainable design. Ecotect has been widely used by designers and consultants for its quick and simple analysis in the early design phases. It has many advantages, but only provides two sky conditions: CIE overcast and uniform skies (Karen and Jae, 2011).

Koutamanis (2004) further noted that the transparent, reliable and efficient treatment of daylighting analysis requires the development of a logical and expandable framework that includes both numerical and synthetic image analysis, moreover, intelligent computer simulation can be an unobtrusive, supportive activity in the background of design activities that both identifies potential pitfalls and allows deferment of the solution on the basis of informed opinions (as opposed to unfounded guesses).

2.5.2 **Impact of building form on lighting**

Phoebe (2007) stated that the building form is responsible for how it is perceived. This is particular to a research by Tiberiu et al (2011) were lighting simulations were conducted for different building shapes. The result however showed a difference between a cubical shape and a rectangular one on the lighting visual comfort of more than 30%. Plate II illustrates the lighting simulation carried out on a cubical and rectangular shape with the cubical shape having lesser shadows at corners and otherwise for the rectangular shape.

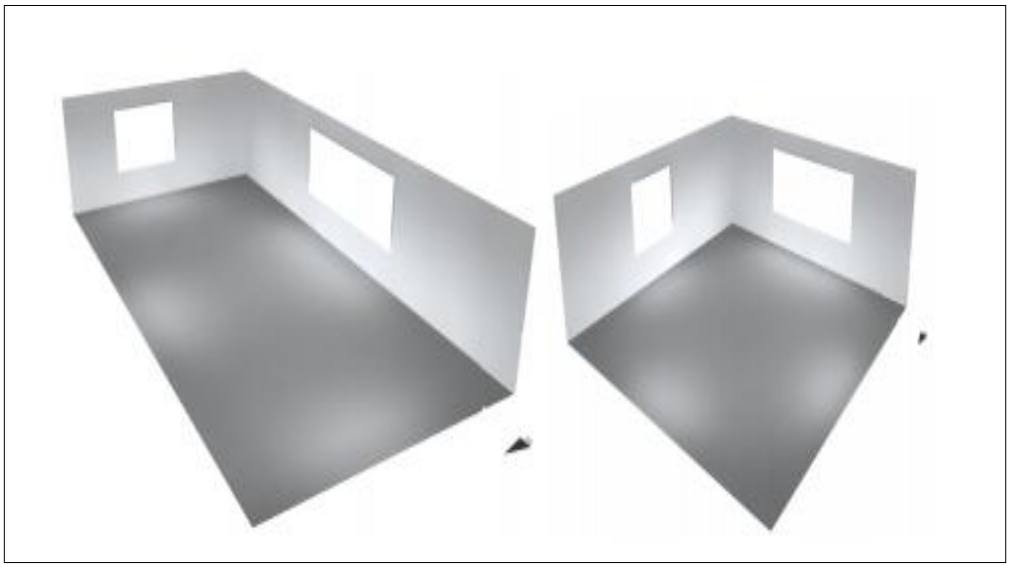


Plate II: Daylighting and artificial lighting in some basic shapes

Source: Tiberiu (2011)

CHAPTER THREE

METHODOLOGY

3.1 **Study Area and Climate**

Kaduna State is located at the North Central Region of Nigeria, lying between latitude $10^0$31'23"N and longitude 7^0 26'25" of the equator. Kaduna was established in 1913 and became the capital city and an administrative headquarters of the old Northern Protectorate. It is situated about 145km/90m in north of the National Capital, Abuja. It has a population size of over 760,084 according to National census 2006. Daytime temperatures can easily exceed 33°C during the dry season (April/May). (climatedata.eu)

Kaduna is home to the Nigerian Defense Academy (1964) Kaduna, Kaduna Polytechnic (1968) Kaduna, Ahmadu Bello University (1962) Zaria, Kaduna State University (2007) Kaduna, and Nigerian College of Aviation Technology, Zaria, Nigerian Institute of Trypanosomiasis Research (1951) Kaduna, The Nigerian Institute of Transport Technology, and etcetera. Making Kaduna state a centre of learning.

3.2 **Research Design**

Oloafe (2010) cited research design to mean the plan, mode or the conceptual structure of a research and the type of approach adopted in the study, which will serve as the blueprint for the measurement of variables, collection and analysis of data. Thus, the evaluative type of research was adopted for this study following the notes of Veal (2006) who cited evaluative research as one which aims at testing effectiveness of projects, policies or programs to determine how they have failed against stipulated standards or targets in order to suggest modifications and alternatives.

The following methods of data collection was used for this study, their relevance and how they were applied to obtain results are discussed below.

The correlated case study research method was used to study and understand Library buildings so as to evaluate the lighting system in them and the calculation of the energy consumption is based on the wattage input consumed by light bulbs.

The following three programs Revit 2014, Autodesk Ecotect 2011 were used and a design for daylight in library was also explored to analyze Daylight Illuminance level, Daylight Factor (DF).

3.2.1 Case studies on Existing Libraries in relation to Daylighting.

Yin (2004) defines case study as an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple source of evidence. However, Veal (2006) noted case study as a dominant factor of architectural research and may be referred to as a research method or unit of analysis which involves the study of an example.

3.2.3 **Case Study Selection Criteria**

The bases for selection of cases are their potential to possess some intrinsic virtues which are in relation with the phenomenon under consideration (Oluigbo, 2010). Hence, the criteria for the selection include the following:

i. The cases were predominantly Library buildings with peculiar lighting issues. Except otherwise, and then buildings with similar functions were analyzed.

ii. The cases had to have some features related to the issues been studied, which will aid in analyzing the building form.

From the above listed selection criteria, the selected cases were selected due to their inherent qualities which are in line with the study area, they include;

1 National Library Kaduna

2 Kaduna State Library

3 Isa Kaita Library, Kaduna Polytechnic main campus

3.2.4 **Data Type and Sources**

3.2.3.1 Primary Data: The primary data of this research is the first hand data collected from the different Libraries in the study area; it involves personal observation of the case in the Libraries and data collected with the aid of observation schedule.

3.2.3.2 Secondary Data: The secondary data of this research is the data collected from the review of relevant literatures such as journals, textbooks and relevant publication on Natural Lighting, its principles and method of application. Most of the secondary data was collected from the internet.

3.2.5 **Data Collection Instruments**

Oloafe (2010) listed some instruments of data collection including the use of questionnaires, tests, observations, audio and video recording, among others. As such, the instruments used for data collection in this research include;

3.2.4.1 Model and Simulations: This involves producing a 3-dimentional sketch of case study structures (using Autodesk Revit 2011) in order to carry out illuminance simulations. According to Karen and Yong (2011) Ecotect has been widely used by designers and consultants for its quick and simple data provision and analysis.

3.2.4.2 Visual survey of Existing Libraries

A field survey and visual survey of cases was done by looking and identifying what has been achieved by the already existing Libraries with reference to elements that allow natural light into the work and reading areas and this was done by the use of photographs and checklist as guide for getting the needed data.

3.2.4.3 Light Energy Use Analysis (Calculating Kwh)

According to Horvey (2013), counting watts is the key to lowering the cost of energy in buildings. In order to determine the savings, it is good utilize the wattages to determine the kilowatts / hour. We do this with the following equations:

FQ x FW/1000 = tkW……..Equation (1)
Where; FQ = Fixture Quantity, FW = Fixture Wattage, tkW = Total Kilowatts

Then, the kilowatt used over daytime operational hours otherwise known as Hours of Usage is derived from equation 2 below:

kW x HrU = kWh ……Equation (2)
Where; kW = Kilowatts, HrU= Hours of Usage, kWh = Kilowatt/Hour

Also, the kilowatt used over daytime operational hours otherwise known as Hours of Usage and the cost of energy in Naira is calculated thus:
Kw/Hr x Ec +FxC = AEc……Equation (3)
Where; Kw/Hr= Kilowatt/Hour, Ec = Cost of Energy, FxC = Annual Fixed Charge, AEc = Annual Energy cost

This data will give the cost savings for periods of the day when artificial light are not in use due to efficient and adequate daylight design system.

3.2.6 **Data presentation and analysis**

Data collected on each case study were analyzed and represented in different forms which include:

i. Figures and plates; Data collected on the case studies were also documented in form of drawings, such as the site plans and floor plans and picture of the building elements investigated like the types of openings were documented as plates.

ii. Tables, Graphs; Data collected on this research was documented and presented on case study assessment tables and graphs to show relationships between variables.

3.3 Validity and Reliability of Research Instruments

Oloafe (2010) opined that for any study to be acceptable as scientific or empirical, the research instruments must exhibit an appreciable measure of validity and reliability. As such, the simulation process was illustrated using a similar approach for day lighting.

Studies conducted by Karen and Yong (2011) shows that using different Daylighting simulation software programs gives different simulation results. The following three programs were used: Ecotect, AGI32, and 3ds Max Design (lighting analysis).

3.4 Variable of Study

The analysis of the various components of each building was based on the research variables which are dependent and independent variables. These variables are used to create a checklist that is used on the field survey.

Dependent variables: The dependent variables in this research were based on the following parameters gotten from the literature review as cited by Christophe (2013).

Building data:

i. Building geometry which is inclusive of the

a. Surface area-volume ratio

b. Shape of building form and elements

c. Depth of buildings

ii. Optical property of material surface

iii. Status of artificial lighting

iv. Status of shading device

v. Surrounding landscape

vi. Ground reflectance

Independent variables: The independent variables of this research were based on the parameters gotten from the literature review as cited by Christophe (2013).

Sky conditions:

i. Date

ii. Geographical site

a. Orientation

b. Climate

iii. Irradiance data

iv. Sky luminous distillation

The selected Libraries were to describe the extent to which the design elements for the control of lighting within the spaces were applied. The case study analysis was done with the Potential characteristics to be considered as follows:

i. Window area

ii. Transmittance

iii. Configuration

iv. Room proportions and reflectance

v. Window orientation

vi. Overhangs and obstructions

vii. Local climate conditions.

This can be viewed under the case study summary and conclusion sheets.

The light shelves and top lighting strategies were adopted to maximize the daylight.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 CASE STUDY 1:

National Library Kaduna, Kaduna State

4.1.1 Background

The Library is located along Bida road in Kaduna State Capital. Established in 1952, as a Public Library and funded by the Federal Government of Nigeria. It acts as the Nations intellectual data bank and aid government officers in connecting to policies and help in the implementation of same. The National Library is the country's largest depository of knowledge, collecting publications both from Government, and private authorities. The Opening hours are between 8am-5pm weekdays and 2pm - 4pm weekend. The state falls within the tropical climatic zone; the site is characterized by mostly clear sky in day time and this permits longer hours of sunshine. The average duration of sunshine varies from 6.0 to 9.8 hours.



Plate III: Main entrance (NLK) Source: Field survey (2014)

4.1.2 Site planning, and general building concept

The Site Plan in Figure 4.1 shows that the library building is oriented towards the south-west on having a generous setback off the access road at the main entry.

The building is about 890m^2 in Area. It is made of Reinforced Concrete Frame, glass and steel.

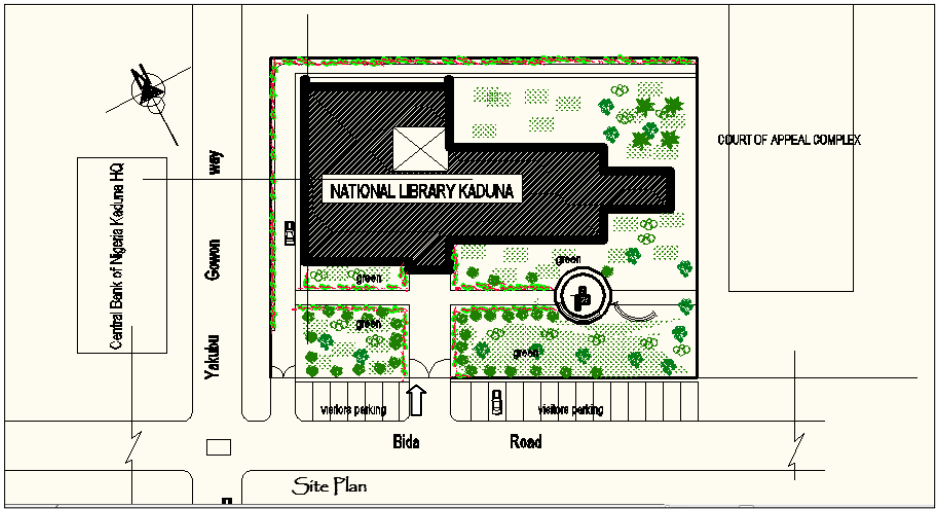


Figure 4.1: Site Plan (NLK) Source: Field survey (2014)

In Plate III shows the main entrance made up of prefabricated concrete and glassed aluminum doors and windows. The roof is covered with alu-zinc, with no provision for roof lighting.



Plate IV: Sun Shading element (NLK). Source: Field survey (2014)

In Plate IV Sun shading screen wall is adapted on the western façade over daylight apertures to minimize direct sun ray and allow in useful daylight.

4.1.3 Spatial organization and space allocation

The entrance to the building opens into the reception/security hall and an exhibition area from where the other units of the building are being accessed. Figure 4.2, the Ground floor houses the Reception/control, Exhibition hall, Main library hall (reference stack and reading area), Staff common room, e-library, offices and Conveniences.

The First floor Plan in Figure 4.3 is linked from the ground floor by stair cases on the east and west ends of the structure contains the serial section, a seminar/holding room, kitchen, a conference hall, office and Conveniences.

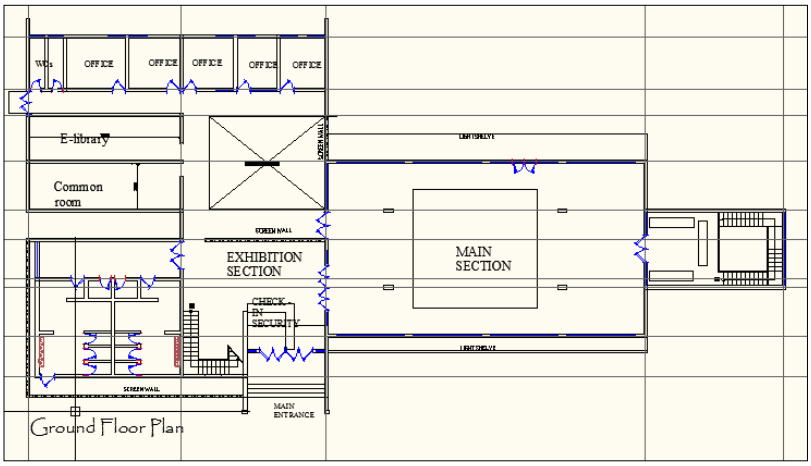


Figure 4.2: Ground Floor Plan (NLK) Source: Field survey (2014)

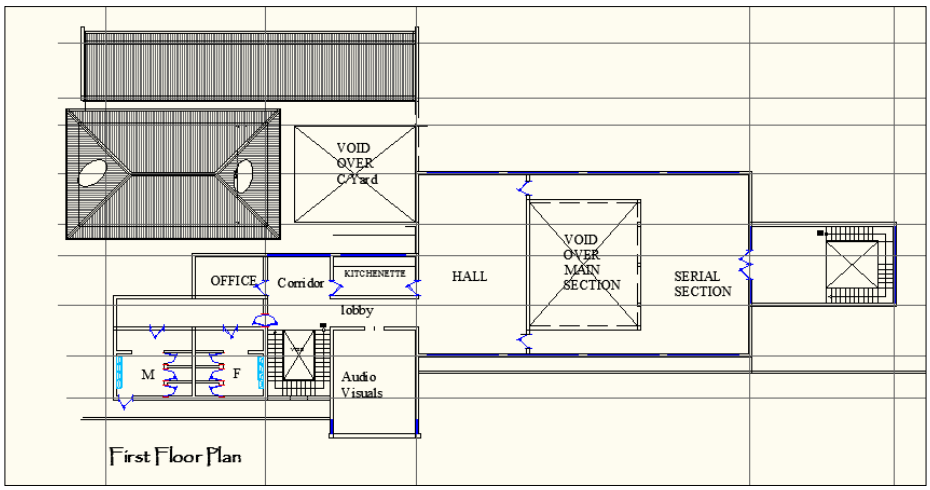


Figure 4.3: First Floor Plan (NLK) Source: Field survey (2014)

4.1.4 Daylight Strategy adopted

The passive control of sunlight is properly used in relation to the building orientation on site. From Plate IV and Plate V the shading elements adopted on the south west helps to reduce solar heat gain, glare and also diffuse the sunlight intensity into the adjourning space as useful daylight. A Court yard is also used to admit daylight and air into the building. Large transparent sliding windows that are both effective for daylight and aeration are employed. The void over the main reference section at the ground floor also allows useful daylight on that floor. The ceiling is made of white color 600mm x 600mm gypsum board. The buildings shape and configuration is also noted as a good design strategy for daylight harvest.



Plate V: Right end of the main entrance (NLK) Source: Field survey (2014)

4.1.5 Variables Considered

Table 4.1: Variables studied in National Library, Kaduna

S/N	SPACE	VARIABLES	OBSERVATION	REMARKS
1	Main Reading Area @ ground floor	Room geometry & orientation	Rectangular, with longer sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	2.8 x 4.6 meters side light aluminum sliding window	Good window head height
		Positions and size of	Stack areas are properly	Do not cause obstruction

		internal barriers	zoned to allow for useful daylight	
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	The east/west ends are properly shaded with screen wall and overhangs	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
2	Government archives	Room geometry & orientation	Rectangular, with glazed shorter sides facing north and south	Direct Sunlight, glare and heat gain contained via orientation
		Area, arrangement of daylight object	3.5 x 3.6 meters side light aluminum sliding window	Good window head height
		Positions and size of internal barriers	Stack areas are properly zoned to allow for useful daylight	Do not cause obstruction
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	ends are properly shaded with screen wall	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
3	Serial/ reference section	Room geometry & orientation	Rectangular, with longer sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	1.5 x 4.6 meters side light aluminum sliding window	Good window head height
		Positions and size of internal barriers	Stack areas are properly zoned for useful daylight	Do not cause obstruction
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	Aluminum louvers and screen walls	Effectively shaded
		Glazing property	Clear glass	Good transmittance

	Sky condition	Overcast mostly	Cloudy season of the year

Source: Field survey, 2014

4.2 CASE STUDY 2:

Kaduna State Library, Kaduna.

4.2.1 Background

The library is located along Bida road in Kaduna state Capital. Established in 1962, as a Public Library and funded by the Kaduna state Government. It serves as the states reference library and it is open between 8am - 8pm weekdays and 8am - 2pm Saturdays to the general public. The state falls within the tropical climatic zone; the site is characterized by mostly clear sky in day time and this permits longer hours of sunshine. The average duration of sunshine varies from 6.0 to 9.8 hours.

4.2.2 Site planning, and general building concept

The building is oriented towards the south-west on site with 8meters setback from Bida road. It has parking arranged to the northern end. Its structure is made up of Reinforced Concrete Frame, wood, glass, steel and has various rectangular shapes connected together by walkways from their separate locations on site. They are no roof lighting. Pattern of sun shading strategies adopted on the western façade includes louvered aluminum luxalon, deep recesses and overhang over the numerous daylight apertures to allow in useful daylight and control heat gain as shown in Plate 4.4 below.

4.2.3 Spatial organization and space allocation

The children lending Library is lying south wards shown in Figure 4.4 below with the Administrative and technical unit, while the Adult section is towards the eastern end of

the site. The reference section is made up of two floors, housing the open reference stack and reading area, mobile resource center, loading bay, bindery, and stack room.



Plate VI: Overhang at children section Source: Field survey (2014)

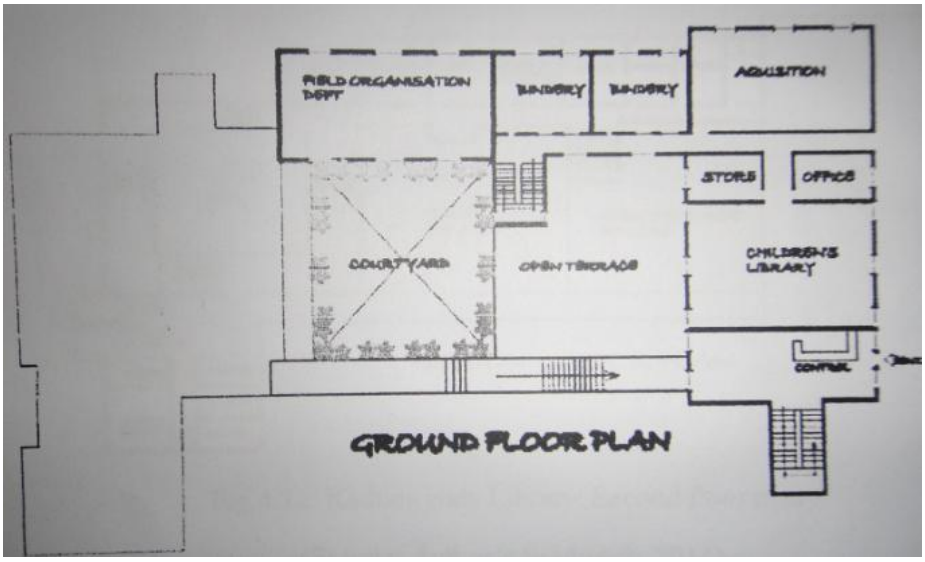


Figure 4.4: Ground floor plan. Source: Field survey (2014)

The first floor as shown in Figure 4.5 contains the technical services section (cataloguing and classification), general office and the accounts section.

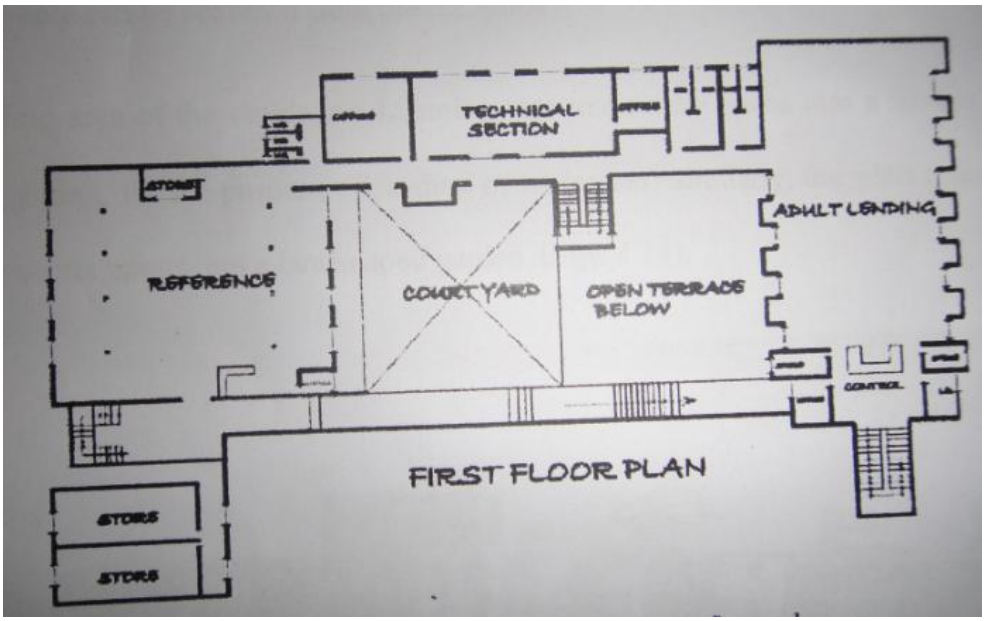


Figure 4.5: First floor plan Source: Field survey (2014)

The second floor accommodates the administrative offices, which includes the Directors office, Secretary, and an open plan office. See Figure 4.6.

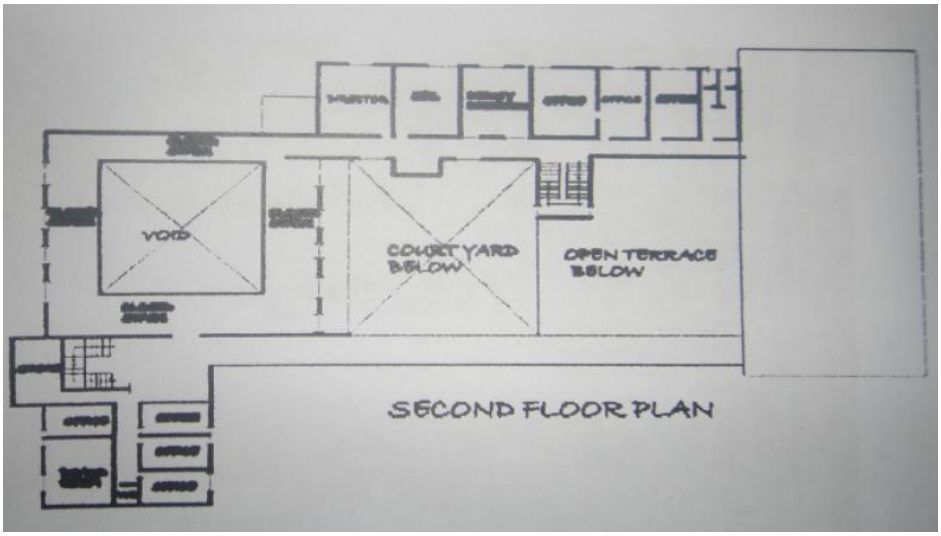


Figure 4.6: Second floor Plan. Source: Field survey (2014)

4.2.4 Daylighting Strategy

The passive control of sunlight was properly used in relation to the building orientation on site. In Plate VI the shading strategy as shown, includes over-hang created by the

first floor above the children lending section, recesses with aluminum louvers over the openings. The court yard introduces daylight and air into the building. In Plate VII, the use of fixed light over projected windows also helps admit daylight and aeration of the spaces. The ceiling is made of white color 600mm x 600mm Fiber board helping to reflect light into the space. The narrow rectangular scheme allows for adequate exposure for daylight harvest and aeration.



Plate VII: View of shading elements used. Source: Field survey (2014)



Plate VIII: projected window and reference Section. Source: Field survey (2014)

4.2.5 Variables Considered

Table 4.2: Variables studied in Kaduna State Library, Kaduna

S/N	SPACE	VARIABLES	OBSERVATION	REMARKS

1	Children section at Ground floor	Room geometry & orientation	Rectangular, with shorter glazed sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	1.2 x 1.5 meters, 1.8 x 2.1 meters side lighting projected windows and aluminum sliding doors	Good windows and doors head height
		Positions and size of internal barriers	Stack areas are properly zoned to allow for useful daylight	Do not cause obstruction
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	The east/west ends are properly shaded with Recessed wall and overhangs	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
2	Adult learning at First floor	Room geometry & orientation	Rectangular, with glazed shorter sides facing north and south	Direct Sunlight, glare and heat gain contained via orientation
		Area, arrangement of daylight object	1.2 x 1.5 meters side light aluminum louvered window	Good window head height
		Positions and size of internal barriers	Stack areas are properly zoned to allow for useful daylight	Do not cause obstruction
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	ends are properly shaded with aluminum louvers	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
3	Serial / Reference section	Room geometry & orientation	Rectangular, with longer sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	1.5 x 4.6 meters side light projected window	Good window head height
		Positions and size of internal barriers	Stack areas are not properly zoned to allow for useful daylight	Act as obstruction
		Positions and size of external barriers	They are not close to openings	Do not cause obstruction
		Shading for openings	Aluminum louvers	Effectively shaded
		Glazing property	tinted glass	Minimal transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year

Source: Field survey, (2014)

4.3 CASE STUDY 3:

Isa Kaita Library, Kaduna Polytechnic Main Campus.

4.3.1 Background

The library is located at the Kaduna Polytechnic Tudun Wada Main Campus, Kaduna State, and Established in 1991 as an academic Library. It serves as the college library and it is open to the student between the hours of 8am - 10pm weekdays and 2pm - 9pm weekend. Kaduna State falls within the tropical climatic zone; the site is characterized by mostly clear sky in day time and this permits longer hours of sunshine. The average duration of sunshine varies from 6.0 to 9. 8 hours.



Plate IX: View of Main Entrance. Source: Field survey (2014).

4.3.2 Site planning and general building concept

The library building orientation is towards the north-east of site. The structure is basically of prefabricated concrete and glass as seen in Plate IX. and made up of various rectangular shapes connected together to form a star like shape as shown on the Plate X and paper model in Plate XI and Plate XII also shows various Pattern of sun shading strategies adopted on the façade and overhang over the numerous daylight apertures to allow in useful daylight.



Plate X: Aerial view of Isa Kaita Library: Source: Google map (2014)



Plate XI: Paper model of the site: Source: Field survey (2014)



Plate XII: Screen and Recessed walls: Source: Source: Field survey (2014)

4.3.3 Spatial organization and space allocation

The main entry contains the security and control point with a stairwell to the right which leads to the upper floors. The lounge greets you once you leave the security point, the

Newspaper archive, technical unit are to the right while the serial section is behind the front-desk to the left of the entry point. The staircase at the lounge link to the subsequent floors, were the Reserve, Reference, Humanities, science and technology sections and the E-library are. The store, computer, accounts and the Librarian's office are on the final floor.

4.3.4 Daylighting Strategy;

Showing in Plate XII is the use of overhangs, high-level windows, screen walls, and recesses which are poorly adopted owing to the fact that it had become a challenge rather than a solution for effective daylight distribution on the floor spaces. A void over the lounge at the ground floor was used to admit daylight and air into that part of the building leaving out the reading and work areas in the library as shown in Plate XIII below. The ceiling is made of white color 600mm x 600mm gypsum board thereby aiding light distribution as shown in Plate XIII below at the lounge area.



Plate XIII: High level windows at lounge area. Source: Field survey (2014).



Plate XIV: Ineffective Daylight sources. Source: Field survey (2014)

Plate XIV shows the electric light bulbs on during the daytime due to inability to get good distribution of daylight in the work and reading spaces at the Ground and First floor respectively.

Table 4. 3 Variables study in Kaduna Polytechnic Library, Kaduna

S/N	SPACE	VARIABLES	OBSERVATION	REMARKS
1	Serial, newspaper section at	Room geometry & orientation	2 Rectangular halls merged together, having glazed sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	1.2 x 3.0 meters, side lighting projected windows	Good windows head height
		Positions and size of internal barriers	Stack areas are not properly zoned to allow for useful daylight, & internal partition with opaque material reduce daylight penetration	Do cause obstruction to admittance of useful daylight
		Positions and size of external barriers	screen are close to openings	Do cause obstruction
		Shading for openings	ends are not properly shaded with screen wall and overhangs	Shading reduce the daylight penetration
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
2	Humanities/ Science & Tech at first floor	Room geometry & orientation	2 merged Rectangular halls with beveled edges, having glazed sides facing east and west	Direct Sunlight, glare and heat eminent
		Area, arrangement of	1.2 x 3.0 meters projected , 0.6 x1.8 meters clerestory	Good window head height

		daylight object	windows	
		Positions and size of internal barriers	Stack areas properly zoned with useful daylight & internal partition with opaque material reduce daylight penetration	Do cause obstruction
		Positions and size of external barriers	They are none	none
		Shading for openings	properly shaded with overhangs	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on season of the year
3	Reserve / Reference section	Room geometry & orientation	2 merged Rectangular halls with beveled edges, having glazed sides facing east and west	Direct Sunlight, glare and heat gain eminent
		Area, arrangement of daylight object	1.2 x 3.0 meters projected , 0.6 x1.8 meters clerestory windows	Good window head height
		Positions and size of internal barriers		Act as obstruction
		Positions and size of external barriers	none	no obstruction
		Shading for openings	overhangs	Effectively shaded
		Glazing property	Clear glass	Good transmittance
		Sky condition	Overcast mostly	Cloudy depending on seasons

Source: Field survey, (2014)

4.3.4.1 Simulations for Case 1- National Library Kaduna

The process for this case study simulation started with the consideration for the strategies adopted to achieve good levels of daylighting. The atrium also serves as a driving force of a naturally ventilated building utilizing the stack effect with warm air in the atrium rising through the roof. The aim of this case study is to ensure that the concept design is achieving what it set out to do and secondly optimize the design to improve its overall performance if possible. The first stage was to build a model of the building and analyze how this existing (baseline) design would perform. At this stage reasonable assumptions were made regarding how the different parts of the building would be used. There were three main areas of the buildings performance that was investigated at this stage.

Tables 2.2, 2.3 and 2.4 both show the standard illuminance level for various spaces and activity zones in buildings. From the model simulation, light levels in the National library, Kaduna can be seen to fall within useful range (See Plate XV and Plate XVI). Figure 4.7 & 4.8 shows the average daylight levels fall within the standard Useful Daylight Illuminance, UDI- (UDI is defined as the annual occurrence of illuminance across the work - plane that is within a range considered “useful” by occupants – 100 to 2000 lux) Mardaljevic, 2009.

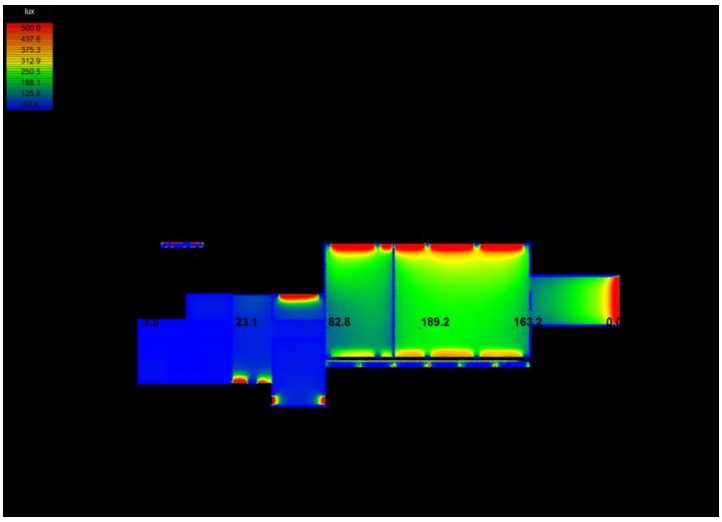


Plate XV**:** Illuminance level at the reading areas. Source: Simulation result National library, Kaduna (2014)

Table 4.4: Average annual daylight levels

	Variables
	Average daylight level, lx
January	513.7
February	505.3
March	482.9
April	391.9
May	299.2
June	255.9
July	273.3
August	344.2
September	435.7
October	461.5
November	500.1
December	548.7
mean	417.2
mean*8760.0 h	3654840.1
min	255.9
max	548.7

Source: Simulation result National library, Kaduna (2014)

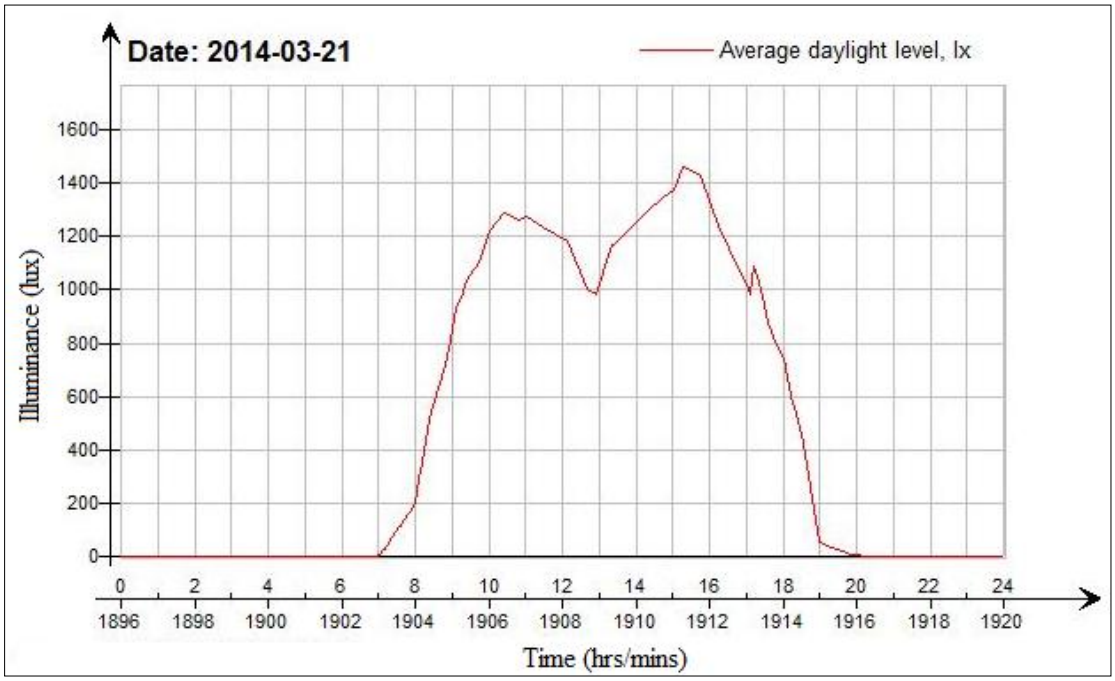


Figure 4.7: Daylight levels for March, 2014. Source: Simulation result National library, Kaduna (2014)

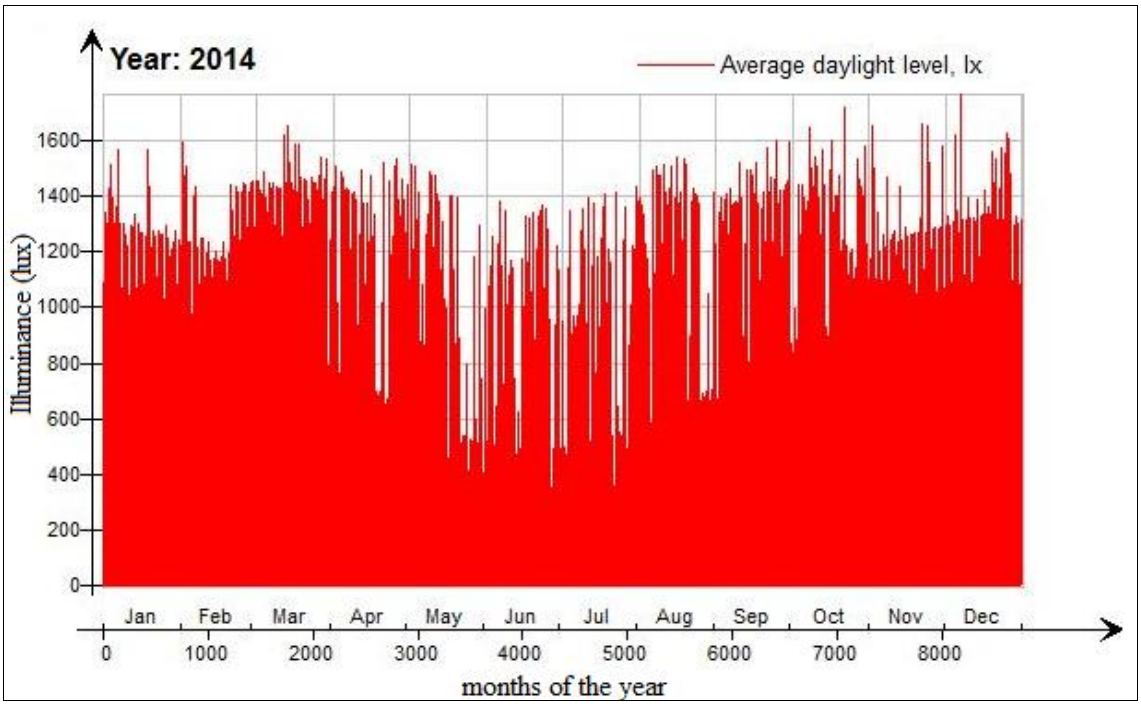


Figure 4.8: Annual daylight levels. Source; Simulation result National library, Kaduna (2014)

Daylight factor is the ratio of the internal illuminance of a work plane and that of the outside open plane and it's expressed in percentages. The values as seen in Plate XVI and Plate XVII below from the simulation report show good daylight factor in the reading area of the National Library, Kaduna.

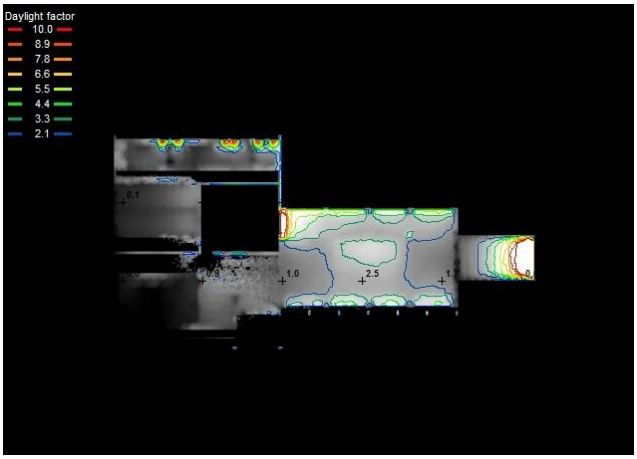


Plate XVI: Daylight factors at the reading Area. Source; Simulation result National Library, Kaduna (2014)

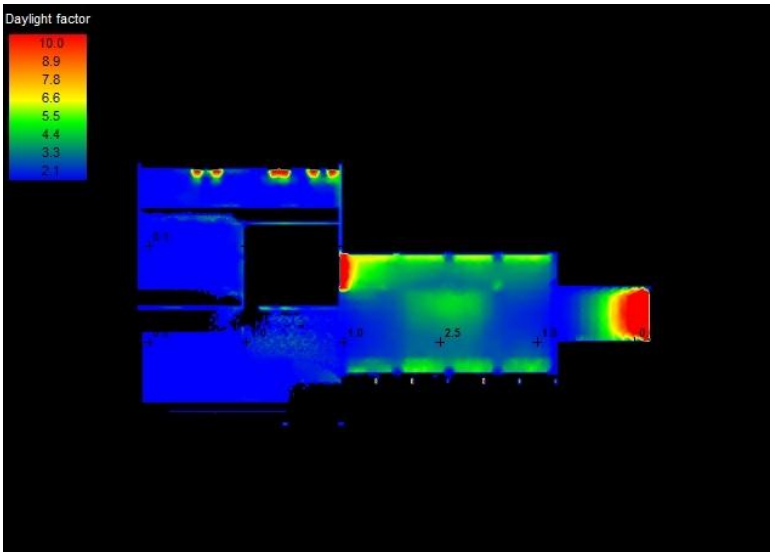


Plate XVII: Daylight Factor on a false contour ray-tracing**.** Source; Simulation result National library, Kaduna (2014)

4.3.4.2 Simulations for Case 2-

Kaduna State Library, Kaduna

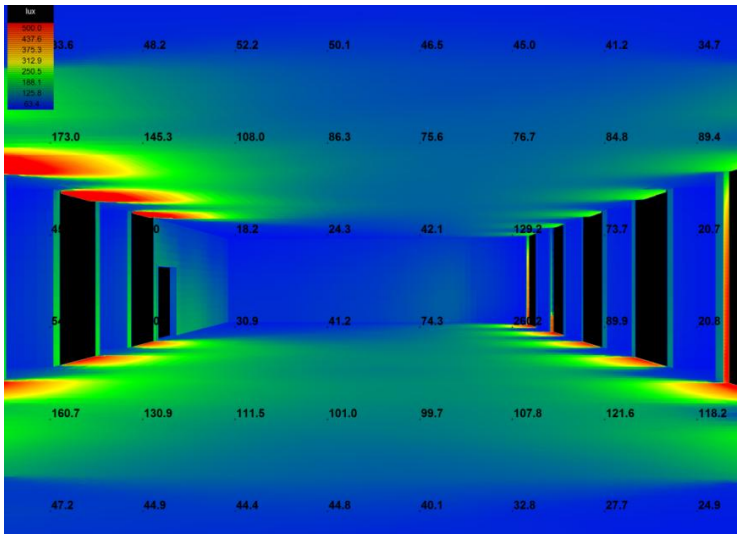


Plate XVIII: Illuminance values in the reading spaces @ Ground Floor. Source; Simulation result State library, Kaduna (2014)

From the model simulation, light levels in the Kaduna State library can be seen to fall within useful luminance range (See Plate XVII and Plate XVIII). The Figures 4.3 & 4.4 shows the average daylight levels fall within the standard. Table 4.4 contains details of the average, minimum and maximum daylight levels (lux).

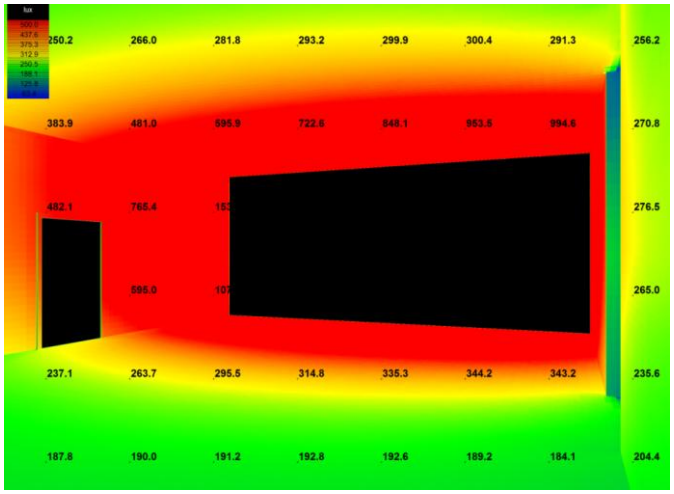


Plate XIX: Illuminance values in the reading spaces @First Floor. Source; Simulation Result State library, Kaduna (2014)

Table 4.5: Average annual daylight levels

	Variables
	Average daylight level, lx
January	183.1
February	178.8
March	177.6
April	155.9
May	126.3
June	109.5
July	116.0
August	141.3
September	167.8
October	170.4
November	180.5
December	195.1
mean	158.4
mean*8760.0 h	1387739.6
min	109.5
max	195.1

Source: Simulation result State library, Kaduna (2014)

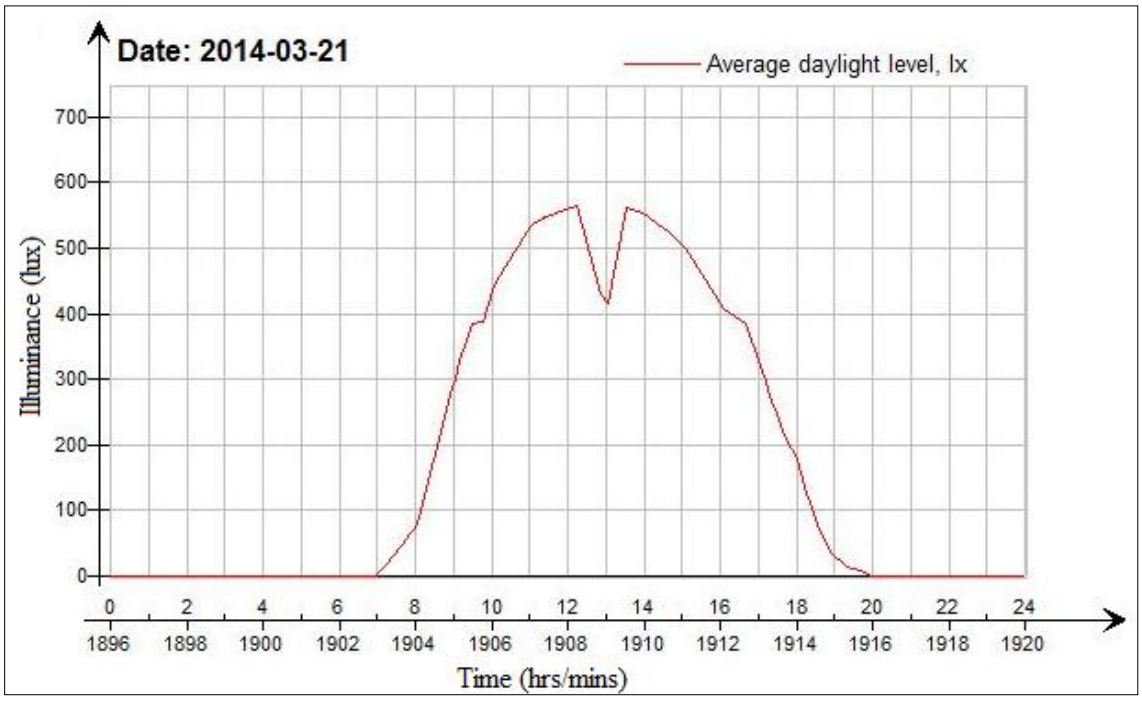


Figure 4.8: Showing Daylight levels for March, 2014. Source; Simulation result State Library, Kaduna (2014)

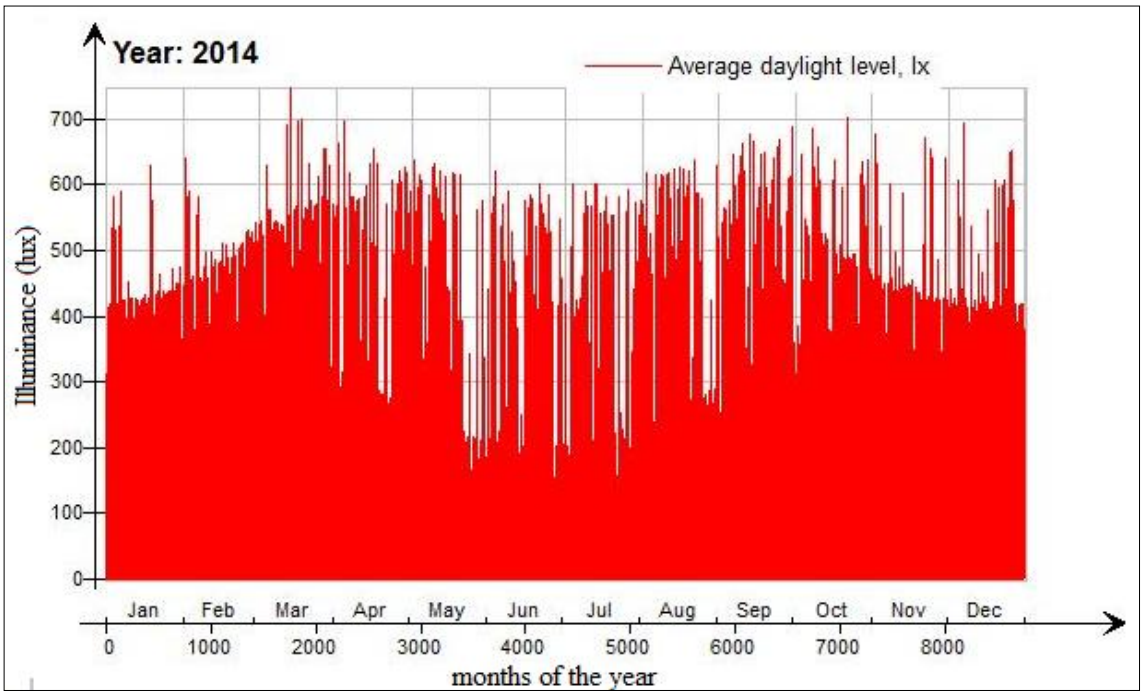


Figure 4.9: Showing annual daylight levels. Source; Simulation result State library, Kaduna (2014)

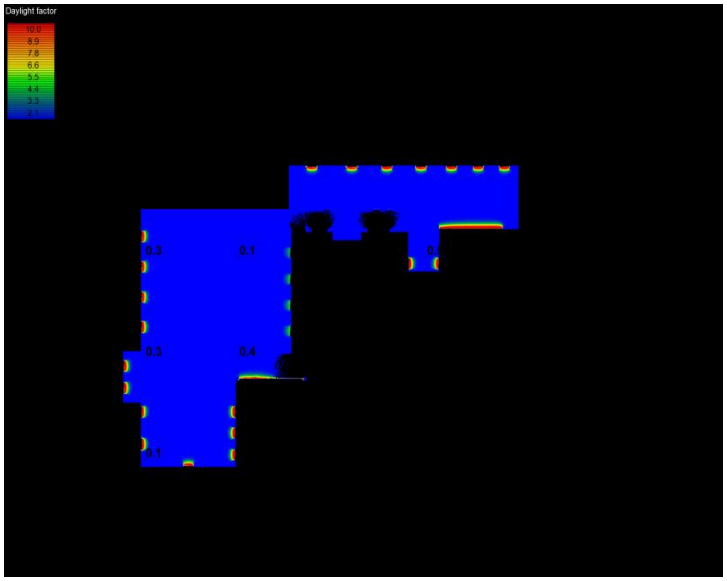


Plate XX: Daylight factor on a false contour ray-tracing @ ground floor. Source; Simulation result State library, Kaduna (2014)

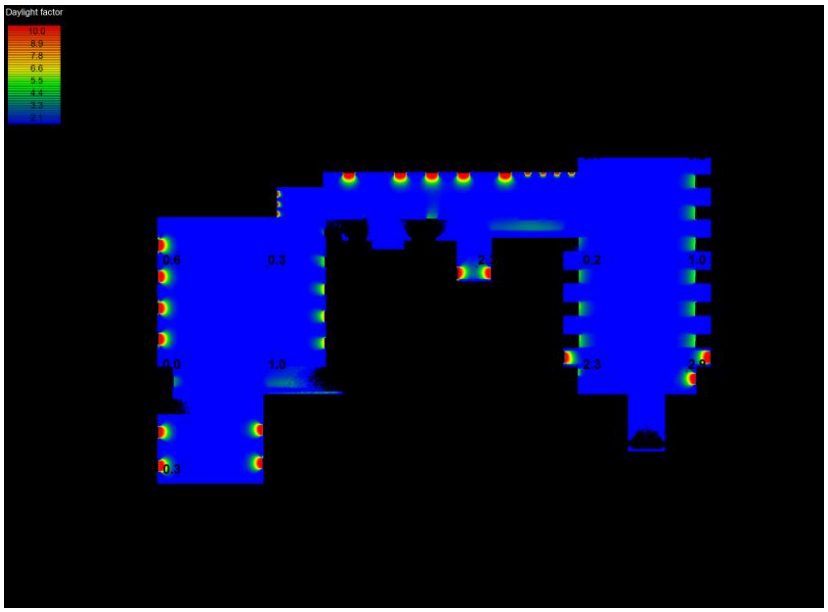


Plate XXI: Daylight factor levels on a false contour ray-tracing. Source; Simulation result State library, Kaduna (2014)

4.3.4.3 Simulations for Case 3- Isa Kaita Library Kaduna State Polytechnic, Main Campus.

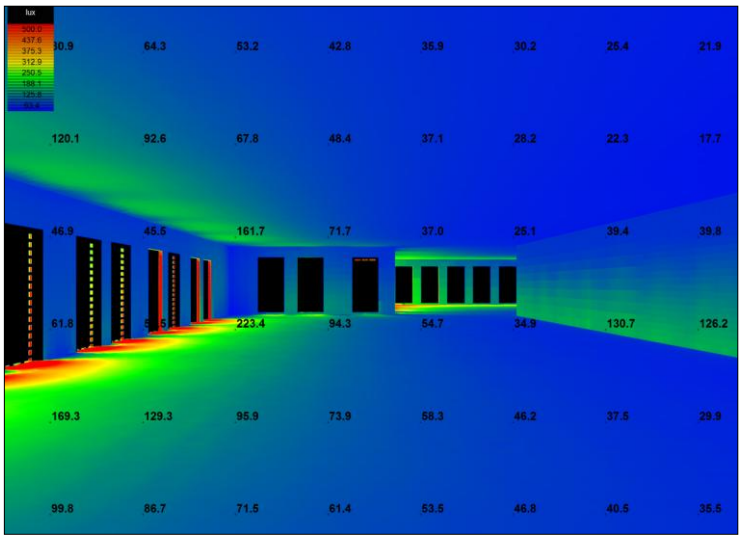


Plate XXII: Illuminance values in the reading spaces @Ground Floor. Source; Simulation result Isa Kaita library, Kaduna (2014)

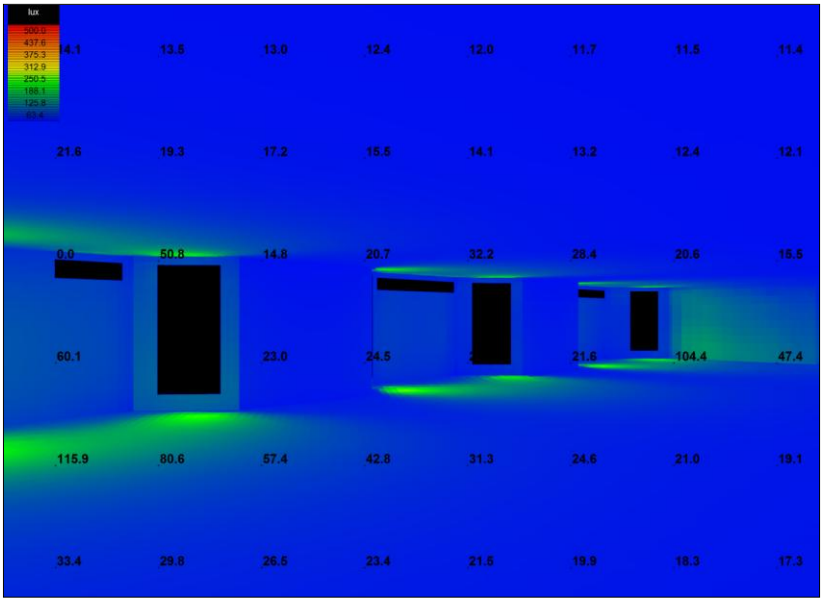


Plate XXIII: Illuminance values in the reading spaces @First Floor. Source; Simulation Result Isa Kaita library, Kaduna (2014)

From the model simulation, daylight levels at the Isa Kaita library below the useful luminance range (See plate 4.22 to 4.24). The Figures 4.10 & 4.11 shows that average daylight levels falls below the standard expected for reading spaces as shown in Table2.2-2.4.

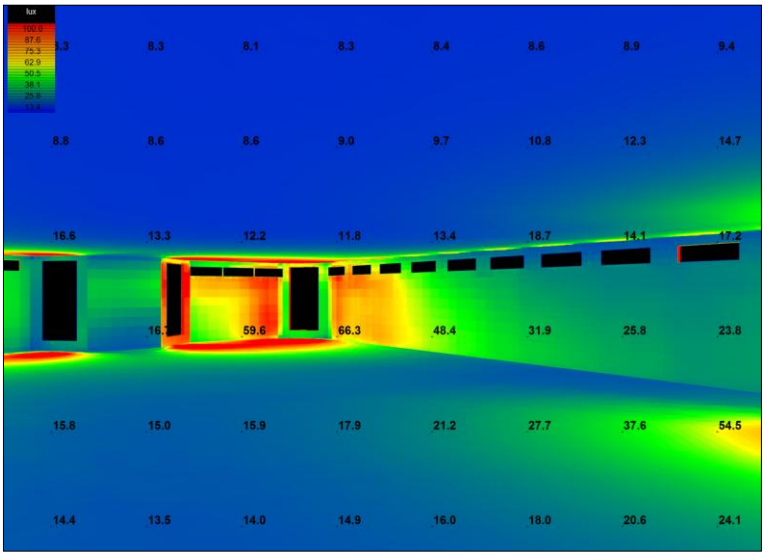


Plate XXIV: Illuminance values on different points in the reading spaces @Second Floor Source: Simulation result Isa kaita library, Kaduna (2014)

Table 4.6: Average annual daylight levels

	Variables
	Average daylight level, lx
January	50.5
February	47.5
March	45.2
April	38.8
May	32.0
June	27.7
July	29.9
August	36.0
September	43.6
October	45.7
November	49.5
December	54.4
mean	41.7
mean*8760.0 h	365208.8
min	27.7
max	54.4

Source: Simulation result Isa Kaita library, Kaduna (2014)

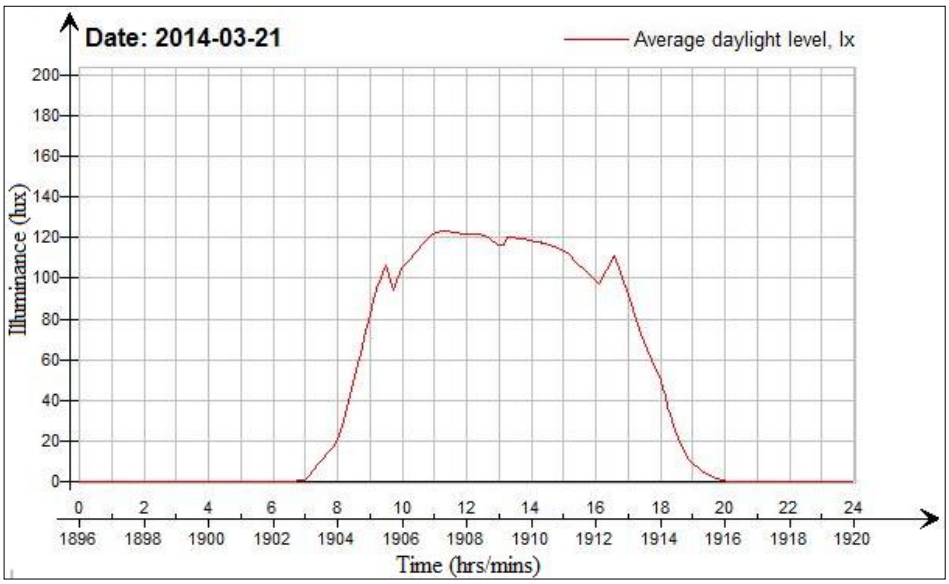


Figure 4.10: Daylight levels for March, 2014. Source: Simulation result Isa Kaita Library, Kaduna (2014)

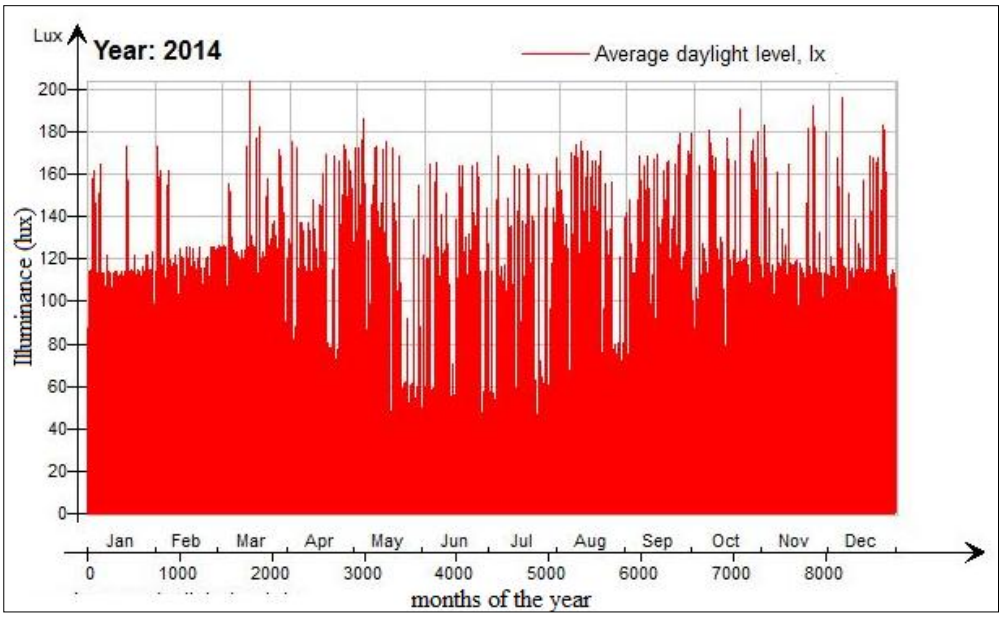


Figure 4.11: Daylight levels for March, 2014. Source: Simulation result Isa Kaita Library, Kaduna (2014)

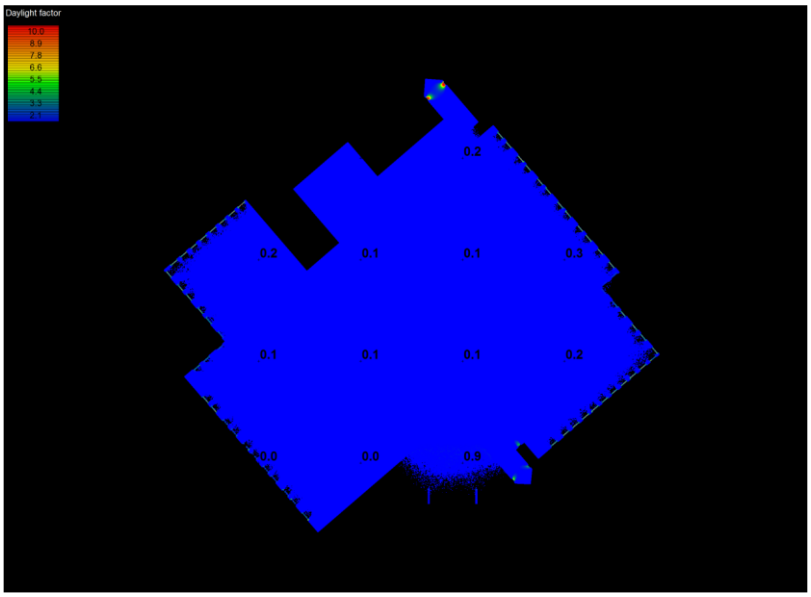


Plate XXV: Daylight Factor ray-tracing @ ground floor. Source; Simulation result Isa Kaita Library, Kaduna (2014)

The daylight factor values from the simulation report as can be seen in Plate 4.23, 4. 24 and plate 4.25 here shows a poor level of illumination in the reading area on virtually all floors. Table 4.6 contains details of the average, minimum and maximum daylight levels (lux).

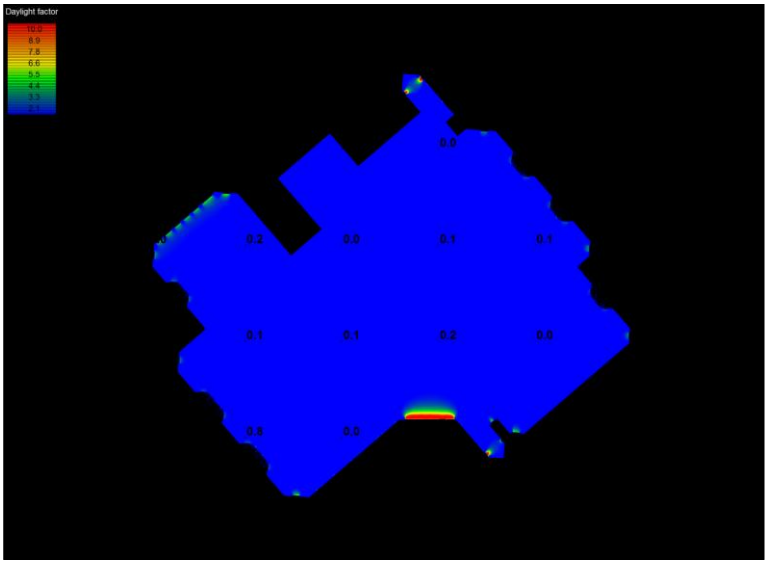


Plate XXVI: Daylight Factor ray-tracing @ First floor. Source; Simulation result Isa Kaita Library, Kaduna (2014)

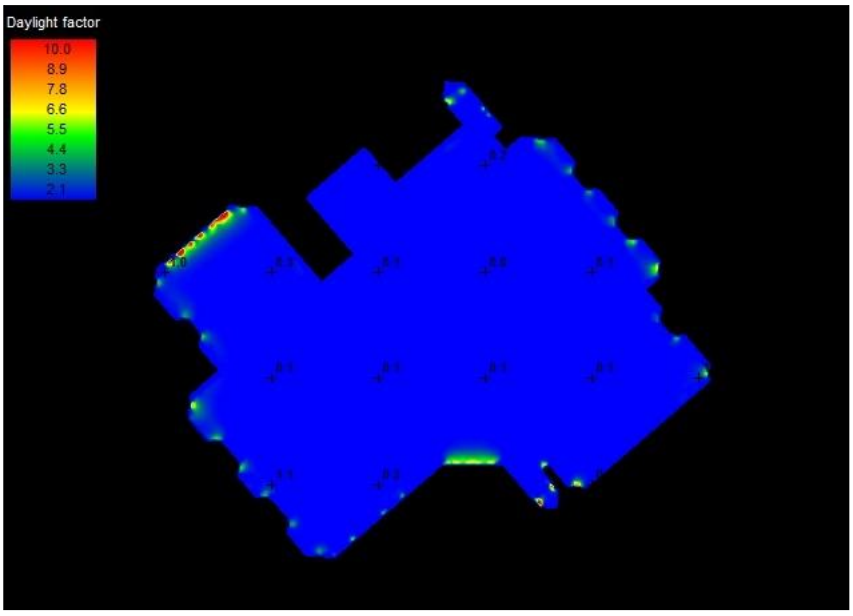


Plate XXVII: Daylight Factor ray-tracing @ second floor. Source; Simulation result Isa Kaita Library, Kaduna (2014)

4.3.5 Conclusions

Dean (2005), observed conditions that can be observed in libraries with relatively poor daylight design to be that electric light fixtures are turned on during the day. Also, Boyer et al (1994) stated that high operational cost could arise in buildings when

daylight system is poorly designed, due to increase in consumption of electricity for using artificial light during the daytime.

The above is true for **Case study 3** - in Plate XXVII Isa Kaita library, Kaduna Polytechnic main campus, as was observed to have their electric light always on during the day in most reading areas, under most sky conditions. The simulation results for the reading areas also confirmed the low level of illuminance in relation to standard specified in Table 2.2.-2.4.

Case study 2- The Kaduna State Library- also would be considered fair since the light levels are close to the standard. However the daylight approaches needs to be modified as they tend to reduce the penetration of daylight. It was also noted that the use of electric light fixtures are only limited to particular hours of the day and under cloudy sky situations.

Case study 1- National Library, Kaduna, is seen to have a good daylight level within useful lighting standard as started by the Illuminating Engineering Society (IES) in Tables 2.2-2.4 above. Therefore, for case 2 and 3 above, poor daylight, increases in electric light use are as a result of lack of passive design considerations at the early stages design and . But for the case 1, there will be significant Light energy cost reduction owing to the use of passive design elements that allow for useful daylight in reading areas during the day.

4.3.6 Light Energy Use Analysis

The total electricity consumption for the electrical lighting system of the selected case kWh per day is shown in Table 4.7.

Table 4.7: Potential Energy Saving

Case	Case 1	Case 2	Case 3
Quantity of luminaires/wattage	59 CFL 30 w	89 FLT/ 30w	84 FLT/ 30w 187/ 40w
Annual operational hour	2184	6118	2288
Annual charge for Electricity (NRA)	7499.40	7499.40	7499.40
Cost of Electricity (NRA)	20.26	20.26	20.26
Annual savings (NRA)	108826.50	411434.2	412900.20

Source: Field survey, (2014)

The kilowatt used over daytime operational hours otherwise known as Hours of Usage and the cost of energy in Naira shows the amount of savings that can be made with effective daylighting.

CHAPTER FIVE

SITE LOCATION STUDIES

5.1 AREA OF STUDY

The study area is in Kaduna, North Central of Nigeria. Kaduna State was created on the 27th May 1967 as one of the six States of the Northern Region of Nigeria. It has Kaduna State as the Capital, with 23 Local Government Area. It has a total land area of about 46,053km^2. Fig. 5.1 shows its location from a global view to the geographical location in Nigeria and all the way to the site location on the land use map of the Kaduna millennium city.

5.1.1 Population

Kaduna State has about 36 indigenous ethnic groups, consisting of the Gbagyi, Katab, Bajuu and Hausa/Fulani tribes. From the 1991 and 2006 population census, Kaduna State population stood at 3,985,618 and 6,066,562. It also showed that 2000 third of the population lives in the urban centers of Kaduna, Zaria and Kafanchan. Data also inferred about 500 persons per square kilometer (National Population Commission, 2006).

5.1.2 Geography of Kaduna State

Kaduna State is located on latitude +10.52 (10^o, 32', 12'N); longitude +7.44 (7.26' 24"E) and altitude – 600m. The entire land structure consist of an undulating plateau with major Rivers in the State including River Kaduna, River Kagom, River Gurara and River wonderful in Kafanchan. (City report, 2008). The Kaduna River remains the most of them all, flowing from its source along the western margin of the Jos-Plateau down to the northwest across Kaduna plains, mentoring about 550 kilometers. The vegetation

within the 70,200 square kilometer drainage basin is moist savannah. The lower course of the River is characterized by a line of dense rain forest, where moisture is more abundant. Annual rainfall averages about 1250mm, occurring seasonally between May and September. Great seasonal fluctuations characterize the rivers water floor with peak discharges occurring between July and September.

5.1.3 Kaduna Millennium City

The New City is strategically positioned between the Federal Capital Territory, Abuja and the commercial nerve center of the north, Kano, Kaduna represents a significant potential for future growth and this is clear from increased in development and expansion experienced away from the central city. It is this rate of development of many satellite towns that informed the development of a master plan for the millennium city, formally known as Makarfi New City.

The millennium city is a development site within the Eastern sector of Kaduna city and along-side the River Kaduna. The site area stands at about 700 hectares, with a projected population of 90,000 persons. It's nearest to the Kaduna city center creates development opportunity especially with good connectivity to the Eastern bypass through a new link road that is presently being constructed. The city is aimed at achieving a sustainable environment which makes the city a good site for the proposed Kaduna metropolitan library.

5.2 SITE SELECTION CRITERIA

The criteria for selecting the site for this project includes

- Proximity to the end users

- Easy accessibility to existing infrastructures.
- Gently sloping land for easy construction process and draining.
- Availability of land for future expansion (The state Government has assigned it for the purpose of a new Library.)
- Calm and conducive learning environment with little or no noise pollution



Figure 5.1: Site Location. Source: Google maps Millennium city, Kaduna, Nigeria. (2014).

5.2.1]Site selection justification;

In Figure 5.2, and Figure 5.3, the New Millennium City lies along the main dual carriage bypass to Abuja with the selected Site designated for the city library as shown on the Land use map (Plot C24) and beacon No. KCB9945 master plans respectively. The site selected is away from the already crowded northern part of the metropolis with the zoning of commercial, Residential health, educational. Being a new settlement that has already been planned by the Planning authorities, it has great opportunities and prospects of becoming a world class city, in terms of communication, transport system, portable water and the state of the Art health care facility already been constructed some meters away from the proposed site.



Figure 5.2: Land use Map. Source; Millennium city web page (2014)

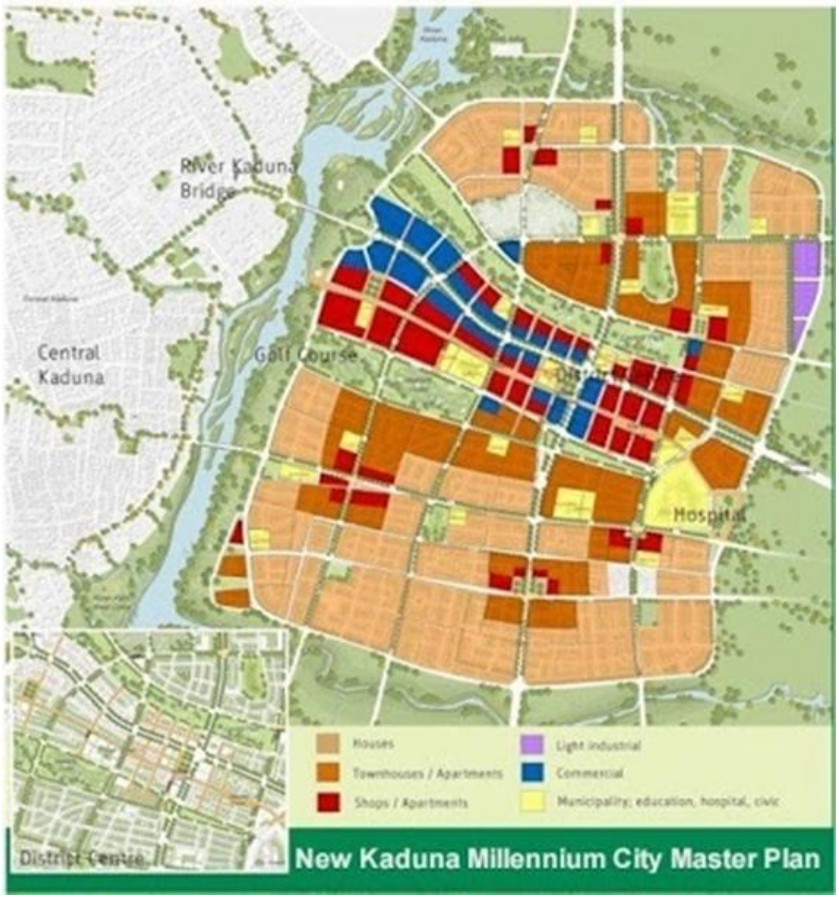


Figure 5.3: Master Plan. Source; Millennium city web page (2014)

5.3 Site Character

The site is characterized by relatively hot and dry climatic conditions with an annual average high temperature of 39°c and an average annual relative humidity of 57.5%. The site slopes gently southwards, towards the Kaduna River as shown in Figure 5.4, Plate XXVIII shows the River and its environment which is characterized by rocky landscape, sparsely scattered green. Plate XXIX shows the existing bridge connecting the old Kaduna city to the new city and Plate XXX shows the road network from Angwan Rimi GRA to the Bridge. In Plate XXXI and Plate XXXII respectively sandy-silt soil, thick foliage trees, can be seen on the site perimeter bounded by already developed residential settlement with infrastructures and amenities to be usurp for further development on the site.



Figure 5.4: Site Plan of Kaduna state Millennium City. Source: Google maps (2014).


Plate XXVIII: River bank. Source: Authors' field survey (2014)



Plate. XXIX: Bridge over the river. Source: Authors' field survey (2014)



Plate XXX: Angwan Rimi GRA. Source: Authors' field survey (2014)



Plate XXXI: Selected Site. Source: Authors' field survey (2014)



Plate XXXII: Housing estate. Source: Field survey (2014)

5.4 SITE ANALYSIS

Site analysis is an inventory completed as a preparatory step to site planning, a form of urban planning which involves research, analysis, and synthesis. It primarily deals with basic data as it relates to a specific site (White, 2004). Numerous elements go into a given site analysis. These elements include location, neighborhood context, site and zoning, natural physical features, man-made features, circulation, utilities, sensory, human and cultural, and climate components. The following elements typically are considered in most sites (White, 2004).

5.4.1.1 Location;

Kaduna Metropolitan library is located in Kaduna metropolis, Kaduna North Local Government Area of Kaduna state, at approximately $10^0$31'23"N and 7^0 26'25"E of the equator and 600 meters above mean sea level. It is situated east of the Kaduna River, along the existing millennium city eastern bypass accessed from the Dawaki round about in Malali/Angwan Rimi GRA in Kaduna.

5.4.1.2 Neighborhood context;

The site is zoned to a less dense and minimally crowded neighborhood. The site is shielded from any potent source of noise by distance and the road by thick foliage trees.

5.4.1.3 Size and zoning;

The site is a 15,000 square meters rectangular plane, with a sand-rocky topography. For the purpose of the design proposal, zoning classifications, set-backs, height restrictions, allowable site coverage, uses, and parking requirements was obtained from the Kaduna state urban planning development authority (KASUPDA), and adhered to.

5.4.1.4 Topographical analysis;

The site slopes gently towards the Northwest, a sandy- rocky contour with a gradient of about 100 meters over 600 meters distance as shown in Figure 5.5. Studies do not reveal any flooding or drainage problems, a stable soil condition and relatively good vegetative cover made up of trees and shrubs are observed.

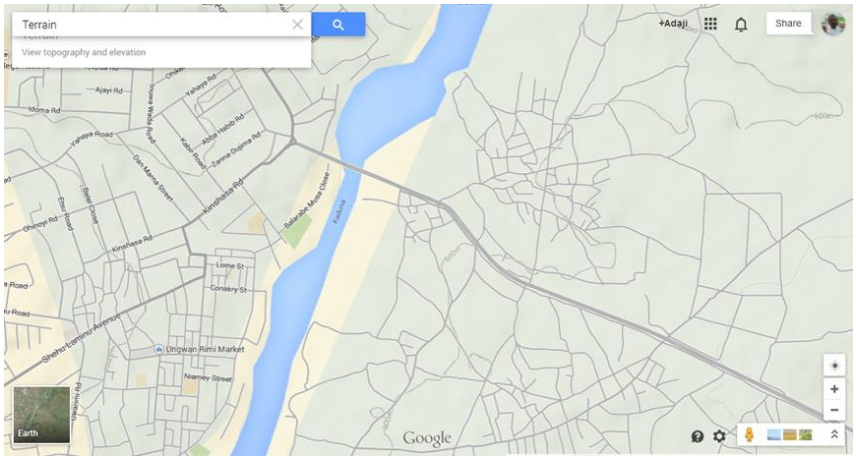


Figure 5.5: Topographic map of Kaduna metropolis. Source: Google maps, (2014).

5.4.2 Climatic analysis

The site is located in a tropical climatic zone with abundant Sunshine. The dry and rainy seasons are also significant.

5.4.2.1 Temperature Analysis

The average temperature for the year in Kaduna according to Nigerian Metrological agency (NiMet, 2014) is 78.0°F (25.6°C). In figure 5.6 the warmest month, on average, is April with an average temperature of 84.0°F (28.9°C). The coolest month on average is January, with an average temperature of 75.0°F (23.9°C) see Table 5.1 below.

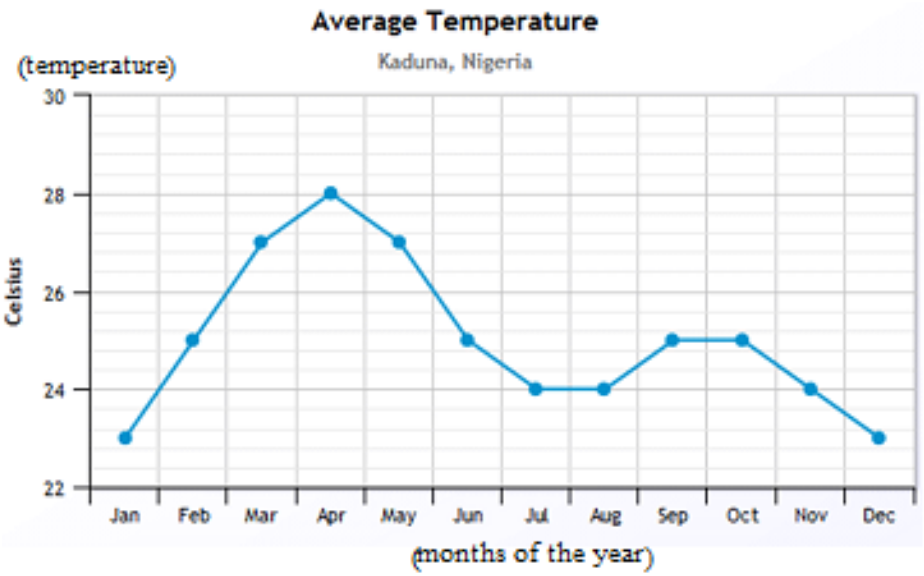


Figure 5.6: Temperature of Kaduna. Source: www.worldweatheronline.com (2014)

Table 5.1 Average monthly temperatures, Kaduna

M	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**ANNUAL**
	A	**E**	**A**	**P**	**A**	**U**	**U**	**U**	**E**	**C**	**O**	**E**	
	N	**B**	**R**	**R**	**Y**	**N**	**L**	**G**	**P**	**T**	**V**	**C**	
C^{o}	23	25	27	28	27	25	24	24	25	25	24	23	25

Source: http://www.worldweatheronline.com (2014)

5.4.2.2 Trade Winds

The prevailing winds in Kaduna State are the south western and northern trade wind patterns. The former originates from the Atlantic Ocean and it brings most cool breeze and rainfall; and the latter originates from the Sahara desert and it brings dusty breeze and hamattan (NiMet, 2014). The wind speed ranges from 2.96 to 4.31 meters per second, varying from month to month as shown in Table 5.2. To this effect barriers should be used and also the building shall be oriented so as to achieve the south western wind and wind breakers shall be introduced to reduce the effect of the hamarttan wind.

5.4.2.3 Rainfall

There exists two seasons in Kaduna state the rainy and the dry season. The rainy season lasts for about six months from April to October (see Figure 5.7). There is heavy rainfall in the southern and the northern parts of the state. The rainfall ranges from (0 to 825 millimeters per month (NiMet, 2014). The design proposal has to adopt a proper system of surface drainage to take away this amount of rain away from the site. Thunder strikes are also prevalent during the rainy seasons therefore thunder deflectors are also a necessary consideration.

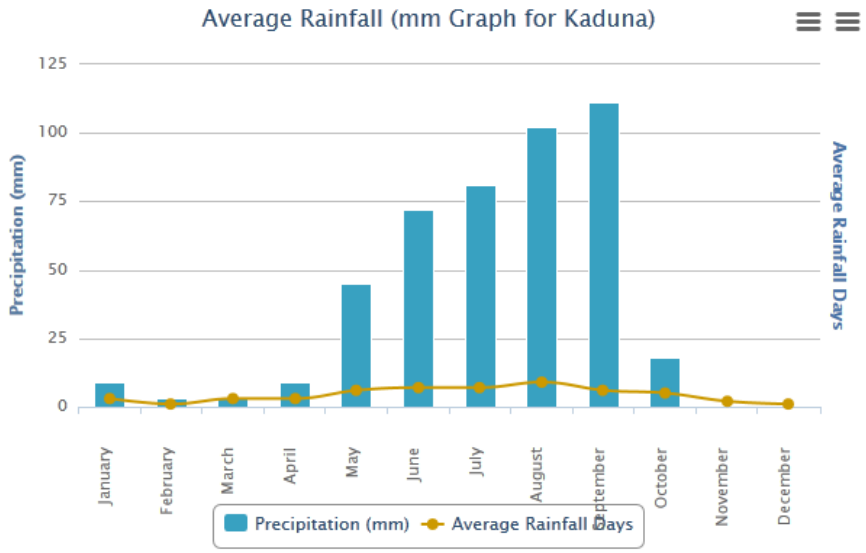


Figure 5.7: Annual Rainfall graph. _www.worldweatheronline.com (2014)

Table 5.2: NASA weather data for Kaduna State

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	5.66	6.49	6.72	6.63	6.41	6.03	5.44	5.03	5.47	5.76	5.80	5.40
Clearness, 0 - 1	0.65	0.69	0.66	0.63	0.61	0.58	0.53	0.48	0.54	0.60	0.66	0.64
Temperature, °C	23.31	25.17	27.67	27.36	26.11	24.61	23.63	23.56	24.22	24.95	25.65	23.87
Wind speed, m/s	3.99	3.86	4.30	4.31	4.21	3.60	3.43	3.24	2.96	3.17	3.69	4.17
Precipitation, mm	0	1	7	56	120	160	218	275	243	71	2	0
Wet days, d	0.1	0.1	0.7	3.6	8.2	11.8	15.3	16.8	13.8	4.6	0.0	0.0

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

5.4.2.4 Shading Analysis

Shading of the building and outdoor spaces reduces summer temperatures, improves comfort and saves energy. Direct sun can generate the same heat as a single bar radiator over each square meter of a surface. Shading can block up to 90% of this heat. Shading of glass to reduce unwanted heat gain is critical. Unprotected glass is often the greatest source of unwanted heat gain in a building. Shading of wall and roof surfaces is important to reduce summer heat gain, particularly if they are dark colored and/or

heavyweight. Figure 5.8 and Table 5.3 shows the sun path data at different seasons of the year in Kaduna, which aids in the design for daylight harvest and shading to curb radiant heat gain.

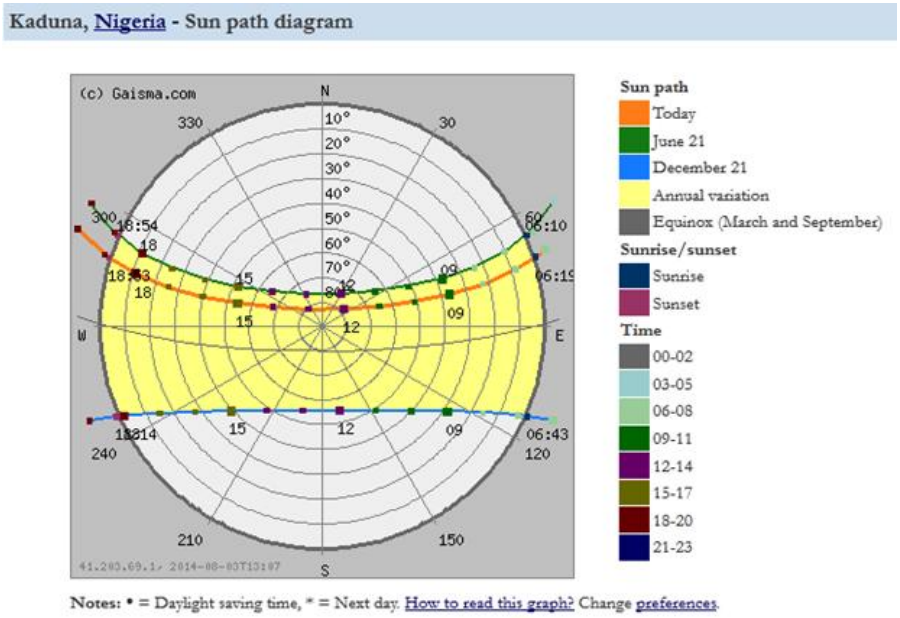


Figure 5.8: Sun Path diagram Source: http://www.gaisma.com (2014).

Table 5.3: Sun Path Data

Kaduna, Nigeria - Sunrise, sunset, dawn and dusk times, table

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	06:19	18:53	12:34		05:57	19:15	13:18	
+1 day	06:20	18:53	12:33	00:01 shorter	05:57	19:15	13:18	00:00 equal length
+1 week	06:20	18:51	12:31	00:03 shorter	05:58	19:13	13:15	00:03 shorter
+2 weeks	06:21	18:48	12:27	00:07 shorter	05:59	19:09	13:10	00:08 shorter
+1 month	06:21	18:39	12:18	00:16 shorter	05:59	19:00	13:01	00:17 shorter
+2 months	06:19	18:20	12:01	00:33 shorter	05:58	18:41	12:43	00:35 shorter
+3 months	06:21	18:06	11:45	00:49 shorter	06:00	18:28	12:28	00:50 shorter
+6 months	06:53	18:34	11:41	00:53 shorter	06:31	18:56	12:25	00:53 shorter

Notes: *Daylight saving time*, * = Next day. Change preferences.

Source: http://www.gaisma.com (2014).

CHAPTER SIX

DESIGN SYNTHESIS

6.1 Proposed Design of Kaduna Metropolitan Library

Libraries plays a major role in any institution or environment, as such it has to be a place that is organized and accessible for information to a defined community for reference or borrowing, and it also provides physical building or room or a virtual space. This therefore informs the nature of my building form and its space arrangement to achieve its standards Under prevailing standards for a design, a product should have beauty of line, color, proportion, and texture (delight); high efficiency, safety, convenience or comfort in use (commodity); ease of maintenance and repair, durability and expression of function in terms of form (strength). These three according to Vitruvius are the basics of a good design. The relative importance of any of these standards may vary depending on the project type. A consideration basic to all good design is the factor of realistic cost. Thus, an efficient and effective design requires, besides artistic ability, combined knowledge of construction principles and materials, construction detailing techniques, cost, and comfort conditions.

6.1.1 Design Concept

A product or event is based on carefully thought out steps considered as the Concept. Concept architecturally is seen to be series of logical steps taken to arrive at the solution to an architectural problem, using principles that are akin to it. Many see concept as something that somebody has thought up, or that somebody might be able to imagine. However, concept is a broad principle affecting perception and behavior: a broad abstract idea or a guiding general principle, e.g. one that determines how a person or

culture behaves or how nature, reality, or events are perceived (Uji, 2002). A look at a library, the first thing that comes to the mind is a collection of books. As such, the design take the form of a book pile, on shelve, opened for reading or kept standing and slightly opened. These are a form of symbolism in architecture, an expressionist approach to design, using a book-form to depict the function of what the building is to serve. Examples are 'the Burj al Arab', a sailing yacht depicting the culture of the people in the coast, 'National Theater Iganmu', a military cap depicting the seat of authority during the military rule.

6.1.2 Conceptual consideration for the Plan

Most library designs take into account the need to take advantage of the Natural light and ventilation. This informs the rectangular forms adopted in most designs, which gives room to flexibility and adaptability of use. The concept behind the proposed Kaduna Metropolitan Library originated from the book holder, commonly used by the Monks, Priest, Islamic scholars, for pain staking studies from the open book set before them on it. Plate XXXIII indicates the use of the book holder as a tool for knowledge acquisition. It also shows that the basic form is the letter 'X' with the upper half as the book holder and the lower part as its stability.

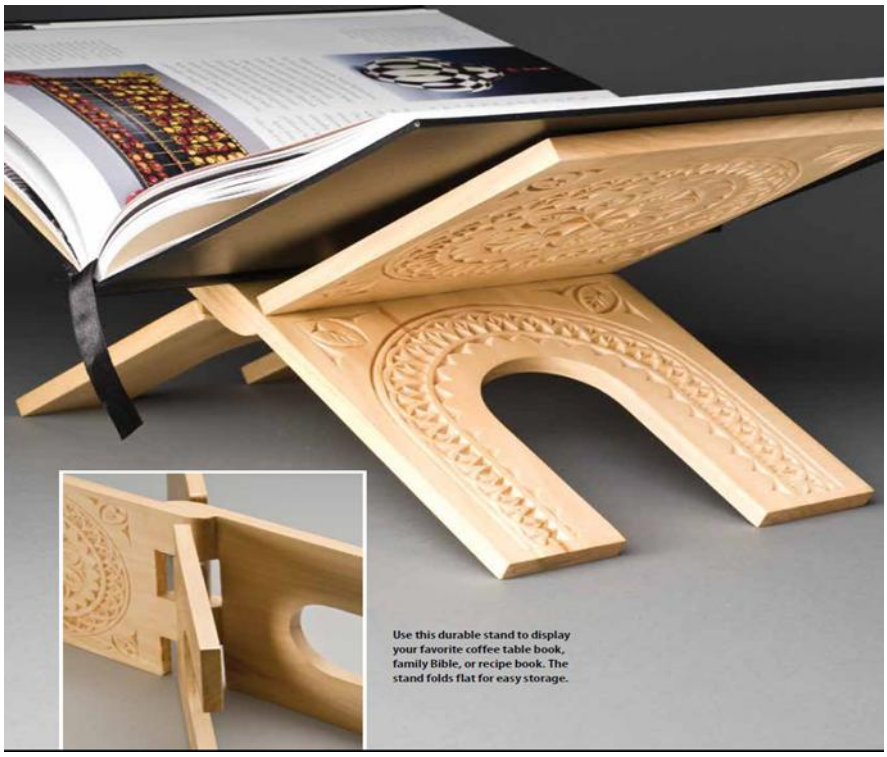


Plate XXXIII: Concept formulation Source Google search (2015)

6.1.3 Building Form

A library is home to research and learning, and books, shelves, reading areas are the basic elements in it. A look at a library, the first thing that comes to the mind is a collection of books. As such, the design take the form of a book kept standing and slightly opened. This is a form of symbolism in architecture, an expressionist approach to design, using a book-form to depict the function of what the building is to serve.

The basic idea in the façade of the building expresses books stacked on shelve and of books piled up to be returned to shelve, after use. Plate XXXIV depicts the building facade generated from book stack area in a library.



Plate XXXIV: Concept formulation (2015)

6.2 SITE PLANNING CONCEPT

The site has been designed in such a way that the arrangement of facilities flows in tune with that of nature and the various element on site. The main access to the site is from the secondary road off the eastern by-pass north of the site.

6.2.1 Site planning and landscaping

Emphasis is placed on a well landscaped environment to aid relaxation and complement activities of the library. Tree canopy shaded driveways, hedges are put in place to enhance the micro climate. The planning of the sculpture gardens follows from fractal principles of scaling, self-similarity and infinity. Stone paving have been used for the walkways, to emphasis use of natural materials – a doctrine of organic and biomorphic architecture.

6.3 DESIGN CRITERIA

Finally, designs to be produced using this scheme and principles, which will be identified as co temporal modern vernacular type, with fundamental considerations on the following:

i. Energy efficiency (passive control)

ii. The introduction of natural principles like natural ventilation and stack effect or chimney effect principles

iii. Harmonization with environment (including ecological integration and bioclimatic considerations)

iv. All of these ideas will be based on the primary knowledge of the tropics and thinking alongside with nature. For in order to produce a building in the hot-dry tropics using passive control systems only to achieve thermal comfort, fundamental knowledge of the tropics and the objectives in this study shall be put to view.

v. Understanding climatic zones and microclimate

vi. Understanding the basic physiology of human thermal comfort

vii. Control of the sun light to reduce heat loads and enhance visual comfort

viii. Use thermal mass to improve comfort and efficiency

ix. Utilize the local wind and breeze as much as can be harnessed for improved comfort

x. Finally, effective choice of construction materials and design technique for optimized results.

6.3.1.1 Orientation;

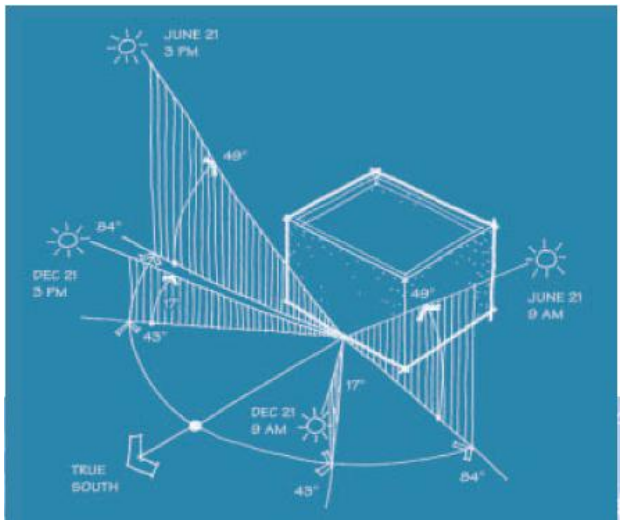


Figure 6.1: Building Orientation

The orientation of the building is essential to its proper functioning and as such, the building is designed to take full advantage of the site climatic and weather conditions as related to the cardinal points.

6.3.1.2 Accessibility;



Plate XXXV: Access to Site

The site is easily accessible by automobile and within walking distance of some potential users. However, pedestrian access will always be secondary. Parking is a key element of automobile accessibility See Plate XXXV.

6.3.1.3 Visibility;

A prominent location is required to attract a large number of readers to the library. A highly visible site along a major street with easy accessibility is ideal. The site (or surrounding sites) involves other buildings; the library shall be oriented in the portion of the site with highest visibility.

6.3.1.4 Image/Visual Quality;

The quality of the existing neighborhood surrounding the library needs to complement rather than detract from the library. The library site is located in an area with a strong positive identity and image. Placing the library at the site should also be compatible with surrounding land uses, both existing and proposed.

6.3.1.5 Demographic Patterns;

The library is located where people can easily reach it and conduct other activities the site is located where a larger percentage of all people to be served have access to it in the normal pursuit of their activities.

6.3.1.6 Site Capacity/Zoning;

The site is large enough to provide a sufficient square or rectangular library “footprint”; the required parking for users, staff and volunteers, future expansion and the necessary allowances for setbacks, zoning requirements and suitable landscaping. The resulting

building should look as if it belongs on the site, not forced on a plot of ground that is too small. For general planning purposes, the size of the site should be approximately four times larger than the proposed library facility. For example, a 10,000 square foot library will require a site that is about 40,000 square feet in size. A smaller site, to accommodate a two-level building, should not be considered. The "savings" in site cost will be quickly lost to much higher operational costs because there will have to be additional staff in order to adequately service two levels.

6.3.1.7 Noise control;

The site was zone to a less dense neighborhood as such noise or pollution from industrial activity is not a concern. The major source of noise is from the access road which can easily be curbed by building a buffer zone.

6.3.1.8 Handicapped Accessibility;

- Parking Lots

1. One handicapped space for each 25 spaces or a minimum of 1 space.

2. Spaces shall be labeled as reserved for individuals who are physically challenged.

3. Accessible parking spaces shall be 2400mm wide with an access aisle of 1500mm.

4. It should not be necessary for individuals using wheelchairs or crutches to wheel or walk behind parked cars.

- Walks and Ramps

1. Public walks and ramps shall be at least 1200mm wide, with a gradient not greater than 1 inch in 1 foot and have a non-skid surface.

2. Walks shall be of a continuing surface, not interrupted by steps or abrupt changes in level. Wherever they cross walks, driveways, or parking lots, walks blend to a common level.

3. Ramps shall have a slope no greater than 300mm rise in 3600mm.

4. Ramps shall have smooth handrails on at least one side which are 850-1200mm in height measured from the surface of the ramp, and extend one foot beyond the top and bottom of the ramp.

5. Ramps and walkways shall have a level platform at the top which is at least 5 feet by 1500mm if the door swings out onto the platform or toward the walk, or 900 x 1500mm if the door doesn't swing onto the platform.

- Entrances and Exits

1. At least one primary entrance to each building shall be accessible to and usable by individuals in wheelchairs or with other handicaps. Doorways shall be a minimum of 800mm (clear opening).

2. The floor in the inside and outside of each doorway shall be level for a distance of five feet from the door in the direction the door swings.

3. There shall be no sharp inclines or abrupt changes in level (more than 0.125 inches) at the sill.

- Stairs and Steps

1. Stairs shall have handrails 850-1200mm in height as measured from the tread at the face of the riser.

2. Stairs shall have at least one handrail that extends at the least 300mm beyond the top and the bottom step.

3. Steps shall have risers 150mm or less in height, with a width of no less than 250mm.

i. Floor Coverings

1. Floors shall have a non-slip surface.

2. If carpeted, the carpeting nap shall be not more than ½ inch thick.

i. Rest Rooms

1. There shall be an appropriate number of toilet rooms (at least one) for each sex, accessible to and usable by physically disabled persons.

2. Toilet rooms shall have turning space 1500mm by 1500mm to allow traffic of individuals in wheelchairs.

3. Toilet rooms shall have at least one toilet stall that:

i. Is 900 wide

ii. Is at least 1200mm, 200mm by 1500mm

iii. Has a door that is 800 wide and swings out

iv. Has a grab-bar on 2 of 3 sides, 850mm in height and parallel to the floor, 1½ inches in diameter, with 0.127mm clearance between rail and wall

v. Has a width of at least 1200mm between the wall and the front of the stall

vi. Has toilet seat 500mm from the floor.

vii. Drain pipes and hot water pipes are covered and insulated.

viii. Mirrors, shelves, towel racks, soap dispensers and disposable units shall be mounted no higher than 100mm from the floor.

- Water Fountains

1. Water fountains shall be accessible to and usable by the physically disabled person.

2. Water fountains or coolers shall have up front spouts and controls.

3. If coolers are wall mounted, there shall be no more than 900mm from floor to opening of spout.

4. If coolers are floor mounted, there shall be no more than 900mmfrom floor to opening of spout.

- Public and Library Telephones

1. There shall be at least one public telephone (hearing aid compatible) accessible to and usable by physically disabled persons.

2. The height of the dial or number pad, and the coin slot, shall be 48 inches or less.

3. There shall be an appropriate number of telephones (at least one) for persons with hearing disability (that is, amplifier, TTD, or TTY). Telephones shall be identified as equipped for handicapped or hearing impaired.

- Controls

Switches and controls for light, heat, ventilation, windows, draperies, fire alarms, and all similar controls of frequent or essential use should be within the reach of individuals in wheelchairs.

- Identification

1. Raised or recessed letters or Braille characters shall be used to identify rooms and offices.

2. Identification shall be placed on the wall, on the latch side of the door, at a height of 1500 mm.

3. Signage shall use the international symbol of accessibility.

- Warning Signs and Hazards

1. Audible warning signals shall be accompanied by simultaneous visual signals.

2. Ramps shall have adequate lighting.

3. Exit signs shall be easily identifiable to all disabled persons.

- Library Specific Requirements

1. Stack areas shall provide a minimum aisle width of 900 mm between stacks, with a preferred minimum of 1050 mm.

2. At least 5%, or a minimum of one carrel of each element of fixed seating, tables, or study carrels, Tops 700-850 mm high, knee space of 675 mm high, 750 mm wide.

Clearance of at least 900mm.

3. Checkout areas shall have at least one lane or point that is 36 inches wide and 900mm high for wheelchair access.

4. Card catalogs (or Public Access Catalogs) and magazine displays shall have a minimum of 900 mm aisle space. Maximum reach height shall be 120 mm and low reach shall not be less than 230 mm off the floor.

6.3.1.9 Circulation

Efforts were made to delineate pedestrian and vehicular routes on the site, and the vehicular routes have been design in such a way that there is no long stretch of straight roads to encourage over speeding and possible accident.

6.3.1.10 Ventilation

The ventilation of Library spaces is dependent on the position of the materials been displayed in respond to light, temperature and humidity as such the windows could be used and there is a provision for HVAC to carter for the ventilation as is required for the various gallery spaces.

6.4 BUILDING MATERIALS AND TECHNOLOGY

Steel, reinforced concrete and Smart glass shall be the dominant building materials for the construction of the edifice. Steel framing and Composite beams and floors will be adopted in construction.

6.4.1 Reinforced concrete

Concrete is a material that works well in compression but has negligible resistance in tension. Hence for structural purposes it traditionally relies on steel reinforcement to carry any tensile forces (this is the role played by the steel part of a composite cross

section, which is effectively external reinforcement), or must be pre-stressed so that even when subject to tension, an element is in net compression. The fluidity of reinforced concrete makes it a good construction material for the all forms and shapes of the buildings element.

6.4.2 Steel

Steel is one of the most sustainable building materials in the world. There are many reasons why steel framing has come to the forefront as one of the best and most feasible alternative building materials for commercial and residential construction. Steel is a superior construction material with many benefits which includes;

- Substantial discounts on builders risk insurance.
- Lighter than other framing materials.
- Non-combustible.
- Easy material selection - no need to cull or sort the pile and small punch list.
- Saves job-site time with ease of penalization off-site.
- Straight walls and square corners.
- Windows and doors open and close as they should.
- Less scrap and waste (2% for steel vs. 20% for lumber).
- Price stability - price spikes are extremely rare.

Consumer perceives steel as better. Cold-formed steel (CFS), being totally non-combustible, can help developers and builders use land more efficiently by allowing taller and wider buildings for the same occupancy classification.

6.4.2.1 Composite beam and slab

The most common type of composite beam is one where a composite slab sits on top of a down-stand beam, connected by the use of a through deck welded shear studs. This form of construction offers a number of advantages - the decking acts as external reinforcement at the composite stage, and during the construction stage as formwork and a working platform. It may also provide lateral restraint to the beams during construction. The decking is lifted into place in bundles, which are then distributed across the floor area by hand. This dramatically reduces the crane lifts when compared with a precast based alternative.

Composite slabs comprise reinforced concrete cast on top of profiled steel decking, which acts as formwork during construction and external reinforcement at the final stage. The decking may be either re-entrant or trapezoidal, as shown below.

6.4.3 Light shelves

The protruding portion of the light shelf, in the case of a combined or exterior light shelf, acts also as a shading device and prevents sunlight from falling directly on the work plane. Moreover it prevents glare and minimizes the brightness near the window, making the light levels in the room uniform. A light shelve as in Figure 6.2, can solve problems at once if it extends past the face of the building.

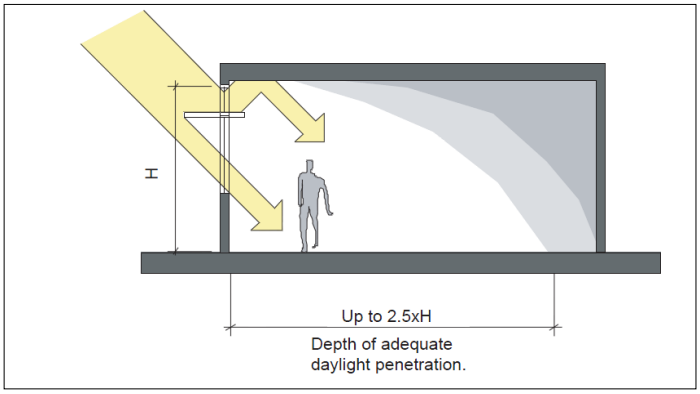


Figure 6.2: Cross-Section of Light Shelve. Source: Keith (2003)

6.4.4 Smart Glass

The expression Smart glass can be interpreted in a wider sense to include also glazing's that change light transmission properties in response to an environmental signal such as light or temperature.

6.5 SERVICES

The following services are provided already around the new city, making it less cumbersome to access.

6.5.1 Water Supply

Borehole Water supply is proposed for the facility and also water mains runs along the road where tap water could be connected; in addition to this, water could be from the river for on-site construction.

6.5.2 Power supply

Power shall be tapped from the KADCO national grid. There is provision for a power house, with two generator sets – one working and one standby, to cater for power failure.

6.5.3 Firefighting System

The installation of firefighting system will aid in prompt management and control of any fire outbreak. Firefighting equipment like smoke detectors, hose reel, water hydrant, dedicated water tanks, and sprinklers should be included in the design.

6.5.4 Storm Water drainage

Storm drains should take advantage of the sites gentle slope in order to get surface water off the site in good time. It should also be designed to connect roof drain pipes either to underground or surface storages tanks for rain water harvest.

6.5.5 Expansion joints

Introduction of expansion joint should be provided to cater for possible effects of settlement on the building.

6.5.6 Refuse disposal

Waste bin are strategically provided, and an incinerator placed towards the rear.

6.5.7 Waste Water and sewerage

A central sewage line should take away all waste water and soil from the site to treatment plant and managed by Kaduna Environmental Protection Agency KEPA.

6.5.8 Heating Ventilation and Air Conditioning System

To complement natural ventilation occasioned by the projected windows adopted, a central air conditioning system shall be installed which will be powered from the solar panel photovoltaic farm on the roof top.

6.6 BUILDING FINISHES

Quality, durability, comfort, safety, thermal control, maintenance, quietness, appearance and cost effectiveness should be the basis for choice of finishes used on the complex.

6.7 CONSTRUCTION METHOD

Steel framing system should be the most appropriate method of construction. Steel beams and columns should be covered in-situ and in-situ composite floors should be adopted for longer spans. Block should be used as infill in line with the framing and all electrical piping and wiring in conduit system.

6.8 SCHEDULE OF SPACE ALLOCATION

Table 6.1: Schedule of Accommodation for Main Building

A	GROUND FLOOR		
S/N	Floor/ Spaces	Floor Area (m^2)	unit
1	CHILDREN SECTION Children activity / play room, Activity / playing room, sleep room	215	1
2	CATALOGUING/CLASSIFICATION SECTION	75	1
3	ACQUISITION SECTION	104	1
4	BOOK BINDERY/JOINERY & STORAGE	45	1
5	MAIN ENTRANCE	144	1
6	MULTI PURPOSE HALL	324	1
7	LIFT/STAIR AREA	32	1
8	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	315	1
9	TOILET	54	2
10	PHOTO DUPLICATING AND PRINTING AREA	18	1
11	ELECTRICAL ROOM	9	1
12	STAIR WELL	22	2
B	FIRST FLOOR		
1	YOUNG-ADULT LEARNING AREA	288	1
2	ACCOUNTS OFFICE	72	1
3	ACCOUNTS SECTION	104	1
4	BOOK SHOP 1	45	1
5	SPECIAL REFERENCE	324	1

6	PHOTO DUPLICATING AND PRINTING AREA	18	1
7	ELECTRICAL ROOM	9	1
8	LIFT/STAIR AREA	32	1
9	EXIBITION AREA	108	1
10	TOILET	54	2
11	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	288	1
12	STAIR WELL	22	2
C	SECOND FLOOR		
1	INTERNET HOTSPOT	144	1
2	SERVER ROOM	18	1
3	GENERAL REFERENCE SECTION 1	288	1
4	GENERAL REFERENCE SECTION 2	252	1
5	BOOK PRESERVATION ROOM/ BIBLIOGRAPHY SECTION 2	180	1
6	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	306	1
7	TOILET	54	2
8	ELECTRICAL ROOM	9	1
9	LIFT/STAIR AREA	32	1
10	STAIR WELL	22	2
D	THIRD FLOOR		
1	HISTORY AND GENEALOGY SECTION	252	1
2	PERIODICALS AND REFERENCE SECTION	135	1
3	E- LIBRARY	288	1
4	AUDIO VISUAL UNIT; video conferencing room, control/software room, store, office	216	1
5	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	306	1
6	TOILET	54	2
7	ELECTRICAL ROOM	9	1
8	LIFT/STAIR AREA	32	1
9	STAIR WELL	22	2
10	BOOK SHOP 2	45	1
D	FOUTH FLOOR		
1	RESERVE SECTION 1	288	1
2	AFRICAN AND NIGERIAN REFERENCE SECTION	252	1
3	BOOK PRESERVATION ROOM	135	1
4	ART GALLERY	216	1
5	TOILET	54	2
6	ELECTRICAL ROOM	9	1
7	LIFT/STAIR AREA	32	1
8	STAIR WELL	22	2
9	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	306	1
10	BOOK SHOP 3	45	1
E	FIFTH FLOOR		
1	TOILET	54	2
2	LIFT/STAIR AREA	32	1
3	STAIR WELL	22	2
4	ELECTRICAL ROOM	9	1
5	RESERVE SECTION 2	72	1
6	HOLDING ROOMS	36	3

7	STORE	18	1
8	ART GALLERY/LOUNGE	143	1
9	ART GALLERY	130	1
10	GOVERNMENT ARCHIVES	103	1
11	SECRETARY	23	1
12	OFFICE 1	28	1
13	OFFICE 2	36	1
14	CIRCULATION AREA; Lift lobby, information desk, control, bag rack area.	420	No

6.9 ARCHITECTURAL PLANNING AND BUILDING DESIGN

The design of the Kaduna metropolitan library is steered by aim, rationality and a passion to create a cost effective study environment that would encourage intense research. The complex spaces are carefully placed according to the activity zones, these includes; Noisy, semi-quiet, and quiet zones.

6.9.1 Site Plan

The whole complex is accessed from two major directions as shown in Figure 6.3

(i) Services Access (lighter traffic to the site from the busy dual carriage eastern by pass at a higher level to connect to the ground floor for the technical and acquisitions /service area.

(ii) Main Public Access (heavy traffic to the site) from the not so busy smaller access road off the eastern by pass. The parking for staff and visitors are seen lined with trees walkways.

The following auxiliary facilities are also provided on site -

Standby Generator, Gate house, Borehole and Water Storage facilities, Maintenance office/Workshops.

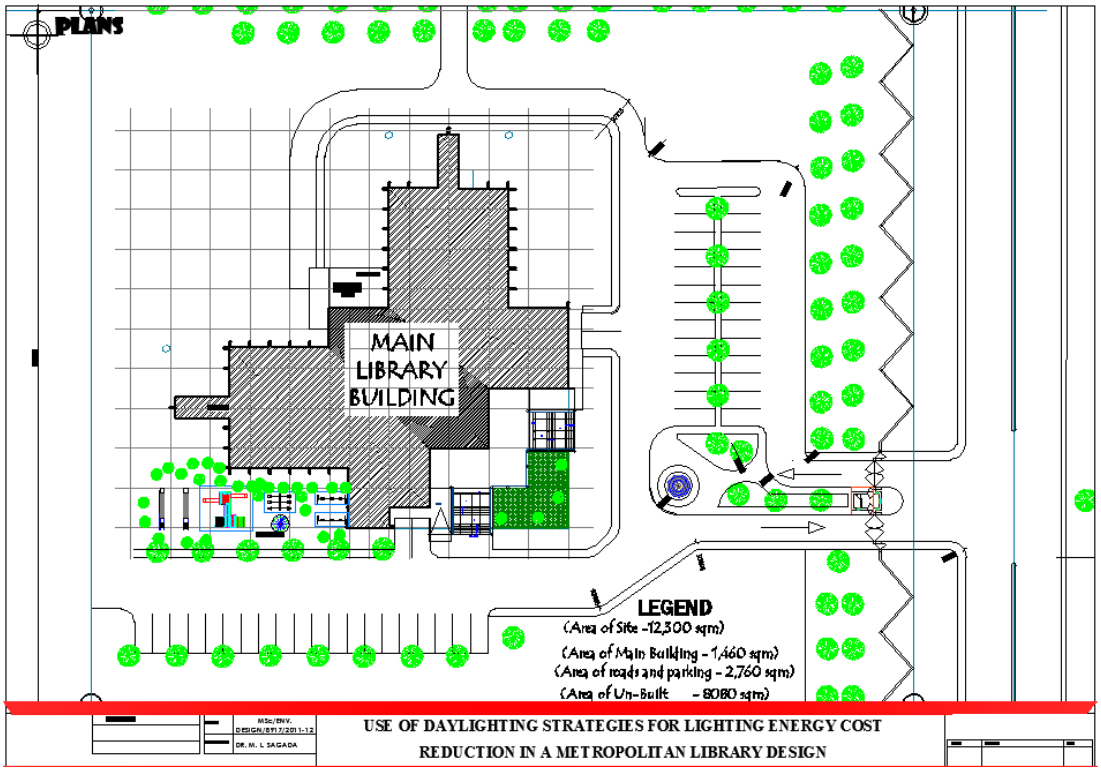


Figure 6.3: Site Plan

6.9.2 Ground floor Plan

In Figure 6.4 the Ground Floor Plan consist of the Children library, technical section, entrance / circulation spaces / information desk, electric room, bookshop photocopy / duplicating stand and the multipurpose hall. The main entrance is an important area of the building, where visitors gain a first impression of the building. The space should be well lit, welcoming, and feel natural in lighting terms.

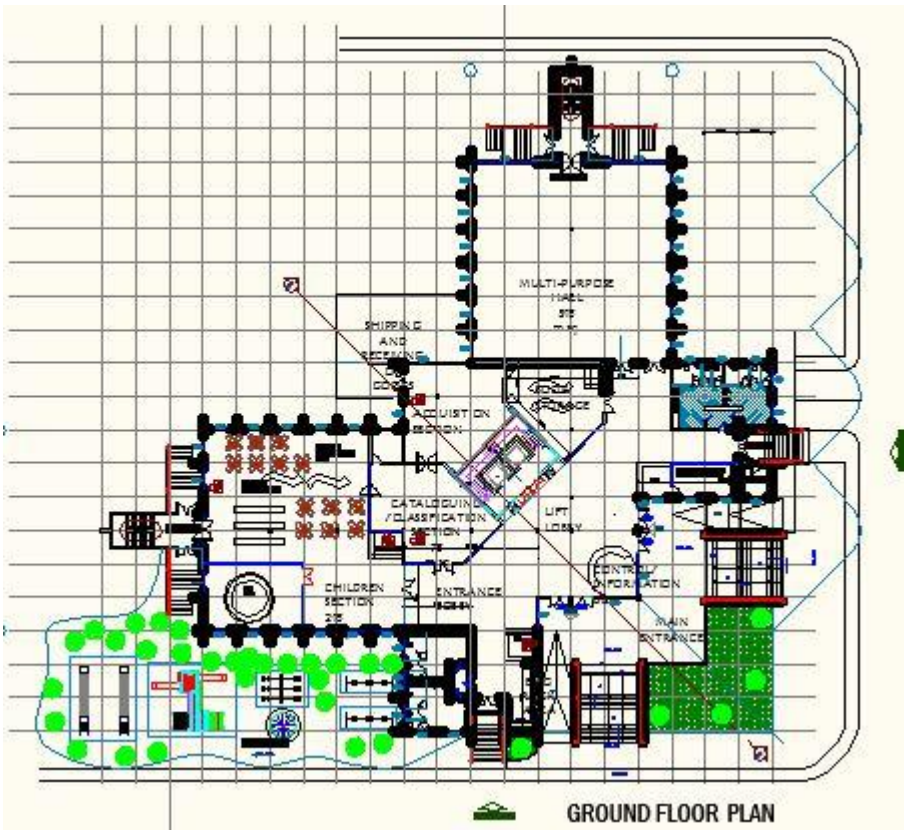


Figure 6.4: Proposed Ground floor Plan

6.9.3 First floor plan

In Figure 6.5, the First Floor Plan accommodates the young adult section, accounts section, bookshop, photocopy / duplicating stand 2, exhibition area, serial section.

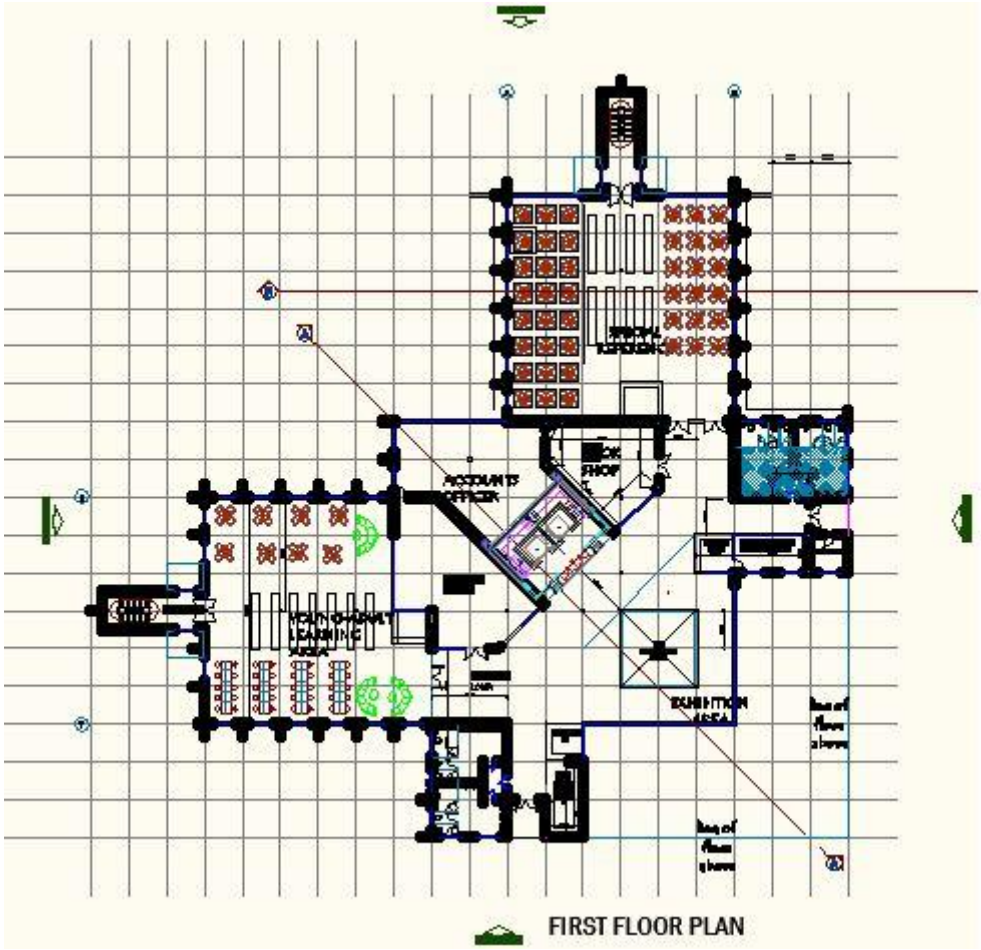


Figure 6.5: Proposed First floor Plan

6.9.4 Second floor plan

The Second Floor Plan in Figure 6.6 contains the E-library, General reference 1&2, book preservation and bibliography.

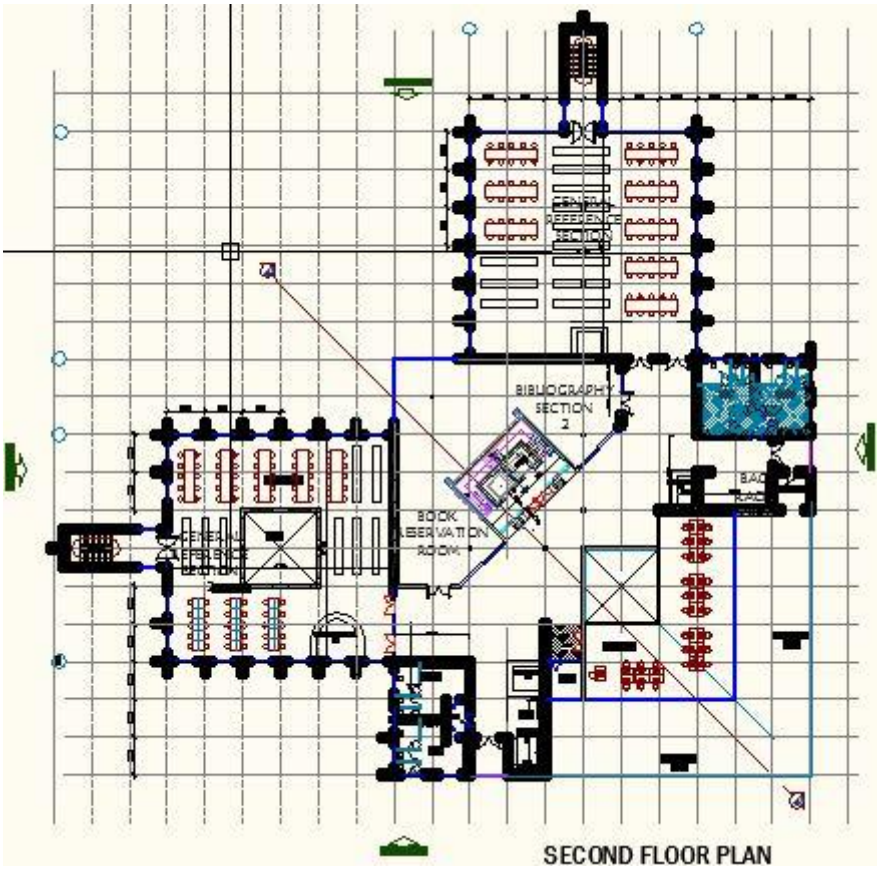


Figure 6.6: Proposed Second floor Plan

6.9.5 Third floor plan

Figure 6.7 is the Third Floor Plan, consisting of the computer / ICT and training room, bookshop, History and Genealogy section, Government Archives.

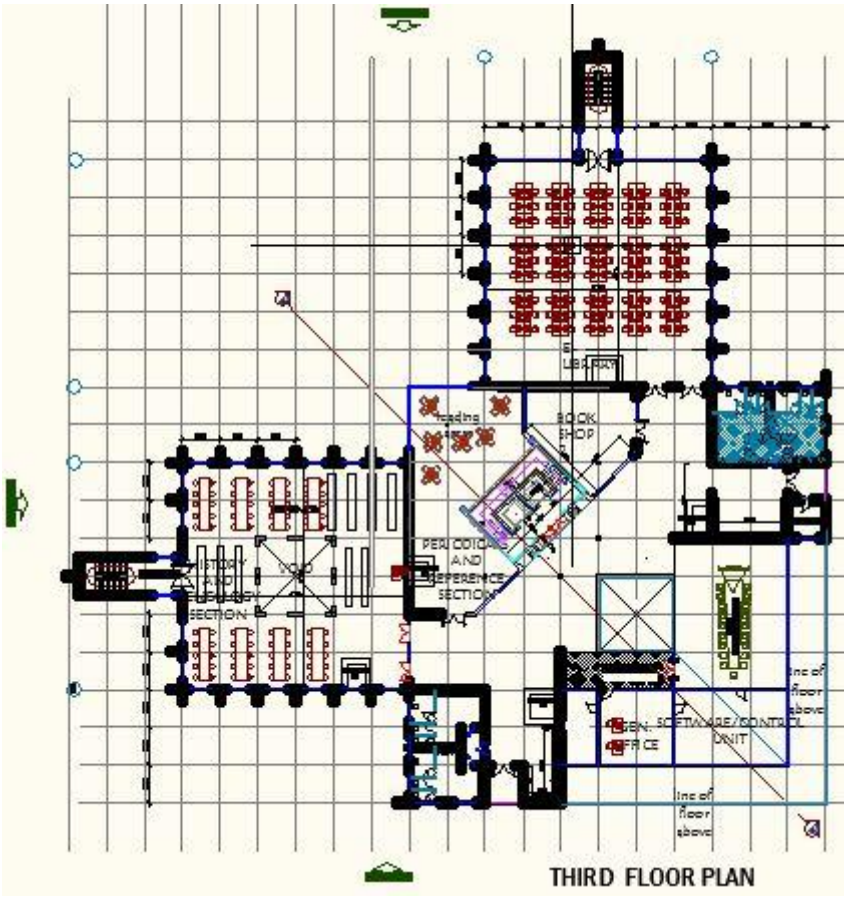


Figure 6.7: Proposed Third floor Plan

6.9.6 Fourth floor plan

Figure 6.8 is the Fourth Floor Plan with a reading and discussion lounge, book preservation, open offices, Africana / Nigeriana Sections and a reserve section

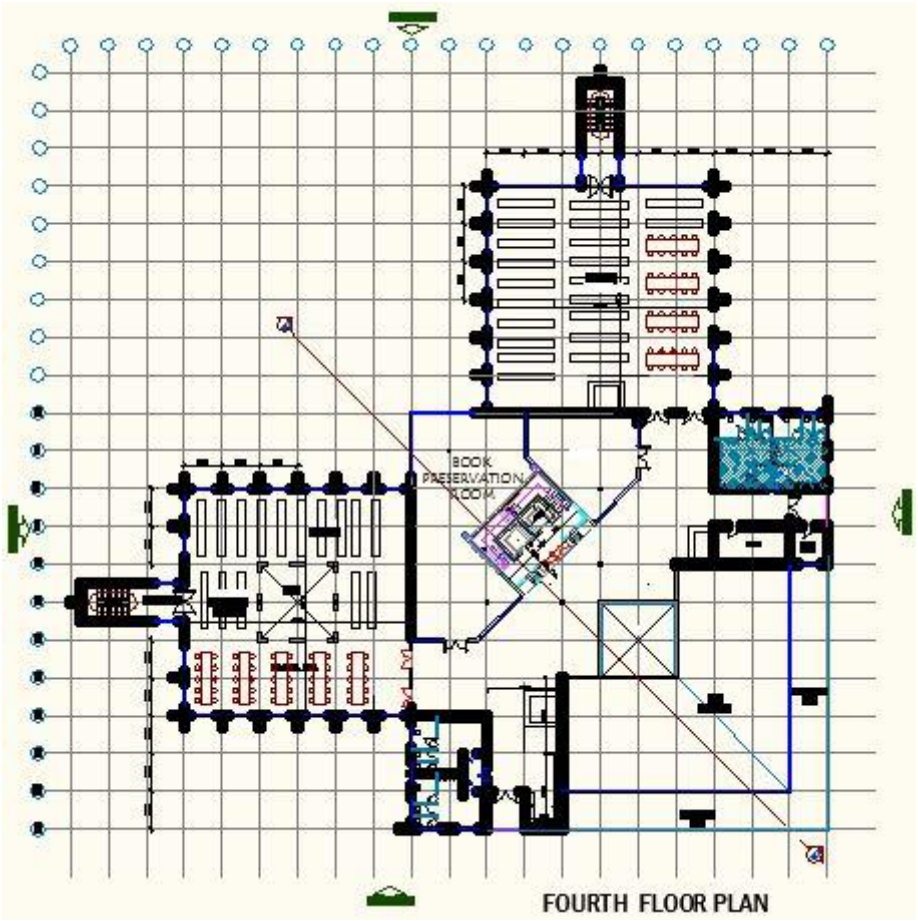


Figure 6.8: Proposed Fourth floor Plan

6.9.7 Fifth floor plan

Figure 6.9 is the Fifth Floor Plan; this floor accommodates the Art Exhibition gallery, Government Archives, Executive offices, Reserve Section, meeting Rooms, holding room 1-3, stores, control point and information desk, lounge with a snack shop.

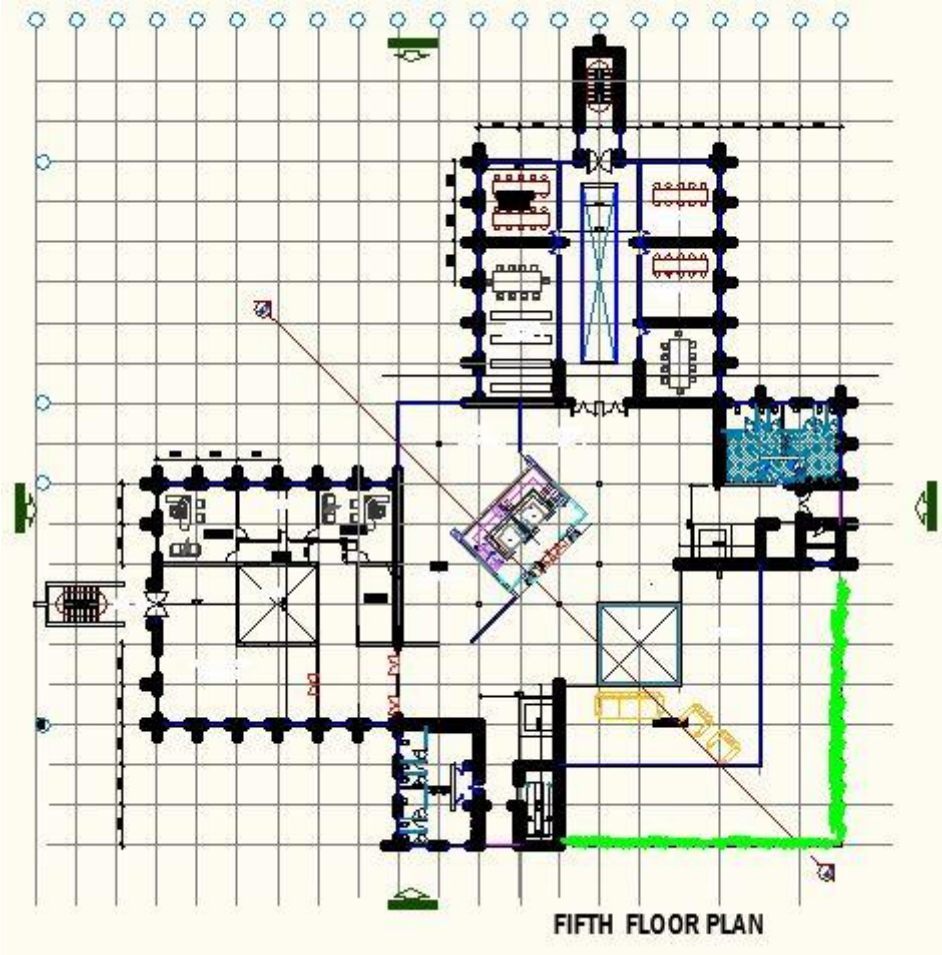


Figure 6.9: Proposed Fifth floor Plan

6.9.8 Service floor

Figure 6.10 is the Sixth Floor also known as the service floor consisting of a green roof garden for relaxation with great views of the millennium rich townscape. The water storage tanks lift machine powered by the photovoltaic, skylight roof covers can all be accessed from this floor for maintenance and operations.

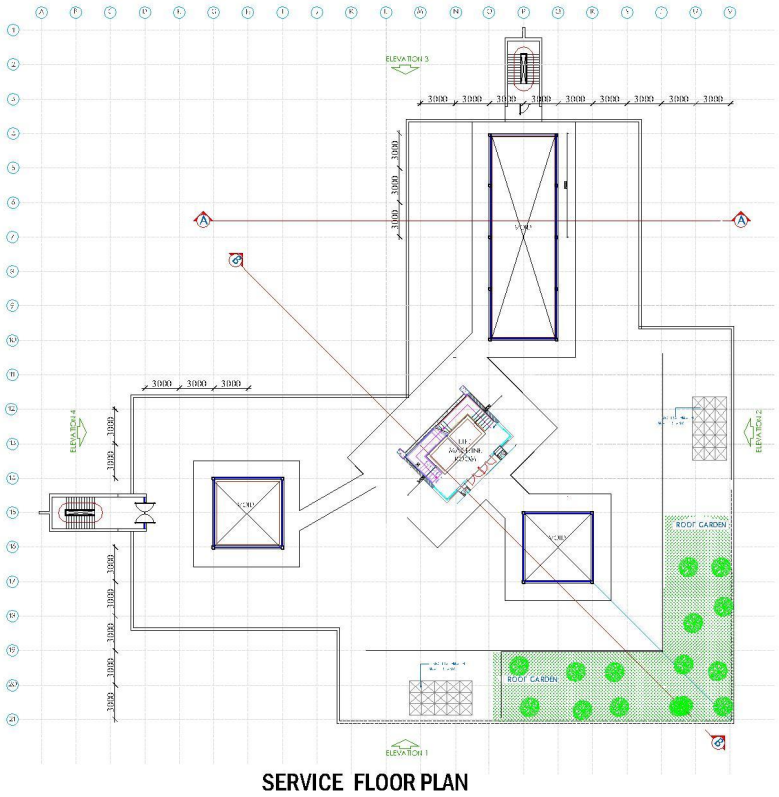


Figure 6.10: Proposed Sixth floor Plan

6.9.9 Roof plan

Figure 6.11 consist of the Roof Plan showing R.C slab with the green roof. It also shows the polycarbonate skylight, and photovoltaic panels used to cover the lift machine room and the high level openings over the atrium. These photovoltaic panels help power the lift in the absence of the municipal power supply.

The polycarbonate skylight roof will provide superior insulating qualities compared to a conventional glass roof, while still allowing the introduction of diffuse light into the space below. This system has further benefit in that it reduces glare and radiant heating effects.

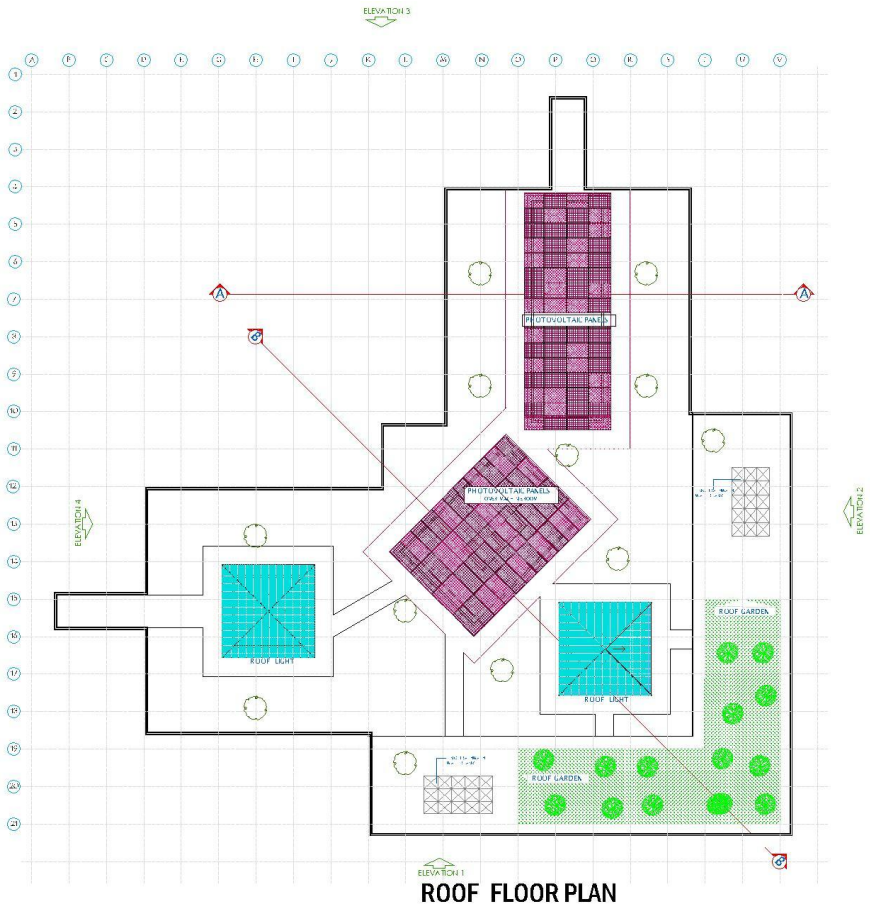


Figure 6.11: Proposed Roof Plan

6.9.10 Section

Figure 6.12a is the sectional views of the complex. Section A-A cuts through the right Arm of the complex revealing the floor system, light shelf used in daylight distribution into the adjourning spaces far from perimeter of the complex as illustrated in Figure 6.12b (Refer to Chapter 2.3b). Also, captured is the different smart glazing (see appendix for properties) used to admit daylight, control heat gain and for view out. Section B-B cuts through the converging portion of the complex revealing the curtain walls, the lift shaft with the staircase around it. The skylight roof is also captured here with the operable high level windows for ventilation.



Figure 6.12a: Proposed Section A - A

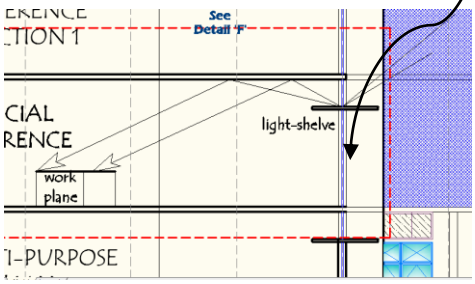


Figure 6.12b: Part Section A - A



Figure 6.13: Proposed Section B - B



Figur 6.14: Proposed Elevation 1



Figure 6.15: Proposed Elevation 2



Figure 6.16: Proposed Elevation 3

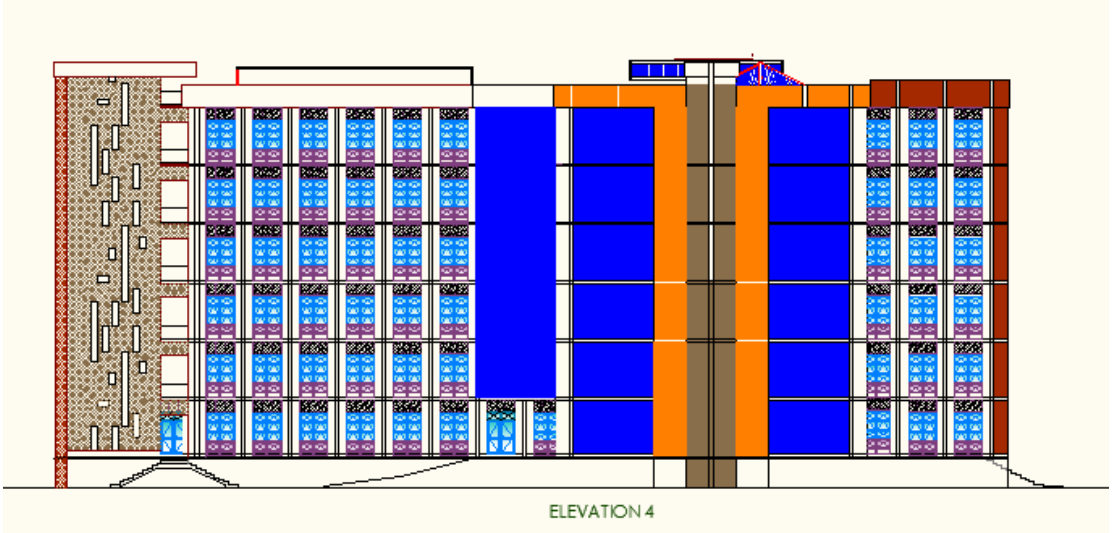


Figure 6.17: Proposed Elevation 4

6.10 DAY LIGHTING ANALYSIS

Daylighting analysis was carried out for three (3) different spaces within the library (lounge area, Government archives, and reading rooms respectively) to ensure that adequate distribution of lighting within the library. To this end, the following considerations where made to ensure the adequacy of the report:

1. The proposed design is located in Kaduna millennium city, latitude +10.52 (10^{o}, 32', 12'N) and longitude +7.44 (7.26' 24"E).
2. The daylight simulation was conducted for six (6) months which consists of two (2) month in each quarter of the year in order that various cloud conditions will be investigated to see how it affects the design.
3. The library is assumed to be occupied Monday through Saturday, from 8am to 5pm, having total annual hours of occupancy to be 1569.0. Thus, the analysis checks for lighting behavior in the hours of 9am, 1pm and 4pm in each of the selected months.
4. Finally, it is important to note that the minimum illuminance level required for the users of a library is 500 lux. Thus, this lighting lux level is checked in

all the spaces being analyzed for the uniform distribution of daylighting within these spaces.

6.10.1 Simulation Report for the proposed library design considering all three selected spaces

A. Daylight Factor (DF) Analysis

67% of all illuminance sensors have a daylight factor of 2% or higher. If the sensors are evenly distributed across all spaces occupied for critical visual tasks, the investigated lighting zone would qualify for the LEED-NC 2.1 daylighting credit 8.1.

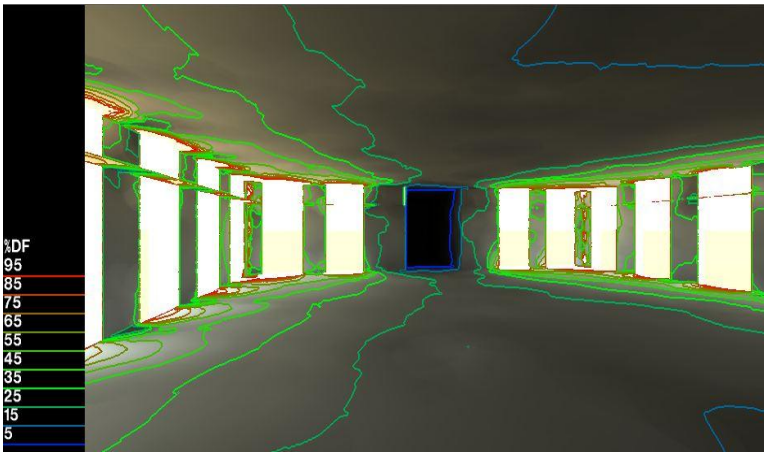


Figure 6.18: Day light factor for Government archives in the month of April

Source: Radiance simulation output

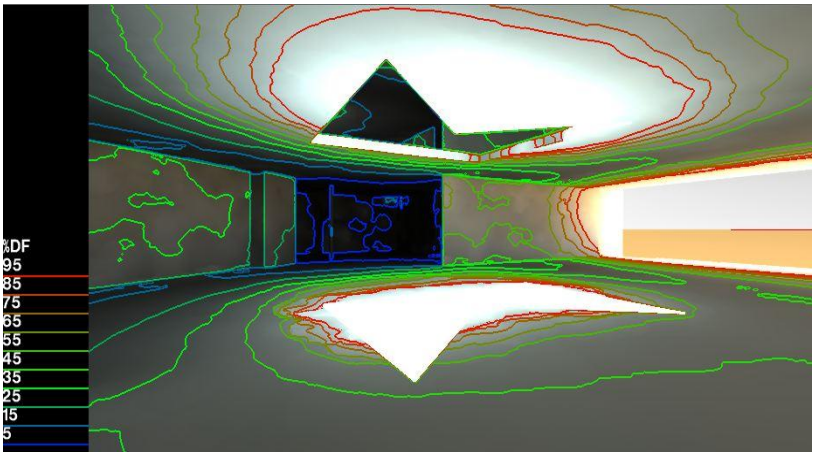


Figure 6.19: Day light factor for general lounge in the month of June

Source: Radiance simulation output



Figure 6.20: Day light factor for general lounge in the month of June

Source: Radiance simulation output

B. Daylight Autonomy (DA) Analysis

The daylight autonomies for all core work plane sensors lie between 45% and 99% for the work plane under consideration. Hence, the daylight quality in the space has a uniform daylight saturation that exceeds 60% of the work plane under consideration.

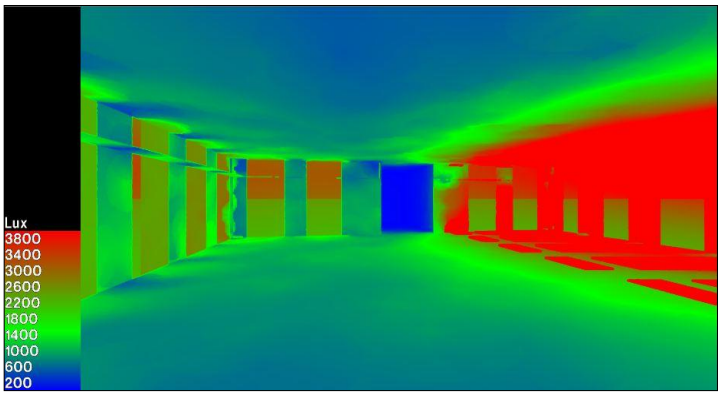


Figure 6.21: False color metric display of the illuminance in Government archives. Source: Radiance simulation output

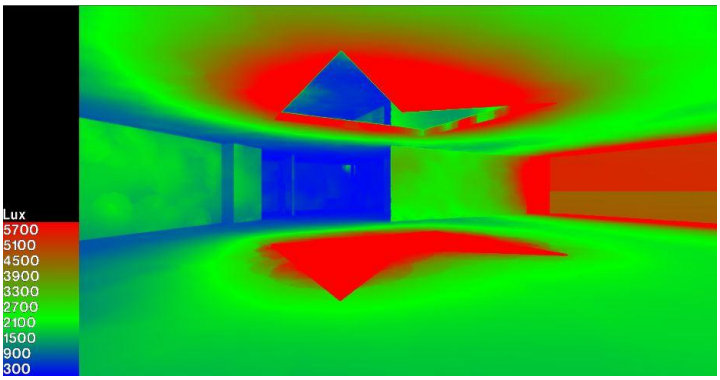


Figure 6.22: False color metric display of the illuminance in the general lounge. Source: Radiance simulation output

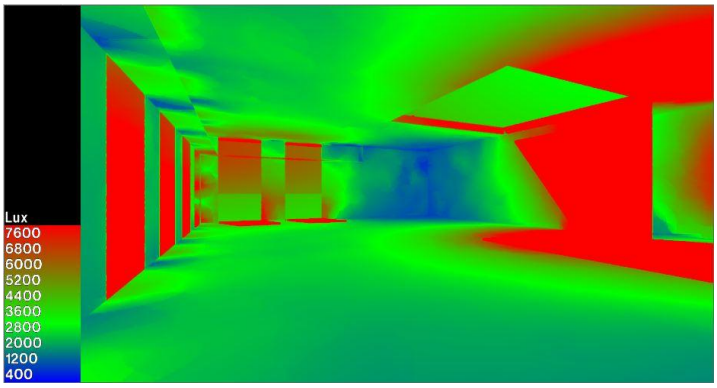


Figure 6.23: False color metric display of the illuminance in the Government Archives 1. Source: Radiance simulation output

C. Useful Daylight Index (UDI) Analysis

The Useful Daylight Indices for the Lighting Zone are $UDI_{<100}$=14%, $UDI_{100-2000}$=76%, $UDI_{>2000}$=10%. Hence, the total number of occupied hours that useful daylight enters this space at its selected work plane is predominantly 61%.

D. Lighting and Blind Control

The general lounges provided have no shading device but however, each floor having the general lounge has the next floor (upper floor) overlapping it, thereby providing a kind of shade to the lounge areas. More so, the other large areas within the library are shaded with light shelves which help in providing more illuminance to the inner depth of the large spaces.

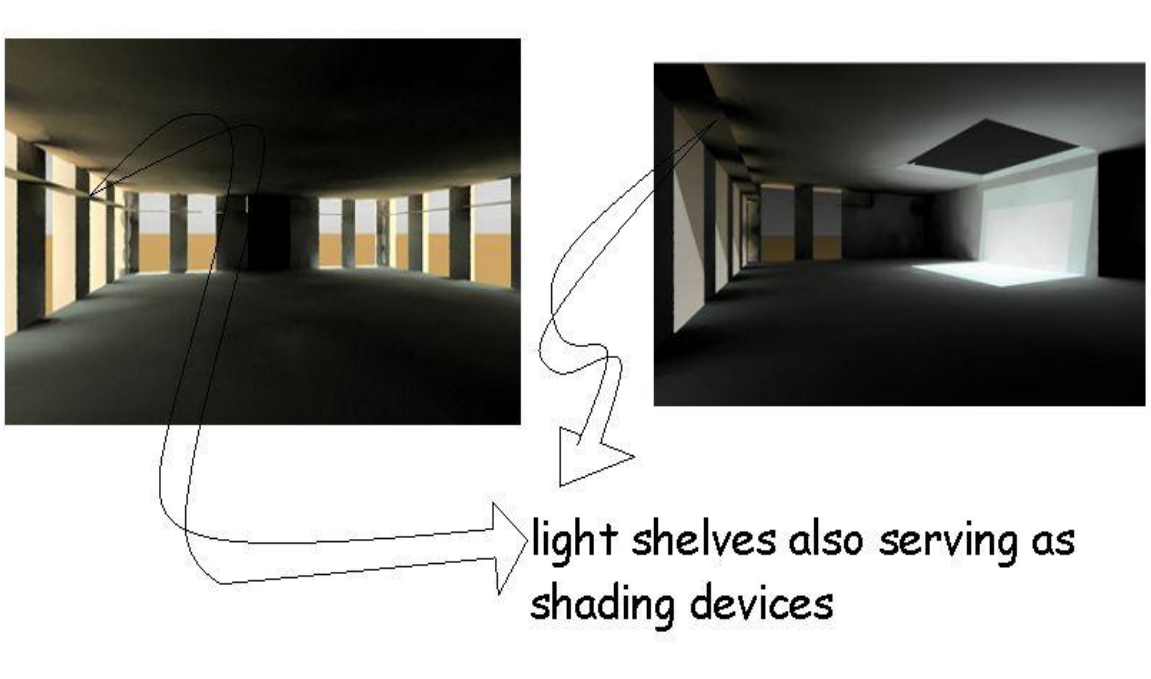


Figure 6.24: Light shelves Source: Researcher's work

E. Continuous Daylight Autonomy (DA_{con}) and DA_{max} Analysis

72% of all illuminance sensors have a DA_{con} above 40%. 5% of all illuminance sensors have a DA_{max} that does not exceed 1%. Hence, glare and heat from excess solar gains have been controlled in the spaces.

F. Scene Visualization. The figure below shows a visualization of the building model.



Figure 6.25: Scene visualization image of the library Source: Daysim Simulation output

The following figures below however, show the scene visualization image of the three (3) spaces been analyzed in the building model.

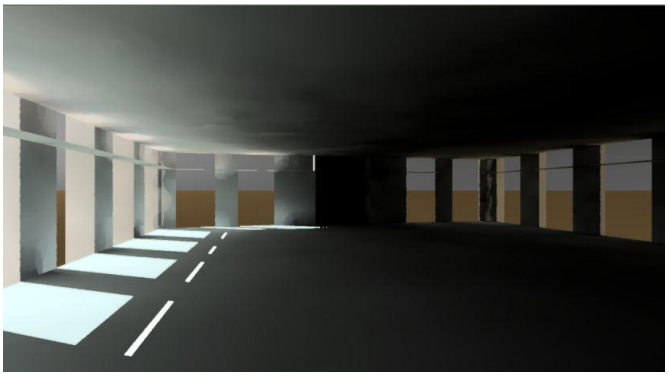


Figure 6.26: Radiance simulation result for Government archives
Source: Radiance simulation output

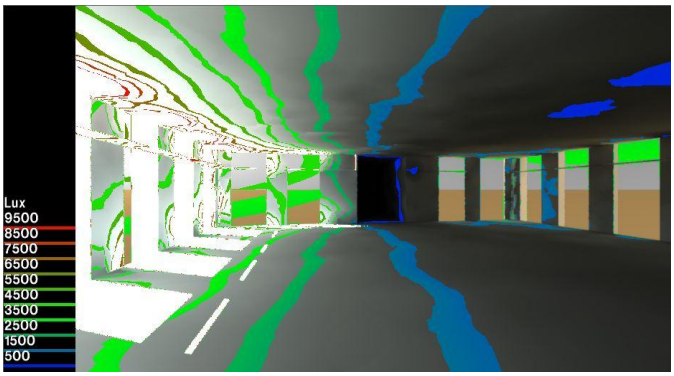


Figure 6.27: Radiance simulation result showing the illuminance achieved by the dynamic day lighting in the Government archives

Source: Radiance simulation output

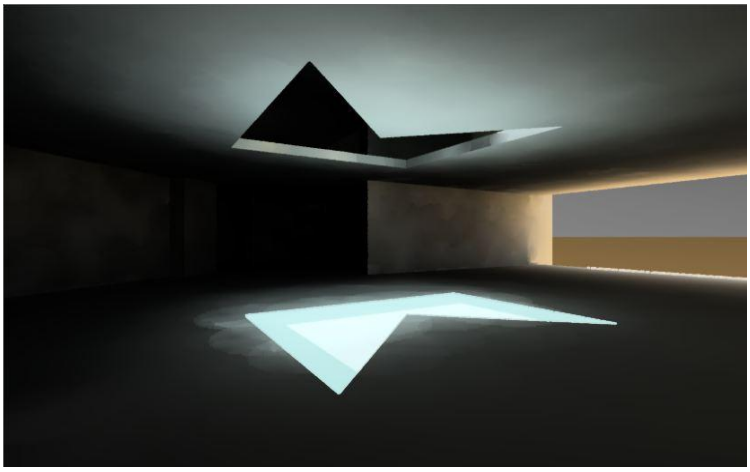


Figure 6.28: Radiance simulation result for general lounge

Source: Radiance simulation output

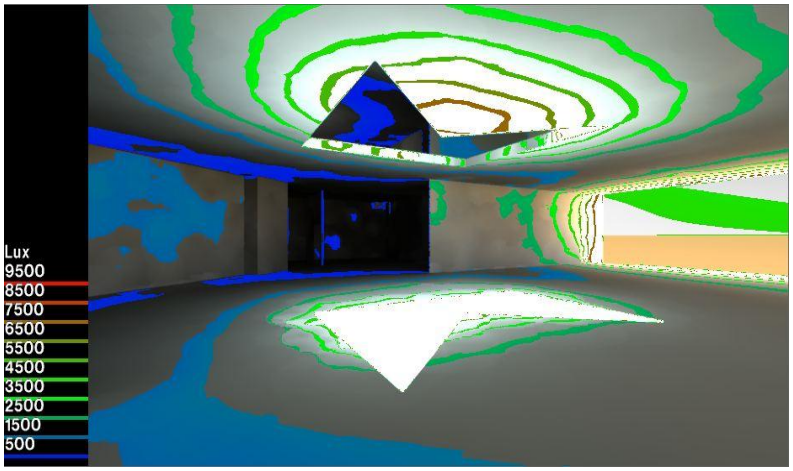


Figure 6.29: The illuminance achieved by the dynamic day lighting in the general lounge Source: Radiance simulation output

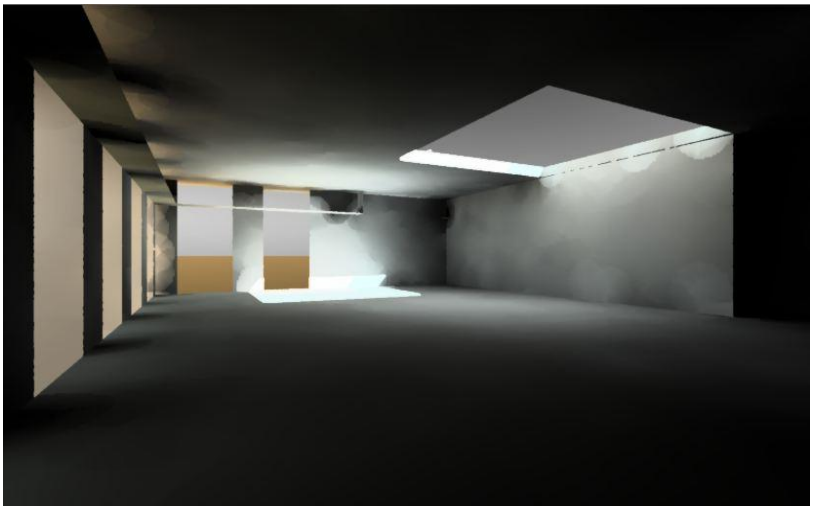


Figure 6.30: Radiance simulation result for Government archives 1

Source: Radiance simulation output

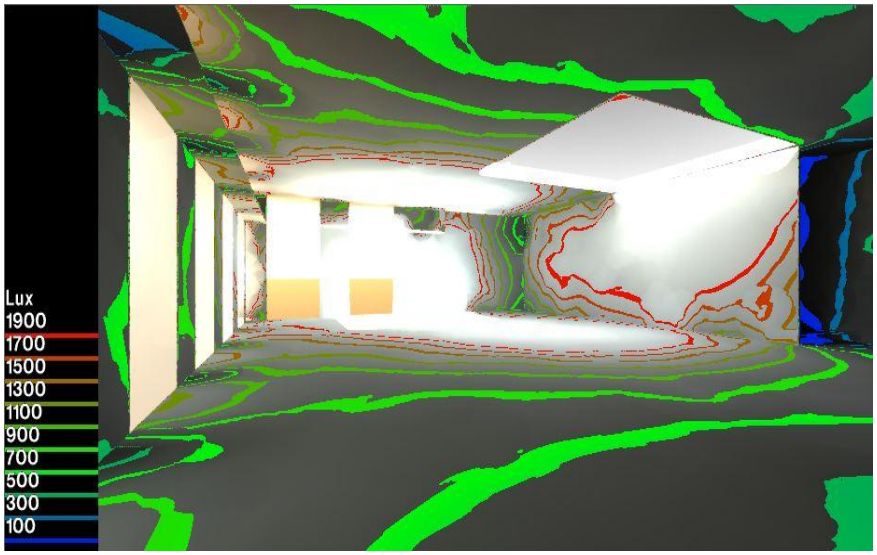


Figure 6.31: Illuminance achieved by the dynamic day lighting in the Government Archives 1 Source: Radiance simulation output

6.10.2 Summary of day lighting analysis report

Efficient lighting (day lighting) is achieved from the results seen from the simulation report. The Useful Daylight Index report (UDI) shows a uniform distribution of light achieved in the library all through the year with the minimum light requirement of 500 lux under the working plane put under consideration. This result is made possible with the use of lighting shelves to bounce in more lights in the work plane and as shading

devices, the use of atriums and in the avoidance of deeper depth (deep planning) in the design of the library.

CHAPTER SEVEN

SUMMARY OF FINDINGS ANDCONCLUSION

7.1 SUMMARY

The library as a tool for intellectual pursuits needs to be an environment that facilitates good research and reading culture, with no impediments. Most libraries depend on artificial source for lighting. Although energy cost could hamper its smooth running, coordinated project design with passive lighting in mind is a solution to its lighting needs for smooth operations. Review of relevant literature in Nigeria and other countries shows the significance of daylighting design.

Findings from writings, works of prominent lighting professionals aided in culminating a set of principles on which light has been ordered, from these principles, theme peculiar to all of them such as nature, context, vista, interaction with site and growth have been extracted.

Case studies were analyzed using general variables and specific variables (directly related to the subject of lighting), of which the light levels in terms of composition, technology, and materials used were considered. Findings from the case studies and literature review were thus used in generating design and planning concepts for the propose facility, these findings demonstrated that emphasis is on the admittance of useful daylight into the building.

The study has established that good planning, design for natural lighting and a good maintenance program can effectively reduce lighting energy cost in operating a library.

7.2 CONCLUSION

Based on data collected from already established sources, and references drawn from related case studies, and oral interview administered, the most significant conclusion which can be drawn from this research study is that today, most learning and study environment have become uncomfortable spaces because of the lighting challenges poised to users especially in a developing country like ours, where one cannot rely on national power generation but must provide alternative sources if good illumination levels must be achieved. Also lighting strategies for energy efficiency and thermal comfort in libraries today are mostly not effectively incorporated at Conceptual / design stages.

Therefore, this study is a timely one, at a period where energy crisis, global warming and thermal comfort issues are most pressing, a priority to architects and designer around the world.

7.2.1 Conclusions For Result Findings

Results obtained from Daylighting studies carried out on the Libraries namely National Library kaduna, Kaduna State Library and Isa Kaita Library, Kaduna Polytechnic main campus, showed that the two of the library buildings fell below standard illuminance level owing to less daylight design considerations. For the National Library, a significant level of daylight in most of the library spaces was recorded, and the dependence on electricity was seen to be significantly reduced.

Thereby in choosing energy effective and efficient daylight strategy from results and literatures, library designed with passive solar design consideration at the conceptual

stages, serves as perfect building solution for cost effective Library lighting and in reducing significantly, over dependence on artificial lighting sources. Daylighting can also increase performance and satisfaction for both building occupants and owners.

The intent of the thesis was to examine how effective daylight strategies can be utilized in the designs of Libraries, its level of applicability in present day architecture with particular reference to learning environment, and to produce an architecture which would be visually pleasing in terms of expression and satisfactory in terms of its energy efficiency both of which are the current waves in architecture and the green revolution. The resulting iconic building shall tell its own story from a distance of its rich content, which would further help to increase the patronage level and provide an excellent platform to boost the research, and reading culture of the people of Kaduna State, and the country at large.

7.3 RECOMMENDATIONS

Buildings are meant to provide a safe and comfortable internal environment despite variations in external conditions.

Therefore with the potentials observed, from the use of daylight strategies for Library lighting, the following recommendations are posited:

i. It has been proven that energy efficient lighting can be achieved by passive control systems in the tropical environment, and the existing building can be retrofitted to achieve this if there is a dearth.

ii. There should be a sense of deeper meaning to daylighting in Library designs from the conceptual stage and through the life of the building , since reading, research remains viable tool to Nation building. Also, conceptual design for buildings should go beyond provision of spaces for

activity, but must adequately consider energy efficiency and the science of usability as part of the whole process in a buildings existence.

iii. The use of advanced building materials (smart materials) should be encouraged to achieve needed reading environment.

iv. These edifices should also serve as venues for plays, recreational purposes, conferencing, educational and commercial activities.

In order to have more accurate evaluation, further studies on various cases in the tropical region are recommended, further studies on the natural lighting, effects of building envelope insulation and internal comfort sensations in tropical climates are also recommended.

7.4 CONTRIBUTION TO KNOWLEDGE

The contribution of this work to the advancement of knowledge is seen, in the use of daylighting strategies as a tool to achieving appropriate lighting levels for study both for existing buildings and at conceptual stages of building design, with little or no cost implications.

Secondly, using the Libraries' environment as a beacon or magnet that should be able to attract, help all ages to improve and develop the reading habit and passion for intellectual pursuit.

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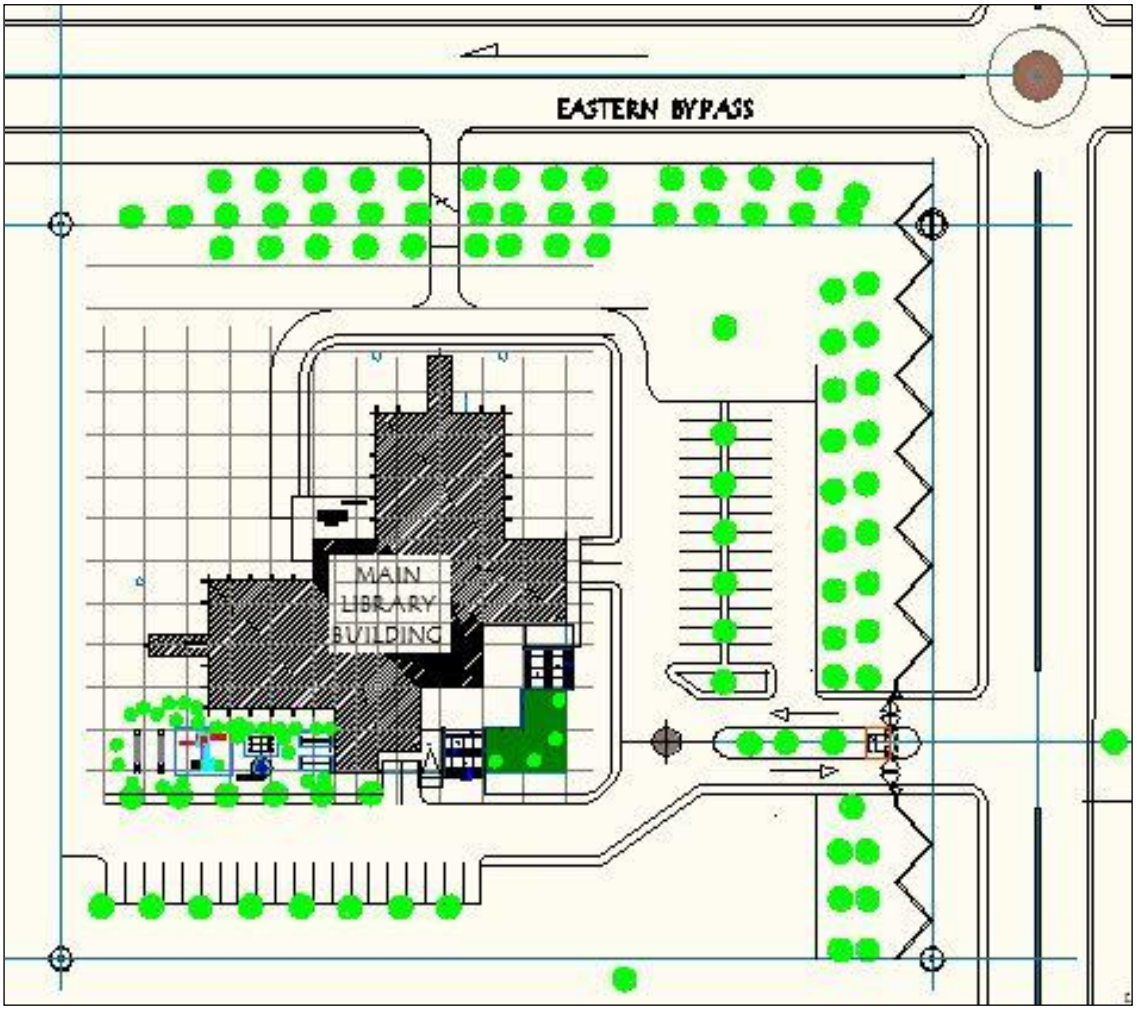
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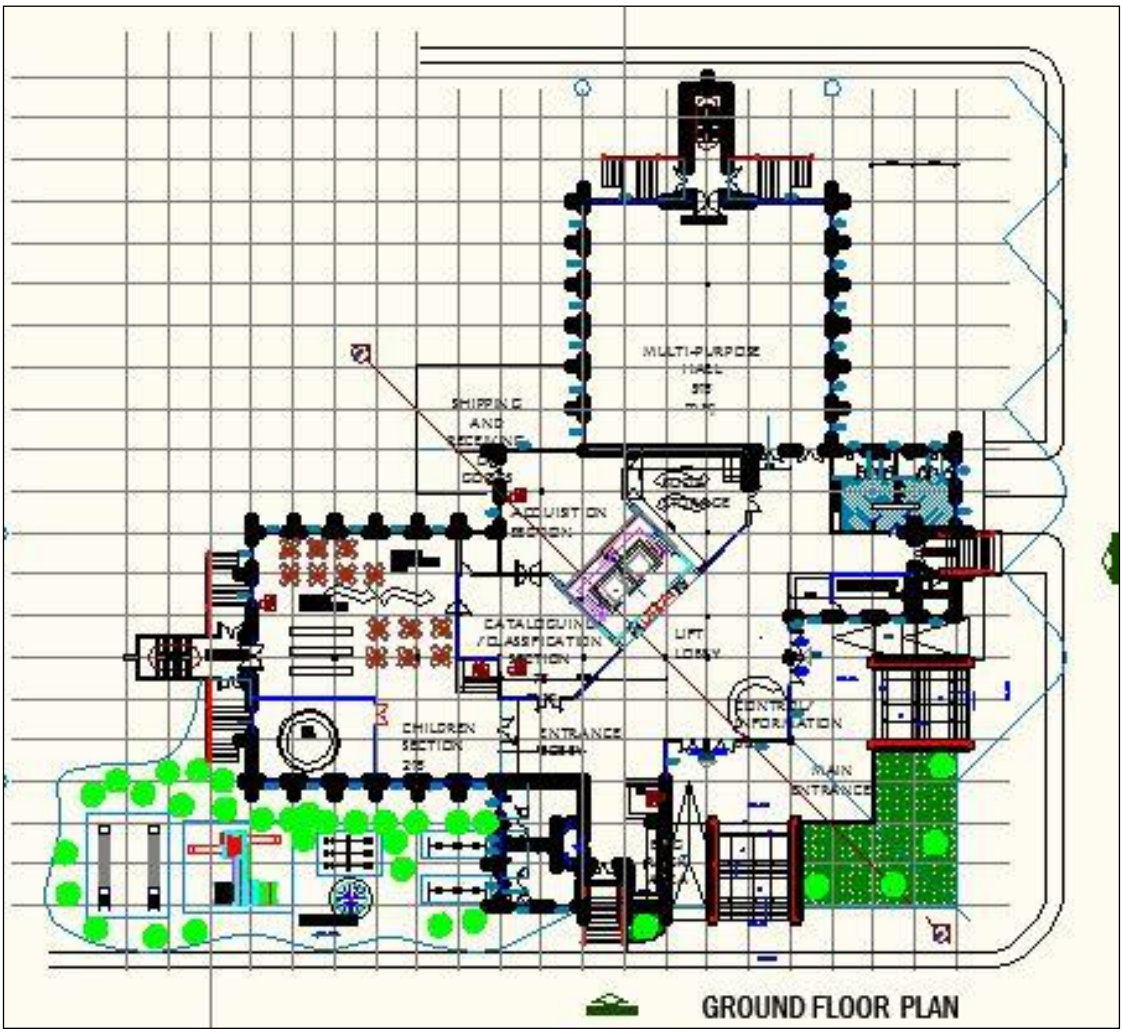
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APPENDICES

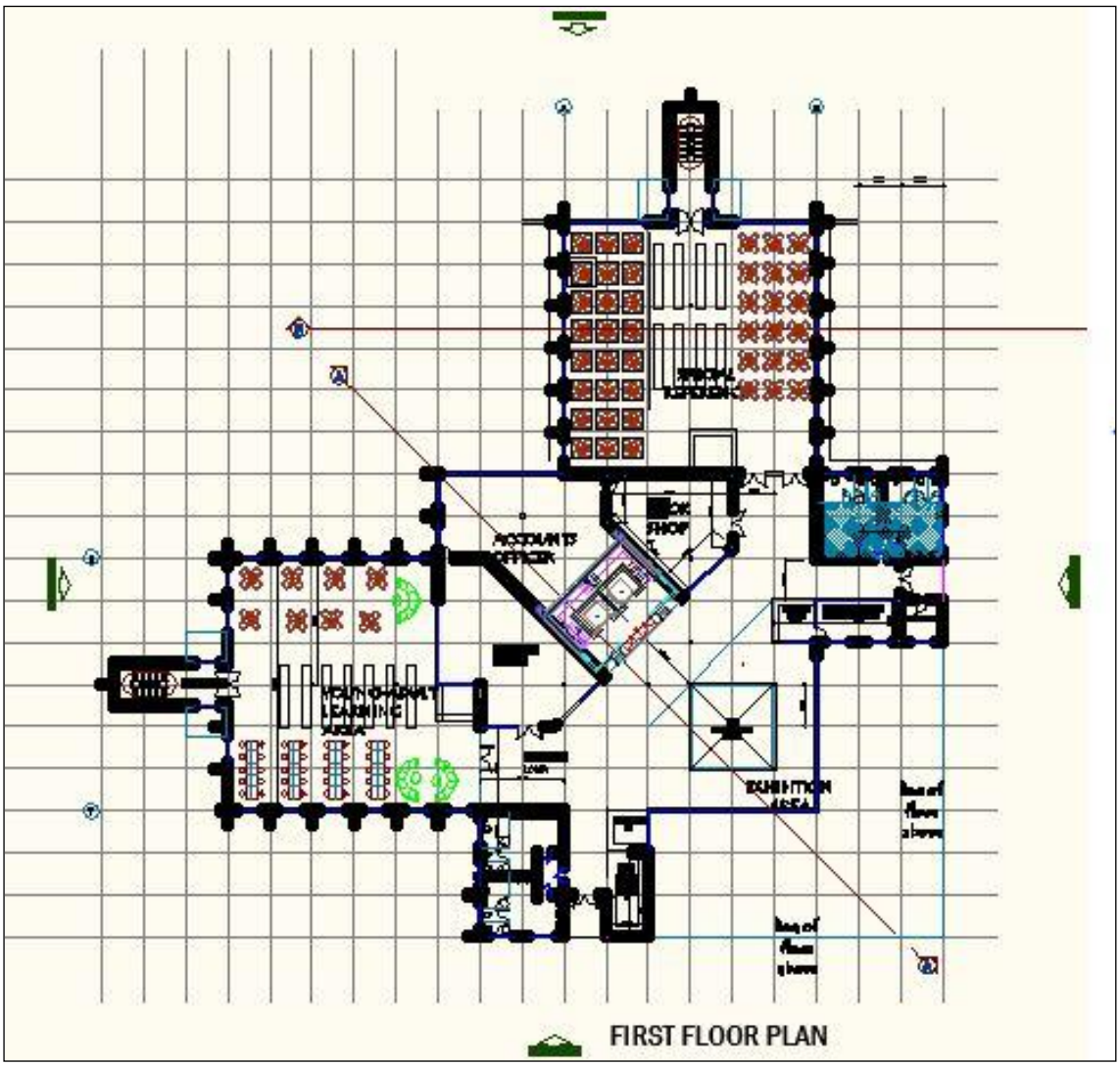
Appendix 1.0: Reduced Plans of Proposed Metropolitan Library, Kaduna



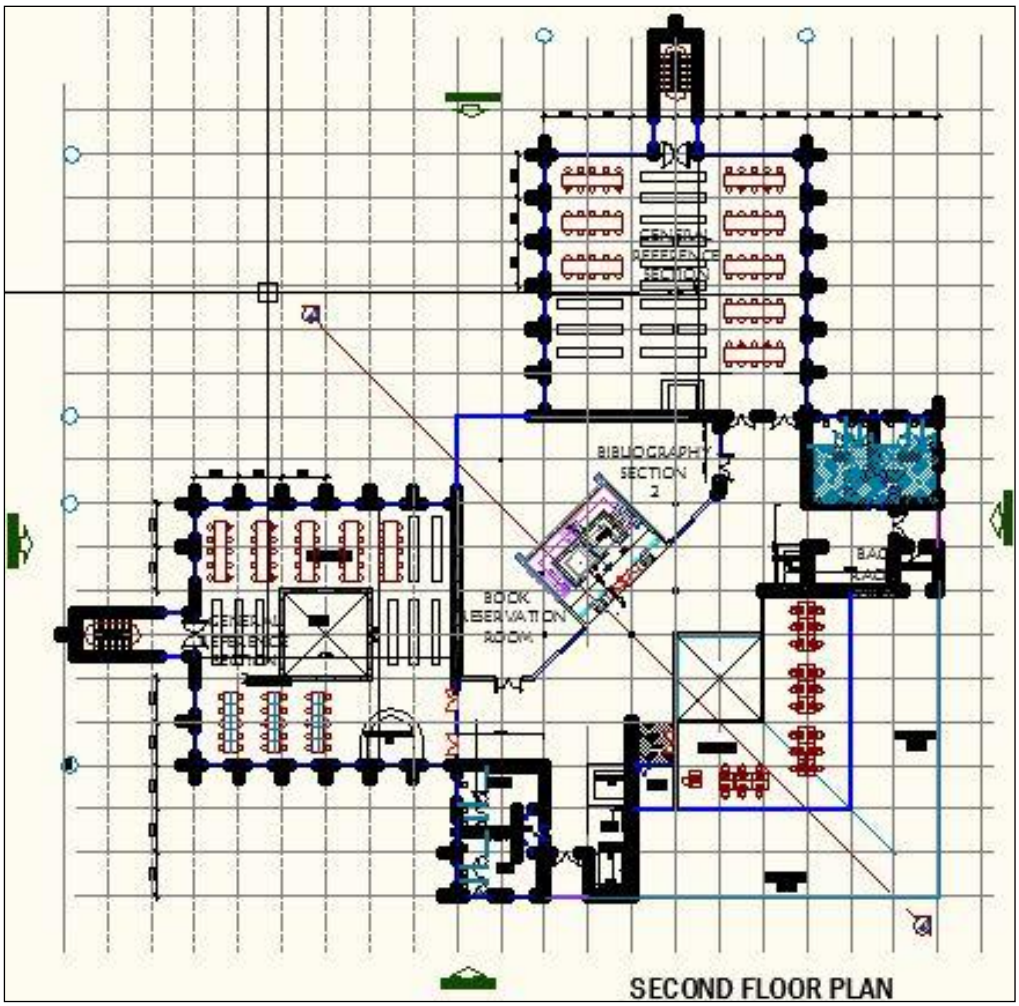
Appendix 1.1 Reduced Site Plan



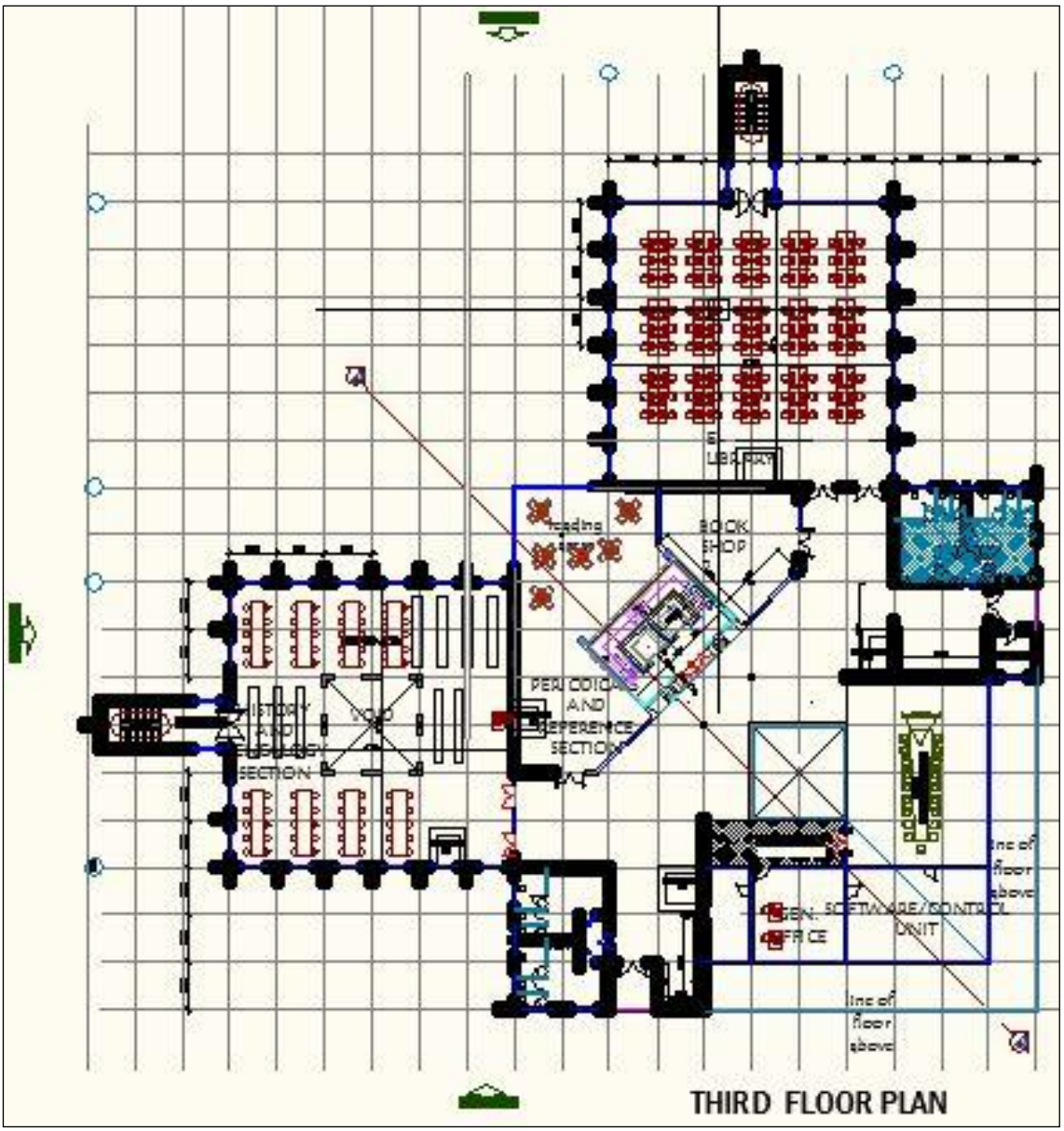
Appendix1.2 Reduced Ground Floor Plan



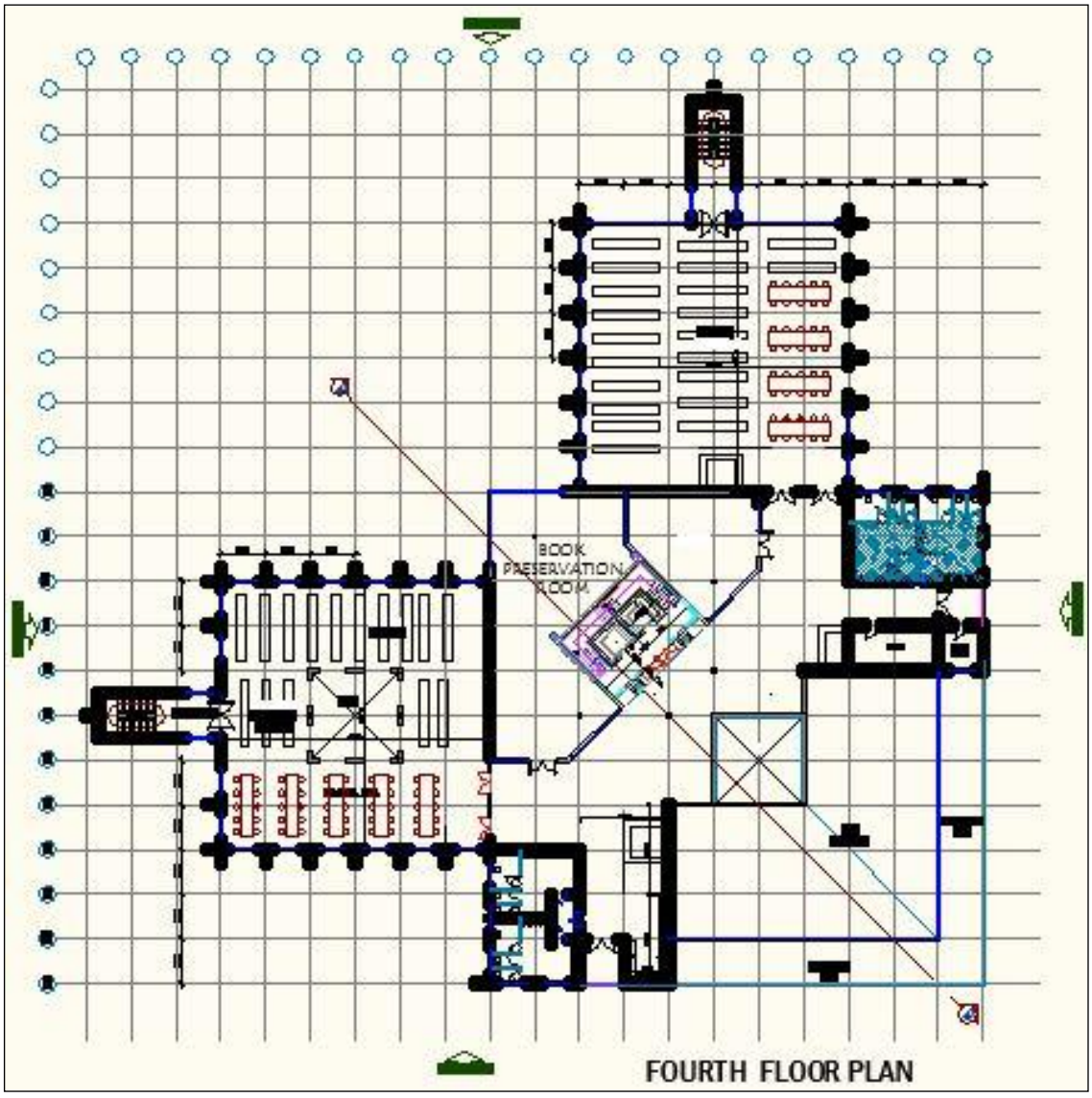
Appendix 1.3 Reduced First Floor Plan



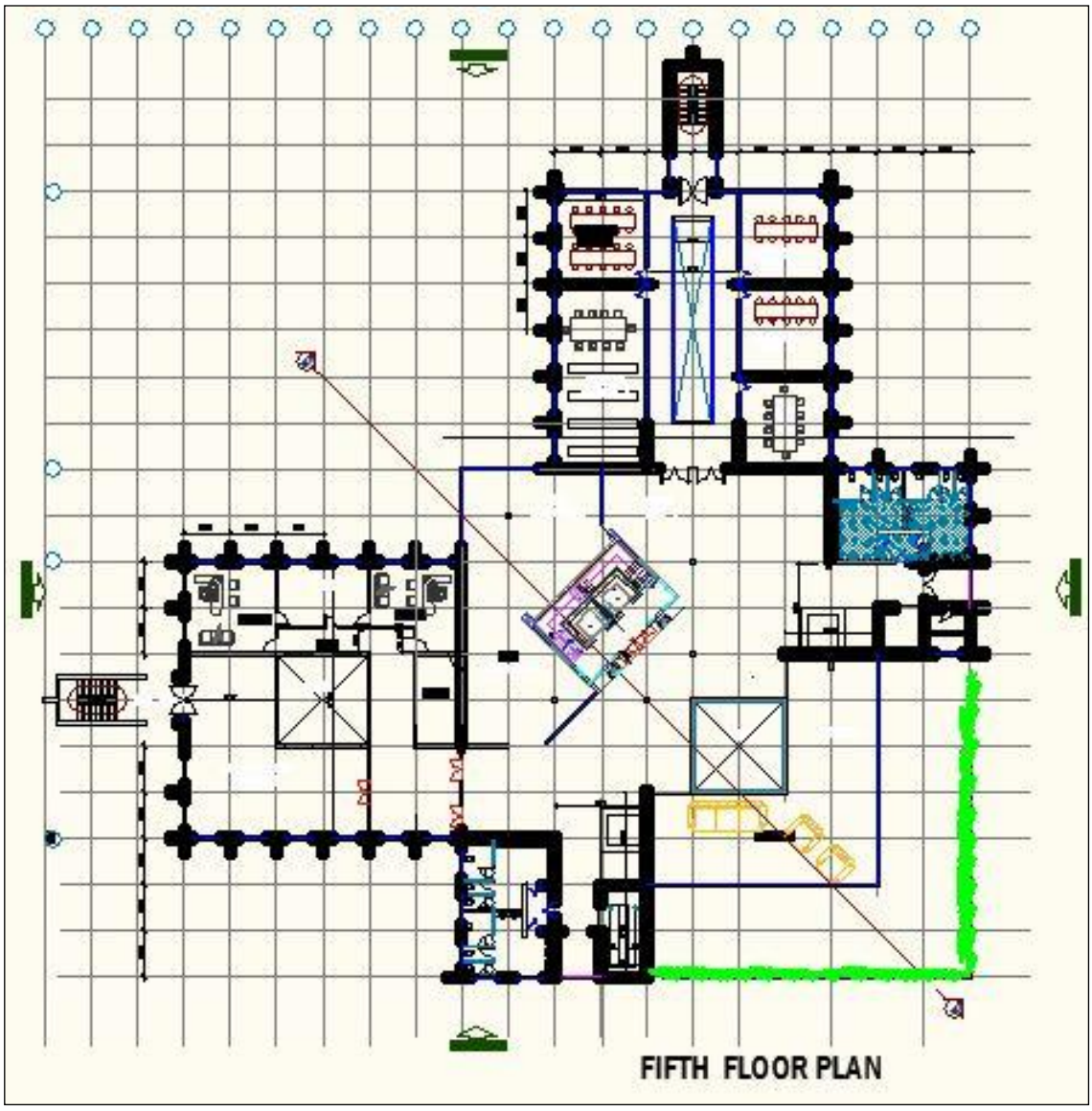
Appendix 1.4 Reduced Second Floor Plan



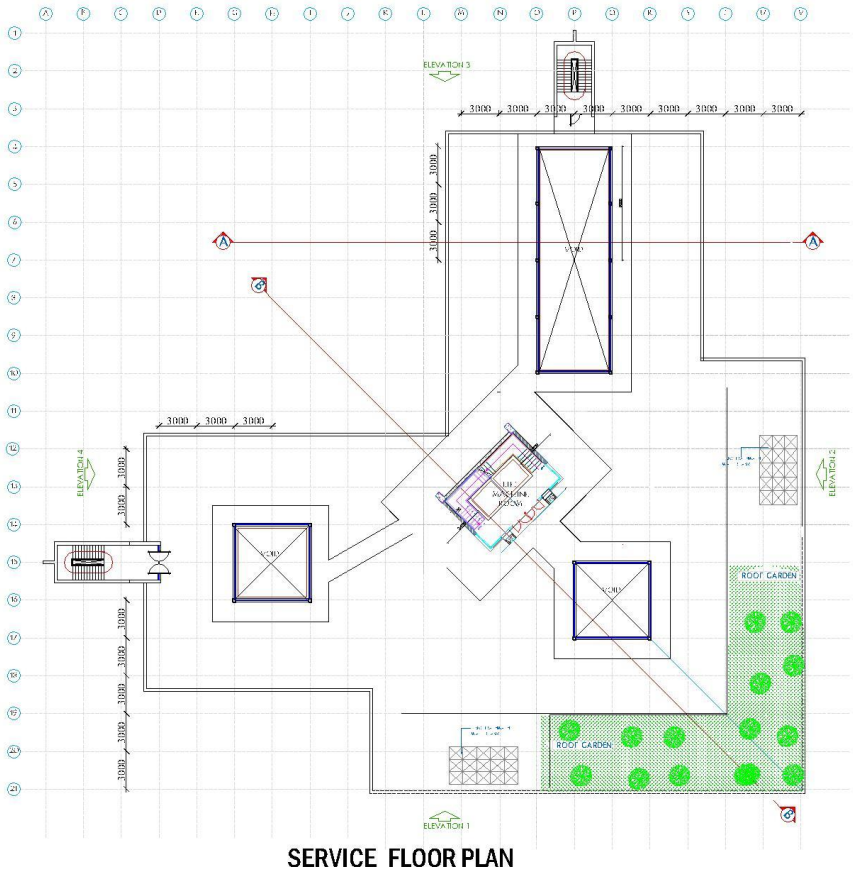
Appendix 1.5 Reduced Third Floor Plan



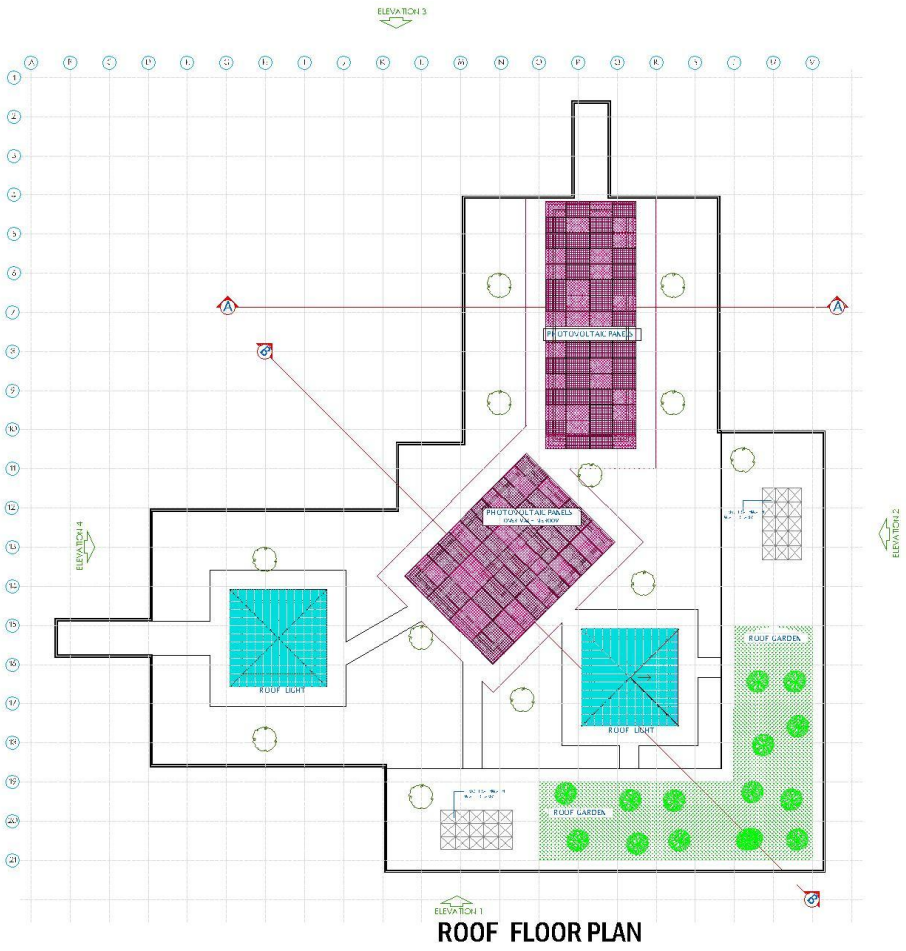
Appendix 1.6 Reduced Fourth Floor Plan



Appendix 1.7 Reduced Fifth Floor Plan



Appendix 1.8 Reduced Service Floor Plan

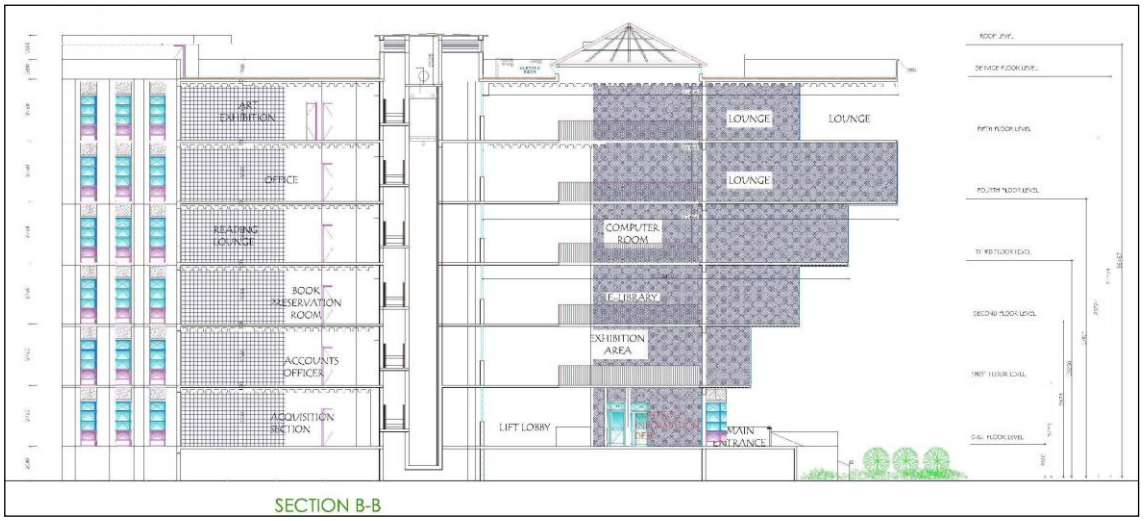


Appendix 1.9 Reduced Roof Plan

Appendix 2.0 Reduced Sections



Appendix 2.1 Reduced Section A-A



Appendix 2.2 Reduced Section B-B

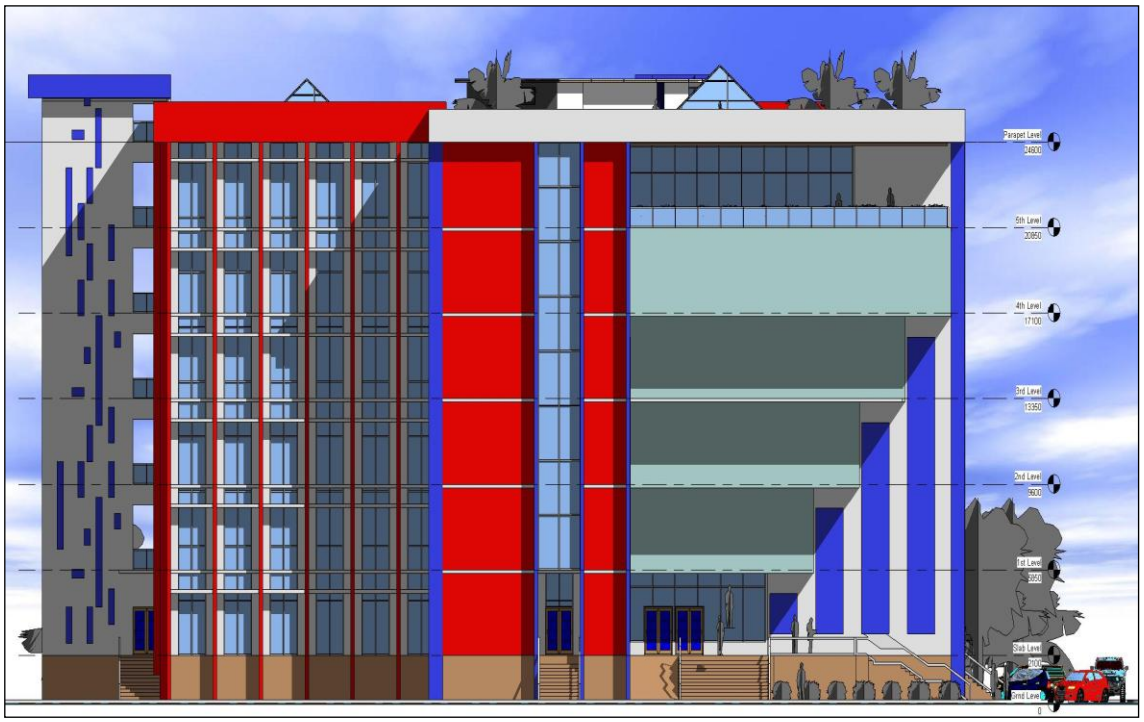
Appendix 3.0 Reduced Elevational Views



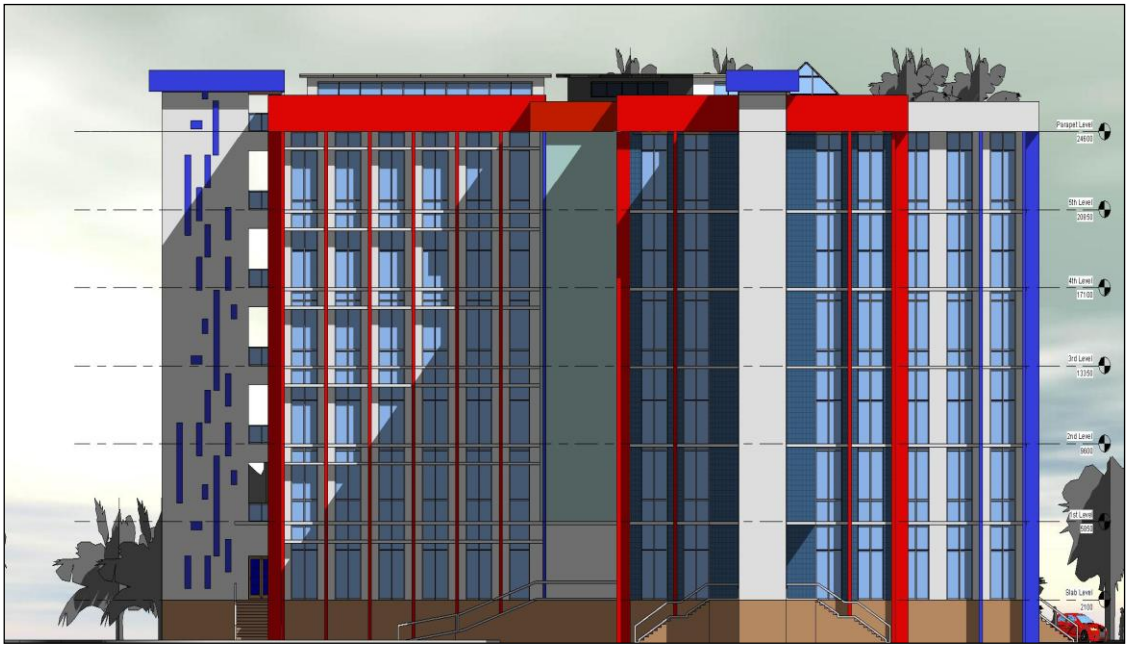
Appendix 3.1 Reduced South Elevation



Appendix 3.2 Reduced East Elevation



Appendix 3.3 Reduced North Elevation



Appendix 3.4 Reduced West Elevation

Appendix 4.0 Reduced 3-Dimensional Views



Appendix 4.1 3-Dimensional Views of Proposed Metropolitan Library, Kaduna



Appendix 4.2 3-Dimensional Views of Proposed Metropolitan Library, Kaduna



Appendix 4.3 Interior Views of Proposed Metropolitan Library, Kaduna



Appendix 4.4 3-Dimensional Views of Proposed Metropolitan Library, Kaduna

Appendix 5.0 Energy distribution Charges (NERC)

Customer Class	Description and examples of Customers in each Class	Monthly Fixed Charge as published in MYTO2 since 2012 that would have taken effect 1st Jun e prior to minor review:	Monthly Fixed Charge after minor review, now effective 1st June 2014:	Energy Charge (per unit) as approved in MYTO2 since 2012, that would have taken effect 1st June prior to minor review:	Energy Charge (per unit) now to take effect 1st June after the minor review:
R1	Consumption is below 50 kilowatt hrs per month, Customer in this class have typically one fan, radio, 2-3 light bulbs.	0	0	4.00	4.00
R2	Consumption is above 50 kilowatt hrs per month. Majority of households fall under this category.	1,280.00	781.13	15.36	17.00
R3	Large residences e.g. government house, small estates, have dedicated transformer and maximum demand (MD) meters.	64,046.08	23,452.61	28.23	28.23
R4	Large estates, also with dedicated transformers and maximum demand (MD) meters.	400,271.36	146,572.69	28.23	28.23
C1	Small businesses e.g. small barbing and hair dressing salons.	1,280.00	624.95	19.36	19.36
C2	Hotels, also with dedicated transformers and maximum demand (MD) meters.	58,060.80	21,260.90	26.24	26.24
C3	Large supermarkets or hypermarkets with dedicated transformers and maximum demand (MD) meters.	362,874.88	132,878.73	26.24	26.24
D1	Small industries e.g. welders, pure water packagers etc.	2,560.00	624.95	21.17	21.17
D2	Larger scale industries, e.g. metal fabrication companies with dedicated transformers and maximum demand (MD) meters.	357,032.96	130,739.51	27.50	27.50
D3	Oil companies, large construction companies with dedicated transformers and maximum demand (MD) meters.	362,874.88	132,878.73	27.50	27.50
A1	Schools, mosques and churches.	1,280.00	624.95	20.26	20.26
A2	Medium sized army barracks with dedicated transformers and maximum demand (MD) meters.	119,624.87	41,989.02	20.26	20.26
A3	Large barracks, large agricultural processing companies with dedicated transformers and maximum demand (MD) meters.	160,000.00	58,589.33	20.26	20.26
L1	Street lights.	1,280.00	624.95	17.17	17.17

Appendix 5.1 Energy distribution Charges (NERC) for Kaduna

Appendix 6.0 Consumer Classifications (NERC)

	Customer Classification	Description	Remarks
1	**Residential**		A consumer who uses his premises exclusively as a residence - house, flat or multi-storeyed house where people reside.
	R1	Life-Line (50 kWh)	
	R2	Single and 3-phase	
	R3	LV Maximum Demand	
	R4	HV Maximum Demand (11/33 KV)	
2	**Commercial**		A consumer who uses his premises for any purpose other than exclusively as a residence or as a factory for manufacturing goods.
	C1	Single and 3-phase	
	C2	LV Maximum Demand	
	C3	HV Maximum Demand(11/33 KV)	
5	**Industrial**		A consumer who uses his premises for manufacturing goods including welding and ironmongery.
	D1	Single and 3-phase	
	D2	LV Maximum Demand	
	D3	HV maximum Demand (11/33 KV)	
4	**Special**		Customers such as agriculture (agro-allied enterprises involving processing are excluded), water boards, religious houses, Government and teaching hospitals, Government research institutes and educational establishments.
	A1	Single and 3 Phase	
	A2	LV Maximum Demand	
	A3	HV Maximum Demand (11/33 KV)	
5	**Street Lighting**		
	S1	Single and 3-phase	

Appendix 6.1 Consumers Classification