AN EVALUATION OF ARCHITECTURAL FORMS FOR IMPROVING ENERGY EFFICIENCY IN SHOPPING MALL DESIGN, ABUJA

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AHMADU BELLO UNIVERSITY, ZARIA

DECEMBER, 2017

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P14EVAT8151

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUETE STUDIES
AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTERS OF SCIENCE DEGREE IN ARCHITECTURE

DEPARTMENT OF ARCHITECTURE

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AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

DECEMBER, 2017

Declaration

I declare that the work in this dissertation entitled "AN EVALUATION OF ARCHITECTURAL FORMS FOR IMPROVING ENERGY EFFICIENCY IN SHOPPING MALL DESIGN, ABUJA" has been carried out by me in the Department of Architecture, A.B.U Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project dissertation was previously presented for another degree or diploma at any university.

Gatta Ngoulou Yannick NGAGUE 14 December 2017

Name of student	Signature	Date

Certification

This project dissertation entitled "AN EVALUATION OF ARCHITECTURAL FORMS FOR IMPROVING ENERGY EFFICIENCY IN SHOPPING MALL DESIGN, ABUJA'' by Gatta Ngoulou Yannick NGAGUE meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Dedication

This thesis is dedicated to Almighty GOD the giver of wisdom for his grace that saw me through this race, to all my family for their love and trust in me.

Acknowledgment

Special thanks to my major supervisor Prof. M.L. Sagada for accepting to supervise this research. I am very grateful for his commitment in ensuring the success of this dissertation sir, you are simply expert. I am also grateful to my minor Dr. R.B. Tukur for her tireless guidance. Special thanks to all the members of the supervisory committee: Dr. S. N. Oluigbo sir, I can say you are my third supervisor you have contributed a lot to this work you have realy helped me from the research aspect to the final design stage, God bless you sir I will forever be greatful; Dr. J.J. Maina; Dr. A. Batagarawa; Arc Mukhtar you have all really helped thanks a lot. Thanks to Dr. A. S. Salisu Head of the Department for his guidance also.

I cannot stop there without given tremendous thanks the people who really helped me during my fieldwork. They gave me a lot of information that I will not get it easily anywhere else; Franklyn Ogene the operation manager of Jabi lake mall; Arc Kingsley architect at Silverbird and the Operation Manager of Ceddi Plaza, Thanks to you all you have made my fieldwork so smooth may God bless you.

Special thanks to my great family for their tried less support in all aspect I will forever remain grateful may God continue to bless them.

I cannot stop there without given also an incredible thanks to all my colleagues in the department of Architecture and anywhere for their support in diverse ways to the success of this dissertation. Special thanks to my friends: Gyang thick boy, Lukman, zainab, Gana, Yaradua calatrava, Makdance, Asma'u, Rashida, Joshua, Mike, Aminu, KB, Andrew, AB, Gabriel, Aisha, Theo, Yaradua white, Joshua P13, Kachalla, Abdul MLA and to all others who names are not mentioned I hereby apologies you are not forgotten believe me. God, bless you all. I will forever remain grateful and I will never ever forget you guys we had a tremendous time together great guys.

Abstract

Today's building industry appears to be entering another era of change, with a view toward minimizing carbon footprint. Understanding building forms offers a great chance of changing the current practice to save energy and other natural resources. Depending on any climate, forms have a major influence on energy consumption of a building. The major electricity end uses in shopping malls in Nigeria is attributed to space cooling and lighting. Hence, this research is aimed at evaluating the effect of building forms to enhance energy efficiency in shopping malls in a composite (Hot-humid and Hot-dry) climate such as in Abuja. The research method used in this study are case study, visual survey and simulation. Autodesk Ecotect® software is used for the simulations. Seven building forms were evaluated, the Cuboid form, Cylindrical form, Cubic form, L shape, T shape, U shape and Triangular shape. The results indicate that the Cylindrical form is more suitable for the composite climate (hot dry/hot humid) of Abuja while for the illumination level the Cuboid form appears to be the best. Cylindrical form saved 29.47% of the total annual energy consumption compared with an L Shape; 25.64% compared with a T Shape; 24.25% compared with a U Shape; 28.35% compared with a Cuboid form; 13.26% compared with a Cubic form and 44.34% compared with a triangular shape for the study location. Secondly, a base case model of Silverbird was created and tested with the factors that determine the choice of forms to enhance energy efficiency as shading, colour, orientation and glazing. The results indicated that the magnitude of energy saving of Silverbird mall on cooling load was up to 7.41% annually and the illumination level is increased by 73%. At the end, the simulation of proposed design with a cylindrical form showed that the cooling per meter square is 25.61% lower than that of silverbird.

The study recommended that Architects and other professionals involves in the building industry should consider building form as one of the key aspect when aiming at reducing the energy load of a building and since in Abuja cooling is the measure issue not lighting; opting for a cylindrical form for building design in Abuja will save more energy and money compared to the others building forms involved in this study. Proper landscape should be integrated in any design because soft landscape coverage on site help in reducing cooling requirement of buildings. At the end the research concludes that with the shortage of power supply, the cost of energy on the rise and the issue of climate change, opting for the right building form during the early design stage will lead ultimately to a tremendous reductions of electricity consumption up to 44.34%, it is significant for the whole building design process.

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Abbreviations

ASHRAE: American Society of Heating Refrigerating and Air Conditioning Engineers

$CO_{2:}$ Carbon Dioxide

^{o}C: Degree Celsius

DBT: Dry bulb temperature

GWh: Gigawatt Hour

HVAC: Heating Ventilation and Air Conditioning

IEA: International Energy Agency

KWh: Kilowatt Hour

Lux: Illumination

M: Meter

M²: Meter Square

MM: millimetre

MRT: Mean Radiant Temperature

MWh: Megawatt Hour

₦: Naira

SHGC: Solar Heat Gain Coefficient

VT: Visual Transmittance

WWR: Window-Wall-Ratio

1.0 INTRODUCTION

1.1 Background to the study

To conserve energy and reduce greenhouse gas emissions in the building industry, rapid calculation and optimization of building energy performance during the early design phase is vital for the whole building design process. Commercial buildings in the world have the second largest energy consumption at 27% (International Energy Agency (IEA), 2012). Another report indicated that, Commercial buildings alone account for 35% of electricity consumption, 45% of which is coal produced; contributing proportionately to greenhouse gas emissions (Roberts, 2012). In Nigeria, twenty percent (20%) of the electricity generated in Nigeria is consumed by the commercial sector (Community Research and Development Centre (CREDC), 2009). Another study by the Energy Commission of Nigeria and United Nations Development Programme (ECN-UNDP) (2005) outlined that, the major and the most significant electricity end uses in Nigerian shopping malls has been attributed to space cooling and lighting. This shows that achieving energy efficiency in commercial buildings will diminish the electricity consumption and greenhouse gas emissions. The power generated is inadequate and unstable, forcing a large portion of commercial sector, industry and households to rely on diesel and petrol generators as primary or back-up source of electricity, which can be expensive and a source of noise and air pollutions (Uyigue, Yapp, Odele, & Lebot, 2010). The current power generated in Nigeria reached the capacity of 5,000 MW (Premium Times, 2016). As a result, it is important to incorporate energy-efficient strategies into designs to minimize the buildings energy usage, while at the same time improving the levels of comfort within buildings.

From the energy audits and surveys conducted in Hong Kong in four shopping mall buildings by Lam and Li (2003) air-condition accounts for 47-54% of the total electricity consumption with lighting in the second-place accounting for the 33-38%. The consumption of such amount of energy can be enhanced by adopting proper design strategy based on local climate. According to Yilmaz (1988) building form, is one of the most important passive design parameters affecting indoor climate and affects the total heat loss and gain through building envelope. One of the most important properties of a sustainable building is to provide thermal comfort conditions for users with a minimum heating and cooling energy consumption (Erdim & Manioglu, 2011). According to Samuel (2015) Over 14% of total annual cooling load of a building can be reduced by using the right form. Yilmaz (1988) also indicated that, orientation of building form determines the amount of heat gained from solar radiation through building envelope.

On the building scale, the architectural design principles which most influence the energy consumption of a building are related to the envelope design: first is the envelope materials through their thermo-physical and optical properties, followed by the envelope form, and the window area per cardinal direction as consequence of the building orientation (Oral & Yilmaz, 2002). In a study conducted by Jeff (2000) architectural form does not only have an impact on space conditioning (heating and cooling); but also on daylighting, the higher the skin to volume ratio, the greater percentage of floor space available for daylighting, because daylight also lowers the cooling requirements of a building up to 15%. Cooling, heating and Lighting therefore represent the most important aspects of building design to decrease energy consumption and it can be optimized by building form. Therefore building form is considered an important factor affecting thermal comfort (Yilmaz, 1988). On the other hand, building form does not affect the energy use of appliances.

Modern Shopping malls today have various forms, shape and sizes. They also have different kind of facilities within them that make them consume a lot of energy (Industries/GaugeTech., 2016). The latest PricewaterhouseCoopers African Retail report stated that Abuja is set to experience a growth rate of 171% in terms of its population size up to 2030; one of the highest figures on the continent (PWC, 2016). Moreover, according to Kocaili (2010) shopping malls are new public spaces, because people prefer them, as they became a part of our daily urban life as multifunctional urban public spaces of modern era, it becoming public magnets.

Recent researches have conducted well-documented studies on effects of building forms on energy efficiency. Zhang, Zhang and Wang (2016) researched on shape optimization of free-form buildings based on space efficiency and solar radiation in the severe cold zones. Their study showed that compared with the cube reference building, the total solar radiation gains of the optimized free form (shape) building is 30-53% higher.

1.2 Statement of problem

To enhance the customers satisfaction based on comfort, alot of energy is required to run a shopping mall and no one can afford to be paying for power that is not used efficiently especially for commercial purpose. So, combined with the deficiency of power supply in Nigeria, the commercial sector relies on diesel and petrol generators as primary or back-up source of electricity, which can be expensive and a source of noise and carbon dioxide emission (Uyigue, *et al* 2010). Cooling and its associated lighting account up to 85% of major electricity end uses in shopping mall buildings (Lam & Li, 2003). In addition, according to Granadeiro, Correia, Leal, and Duarte (2013) the architectural design variables which most influence the energy performance of a building are the envelope materials, form and window areas. Therefore, in order to enhance energy efficiency in shopping malls; it is important

to assess the effect of its form. Samuel (2015) evaluated the effects of building forms on thermal comfort in office buildings in hot humid area of Lafia; his result has shown that cylinder forms perform best within the chosen study location. Nevertheless, how the architectural form can enhance energy efficiency in shopping mall in composite climate of Abuja has not been investigated.

For the above discussed, building form is a necessity in conceptualizing and designing of such facility in its entirety and considering that Abuja experiences hot-humid/hot-dry climate, building form would be appropriate in enhancing energy. Therefore, this identified gap therefore formed the basis for conducting this research.

1.3 Justification

As stated earlier shopping mall buildings, consume a lot of energy on cooling and lighting and numerous studies have shown that building form plays an important role in saving energy. Therefore, given the current strong dependence on fossil fuels for electricity generation because of the deficiency of power supply in Nigeria, generators are used as primary or back up source of electricity by the commercial buildings. Any reductions in the consumption of electricity for cooling and lighting can ultimately lead to low energy bill and today there is a need for saving conventional energy, saving money, improvement of the indoor living conditions in a sustainable way and most especially protection of the environment and our planet because of global climate change. The main reason of conducting this study in Abuja is that presently it is fastest growing city in terms of population rise in Nigeria. In 2015, the population was 3 million and it will by 2018 rise from 5 million to 10 million (National Mirror, 2015). Moreover, according to McCarty (2014) the increase of populations in urban area required additional commercial, recreational and residential buildings.

1.4 Aim and objectives

The research is aimed at evaluating building forms for enhancing energy efficiency in shopping malls for the composite climate of Abuja.

The aim is achieved through the following objectives:

i. To investigate the level at which the factors that determine the choice of building forms to achieve energy efficiency considered in the existing shopping mall.
ii. To evaluate the effects of building forms on annual cooling, heating load and illumination level.
iii. To determine the suitability of alternative building forms for energy efficiency.
iv. To demonstrate the findings through a proposed shopping mall design.

1.5 Research questions

i. To what extent has, the existing shopping malls achieved their energy efficiency through these factors that determine the choice of building forms?
ii. What level of energy efficiency is achievable through building forms for the composite climate of Abuja?
iii. What is the most efficient building form for the climate of Abuja?

1.6 Scope

This research emphasis on the suitability of alternative building form for energy efficiency; and the building forms involved in the study are the most commonly used building forms: Cuboid form; Cubic form; L Shape; U Shape; Cylindrical form; Triangular shape and T shape. Ecotect® simulation software was used in evaluating the forms. The study is conducted in the composite (Hot dry/Hot humid) climate of Abuja, Nigeria.

1.7 Significance of the study

In architecture, improving energy efficiency of a building and reducing environmental impact is one of the responsibility of the architects. Therefore, the research will add to the literature on building forms for shopping mall in hot humid/hot dry climate in general as it contains recent information on the concept. It will also help to give an understanding about the interactive relationship between the building forms and the environment. This research can serve as a guide for students, to various professionals involved in building industry and as well as government agencies making policies on environmental control and sustainable design.

2.0 LITERATURE REVIEW

2.1 Introduction

Having stated the problem, it was essential to conduct an intense literature to elaborate the concept of architectural form related to building energy consumption. Firstly, numerous literature exists already on building forms in general; but this chapter is focused more on how building forms optimizes energy efficiency. It reviews the concept of building form and energy efficiency in general.

This chapter thus documents work done by many other researchers in this aspect and analyses some of the existing literature to find out how they conducted their research. It also identified the major electricity end uses in shopping mall buildings. Finally, the several ways of optimizing building form and energy performance are highlighted.

2.2 Concept of architectural forms

A three-dimensional shape is called a form and is one that takes up real space; while shape is made when a line is closed and space is enclosed. A two-dimensional shape is one that is drawn on a flat surface such as paper as shown in figure 2.1 below (Media studio, 2013). Architectural drawings often try to indicate what the proposed building will look like as a three-dimensional form by creating the illusion of three dimensions through the use of orthographic projection, perspective and other drawing techniques. Media studio (2013) explained the concept of shapes and forms as following:

i. Forms are the more complex structures like sphere, cube, cone, etc. while shapes are the most basic figures like rectangles, circles, triangles, and squares.

ii. Forms are in three-dimension 3D they have length, width, and height; while shapes are in two-dimension 2D they have length and width.

iii. Forms exist beyond the space of shapes while shapes exist in the space of flat and simple drawings, printings, and painting surfaces.

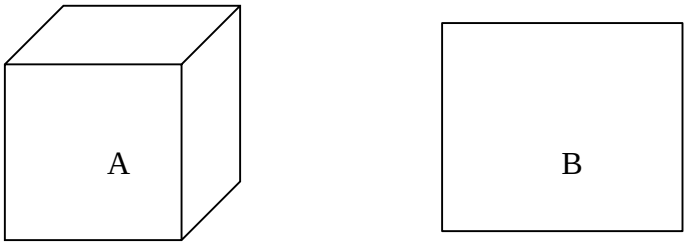


Figure 2.1: Form is represented in 3D (A) Shape in 2D (B)

Source: Author (2016)

2.2.1 Regular and irregular shape

Regular forms are those whose parts are related to one another in a consistent and orderly manner. They are generally stable in nature and symmetrical about one or more axes as shown in figure 2.2 below.



Figure 2.2: Regular shape

Source: macromedia (2005)

Irregular forms have parts that are dissimilar in nature or relate to one another in an inconsistent manner. They are generally asymmetrical and more dynamic than regular forms see figure below 2.3.

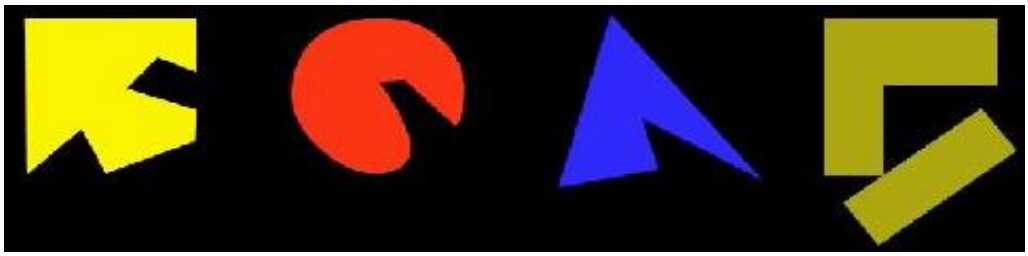


Figure 2.3: Irregular shape

Source: macromedia (2005)

Both regular and irregular forms and spaces can co-exist in response to context, program, and desire. Regular forms can be contained within irregular forms or compositions; irregular forms can be enclosed within regular forms.

2.2.2 Transformation of forms

Form can be transformed by altering one or more of its dimensions and still retain its identity as a member of a family of forms. A cube, for example, can be transformed into similar prismatic forms through discrete changes in height, width, or length. It can be compressed into a planar form or be stretched out into a linear one. Depending on the extent of the subtractive process, the form can retain its initial identity or be transformed into a form of another family (Macromedia, 2005).

2.3 Bioclimatic architecture and architectural forms

Firstly, Bioclimatic architecture refers to designing buildings and spaces (interior-exterior) with low energy consumption, based on local climate conditions (Kartal & Chousein, 2015). According to BioclimaticX (2016) Bioclimatic architecture deals with design and architectural elements or criteria, avoiding complete dependence on mechanical systems, which are regarded as support; a good example of this is using natural lighting and ventilation or mixed mode ventilation.

Building form is one of the principle of bioclimatic architecture that can reduce the energy consumption avoiding whole dependence on heating ventilation and air conditioning (HVAC) including lighting.

Praharaj (2014) worked on ‘’Effect of Building Form for Low Energy Architecture: Evaluation of Bio-Climatic Design, Bhubaneswar’’ In this study, the author examined the effect of different plan forms on the total solar radiation received by vertical surfaces of the buildings. The impact of building location and orientation on thermal comfort has been investigated also. The author analysed the climatic conditions with respect to

thermal comfort in buildings for the location of Bhubaneswar. Different building shapes (square and rectangular) have been studied with variations in width-to-length ratio (aspect ratio) and building orientation. Based on that the optimum aspect ratio (Length: Width) of the building over the location of Bhubaneswar has been found out which will receive minimum radiation in summer and maximum radiation in winter. His result shows that though for economic consideration a square plan is an ideal one for the Bhubaneswar climate (Praharaj, 2014).

Olgyay (1963) in his book title design with climate gave conclusions on building forms that:

i. The square building is not the optimum form in any location.
ii. All shapes elongated on the north-south work both in winter and in summer with less efficiency than the square one.
iii. Free forms (irregular forms) are more suitable for cold climate.

2.4 Energy efficiency

Energy efficiency is a way of managing and restraining the growth in energy consumption; something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input (IEA, 2015). The Department of Energy and Climate Change (2012) also defined energy efficiency as a measure of energy used for delivering a given service. Improving energy efficiency means getting more from the energy that we use. Energy efficiency is at the heart of the Europe's transition to a resource-efficient economy and the Europe 2020 strategy for smart, sustainable and inclusive growth; the strategy includes three complementary energy and climate headline targets by 2020, namely: to lower greenhouse gas emissions by 20% relative to 1990, to generate 20% of primary energy from renewable sources and to achieve 20% primary

energy savings relative to the 2007 projections for 2020 (European Expertise centre (EPEC), 2013).

According to the Department of Energy and Climate Change (2012) there are different ways to improve energy efficiency:

a. Innovation: can lead to the equal or greater output with less energy.
b. Cutting out wasted energy: reduces energy needed while maintaining output.
c. Heating and cooling technologies: such as heat pumps and air conditioning, can deliver greater output for less supplier energy.

2.4.1 Factors that influence energy consumption in buildings

According to the European Standard (European Standard 15232, 2012) as cited in (Siemens, 2013). The following are the six primarily factors that have impact on energy demand of a building:

i. Outdoor climate
ii. Building shell (envelope)
iii. Building technology and energy technology
iv. Operation and maintenance of the building
v. Building use and user behaviours
vi. Interior room quality

The world generates more than 78.7% of its energy from non-renewable sources with Nuclear Power 11%, coal 40.3%, oil 5%, natural gas 22.4%, hydro 16.5% and others 5% (World Nuclear Association, 2016). Therefore, by designing sustainable buildings, carbon dioxide (CO_2) emission in the world will diminish and a lot of energy can be saved.

2.4.2 The benefits of energy efficiency

The International Energy Agency states that we should place the highest priority on becoming energy efficient, as this offers the highest potential for reducing carbon emissions, at the lowest cost. Energy consumption in residential and commercial buildings represents approximately 40% of total final energy use, and is responsible for 36% of the European Union's total CO_2 emissions (EPEC, 2013). Therefore, applying available energy efficiency technologies and methods to residential and commercial buildings would have a substantial impact on energy usage and carbon emissions in the world.

2.5 Building forms and energy efficiency

The form and exterior structure of a building play major roles in determining its energy efficiency (eXtension, 2013). The Canada Mortgage and Housing Corporation (CMHC) (2014) stated that architectural form not only has an impact on space conditioning (heating and cooling) energy use but also determines the availability of roof and wall areas for solar energy collection. A right building form can solve a lot of problem in buildings. Alter (2009) reported that Julia Gersovitz of Montreal's architects made the point that buildings used to look like alphabets, minimize the distance to the exterior wall and maximize natural light and ventilation. Research has shown that building form is important when considering daylighting and heat loss or gain in buildings they play an important role in the thermal processes taking place within the building as well as with the building and its surroundings.

Du (2012) conducted a study on ''The Impact of Building Morphology on Energy Consumption'' In his work, Adland project was used as a case study in order to investigates how the building morphology which is one aspect of the architectural quality will impact the heating demand of buildings. The building simulation Ecotect software

was used during his study to evaluate the heating consumption of different building organizations. At the end, his simulation results indicated that, with exception of linear organization and L-Shaped organizations, the heating demand differences of different building morphologies could almost be ignored. Finally, the study concluded that both linear organization and L-Shaped organization are a preferable design solution for Adland project (Du, 2012). Usually, buildings with more surface area gain heat and lose heat much more quickly than those with less surface area. The study has proven that some building forms have almost the same energy consumption compared to other forms.

The surface to volume ratio dominates the condition inside of building and if a building has a large surface area, the internal condition inside of buildings. However, in Du's works he did not involve other basic forms for more comparison. Building that have a large surface area, the internal condition is more influenced by the external climate than in one with less surface areas. Smaller buildings have larger skin/volume ratio than large buildings. A building with less surface area is dominated by its internal load, which is the heat of the people, machinery, lighting and so on.

According to Astrish, Morris and Walters (n.d.) there are three commonly used building forms:

1) Linear Forms: These forms are narrow width and long length and offer good side lighting opportunities.
2) Centric Forms: Centric forms have an internal core around which other spaces are organized. There is a fairly equal length-to-width ratio which provides opportunities of atrium, light wells and courtyards. Where the above cannot be used, careful building zoning is used.

3) Clustered Forms: These forms consist of a series of smaller masses in a variety of configurations which offer extensive surface area for top lighting, side lighting (Astrich, Morris, & Walters, n.d.)

All these forms (linear forms; centric forms and clustered forms) can be regular or irregular.

2.6 The Function of building form on cooling and lighting

There are some few important things to understand how shape of a building affects its energy efficiency. Firstly, heat is transferred through a building envelope at different rates depending upon the efficiency of the materials used. Heat moves only when there is a difference in temperature between two objects that are in contact, and it always moves from the warmer to the cooler object. To be comfortable inside a building we usually want the inside to be at a different temperature than the outside. The form of a building play a major role in reducing energy consumption in any building (HomeEnergy, 2013). The exterior structure, which is also called building envelope, comprises of the walls, roofs, windows, doors, and cladding. The footprint and envelope of a building can either enhance its energy efficiency or cause higher energy consumption (eXtension, 2013).

Erdim and Manioglu (2011) also worked on ‘‘Impacts of building form on energy efficient heat pump applications’’. In their study; in order to provide energy conservation and climatic comfort in buildings, an approach which aims to control the energy consumption of heat pumps by controlling decisions related to building design parameters have been developed. The building forms involved in their study were the (L form and rectangular form). It was observed that the annual heating and cooling energy consumption of air source heat pump application were calculated for two different building forms which have the same floor area, volume and, optical and thermos-physical properties (same material properties) of building envelope were examined in Ankara,

Turkey. The forms were simulated using program, eQUEST. The results have shown that in all calculations, the energy consumption of rectangular shaped building forms is 9-10% less than the energy consumption of L shaped building form (Erdim & Manioglu, 2011).

2.7 Building form and solar access

Building form can affect solar access and wind exposure as well as the rate of heat loss or heat gain through the external envelope. According to Praharaj (2014) for a built form, vertical surfaces are the most critical to the impact of solar radiation. The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affect the thermal performance of the building. The general design objectives are to contain the exposure of external elements by means of compact building envelope and careful consideration of the treatment of different elevations. Yilmaz (1988) highlighted that, the total heat loss change with building form even if the floor area is constant for a building, façade area of the building may change due to the change in the building form. Moreover, bigger façade area may require bigger window area from daylighting point of view and therefore heat loss through glazing increases; building form is considered an important factor affecting total heat loss and thermal comfort.

Catalina, Virgone, and Iordache (2011) worked on: ‘’Study on the impact of the building form on the energy consumption’’ In their study, thermal and lighting simulations were conducted for different building shapes, glazing areas and meteo files in order to establish their impact on the electrical and thermal consumption. The study was orientated towards office buildings, were the electric energy has the highest rate of all consumptions. At the end of the study, the authors found a difference between a cubical shape and a rectangular one on the lighting visual comfort of more than 30%. In the same time, the heating demand is reduced by 6-10 % if a more compact shape. Their study has

also shown that the building morphology is an important design parameter in the process of finding energy efficiently project with a non-negligible impact on the daylighting and heating consumption.

2.7.1 Criterion for optimum building form

For the Criterion for optimum shape Praharaj (2014) stated that ‘’It can be taken as a rule that the optimum shape is that which receives the minimum amount of radiation in summer and maximum amount of radiation in winter. It is widely believed that a square building has the best characteristics of preserving the heat in winter and remaining cool in summer. This conviction is based on the fact that a square building combines the largest practical volume with the smallest outside surface’’.

2.7.2 Factors determining the choice of Building form

Building form and orientation are architectural decisions that have significant impacts on heating and cooling loads, as well as on daylighting and opportunities for passive ventilation, passive solar heating and cooling, and for active solar energy systems (Ürge-Vorsatz, et al., n.d.)**.** But there are actualy many fa ctors that can opitimize the form of a building. Numerous studies have identified that the factor affecting the building form for achieving energy efficiency as follow: orientation, window to wall ratio, colours, shadings, envelope material, glazing and landscape. For example, it is also known that vertical shading divices are preferable on east side of the building while horizontal shading divices are preferable on the west side (Townsville, 2014).

2.7.3 Preferable window-to-wall ratios for commercial buildings

There are no energy benefits or daylighting with window-to-wall ratios over 60% percent, and in most cases an area of between 25 and 40% is optimum that is, lowest energy consumption (Straube, 2008). Even at these ratios, windows in a low-energy building should generally be high performance triple-glazed in cold climates, with large thermal

breaks over 12.5mm thick and some form of exterior shading preferably operable. The location of windows is critical to a building's ability to collect heat from the sun - north-facing windows are best, east and west facing windows can lead to glare and overheating, while south facing windows receive very little direct sun.

2.7.4 Self-shading building form

Self-shading building are buildings, which are designed such that it is self-shaded through massing, or articulation results in sheltered built forms, and cuts off a large amount of direct solar radiation. In warm and humid climate, the envelope should be designed so that it remains shaded for the greater part of the day; the external walls should be so planned that they shade each other.

Shaping building for self-shading, building form can assist cooling by providing self-shading through wings and other mass articulations, balconies, deep reveals, or arcades. Praharaj (2014) has clearly stated that, ''Building form has significant effect on the exposed walls and roof; exposed surface area is one of the parameters used in determining heat gain''. It is however important to determine how minimum fabric heat gain may be achieved in terms of building form so that some basic standard may be arrived which can subsequently be used to compare the consequences of alternative building form.

Kocagila and Oral (2015) studied ''Effect of Building Form and Settlement Texture on Energy Efficiency in Hot Dry Climate Zone of Turkey''. The building form involved in their study are mostly self-shading building form. Their study was aimed to investigate the effect of building form and settlement texture on heating and cooling loads by analysing design parameters of traditional Diyarbakır houses as the representative city of the hot-dry climate zone in Turkey. The forms involved in their study were the L-type plan, U-type plan, inner courtyard plan and central courtyard plan. Design Builder

software was used for the simulations, which uses Energy Plus simulation engine. Their result has shown that, the heating and cooling loads increase and among different building form alternatives, inner courtyard plan type requires the lowest heating and cooling loads while L-type plan the highest (Kocagila & Oral, 2015).

2.8 Building form and daylight access

The use of natural light in buildings has many implications for the energy use in buildings. According to Mushs (2000) daylight lowers the cooling requirements of a building up to 15%. Natural light is more efficient than electrical light, by providing more light for less heat than artificial light, and we have learned that in shopping mall buildings lighting has the second energy consumption. During the summer, months' excess heat generated by artificial lighting may entail the consumption of further energy for mechanical cooling. Some building form increases exposure to daylight, the higher the skin-to-volume ratio, the greater percentage of floor space available for daylighting.

i. Incorporate envelope features that improve daylighting: Deep reveals, splayed reveals, exterior fins, and similar characteristics of the envelope structure improve daylight distribution and control glare.

ii. Consider colour and texture of exterior surfaces: Light-coloured surfaces will reflect more daylight than dark surfaces. Specular surfaces (e.g., glazed tile or mirrored glazing) may create glare if viewed directly from an office. Diffuse ground-reflected daylight can increase daylight availability.

Long and narrow footprints are better than square ones for access to daylight. Buildings can be arranged as a series of wings to minimize land requirements while still allowing access to daylight as shown in figure 2.4 below. The space between the wings should not be too narrow that they shade one another. Although square buildings have lower heating loads, daylighting the interior is difficult and the imbalance between

perimeter heating loads and interior cooling loads necessitates a complex HVAC system. Multiple-storey buildings benefit the most from narrow plans that keep work areas within 10 metres of the exterior (Public Works and Government Services Canada 2002).



Figure 2.4: Building Footprints with Good Daylight Access

Source: Public Works and Government Services Canada (2002)

2.8.1 Design Parameters affecting the distribution of light in building

According to the Advance Lighting Guideline (ALG) (2010) The Design parameters are those that designers have control over, such as the shape and orientation, the size of windows, the glazing of the windows, shading systems, landscape, floor to floor height, ceiling geometry, colour of finishes etc. Each design decision turns design parameters into context for the decisions to follow. This is why early design decisions, such as building shape and orientation, are most important.

i. Building form

According to Public Works and Government Services Canada (2002) long and narrow footprints are better than square ones for access to daylight.

Alter (2009) reported that Julia Gersovitz of Montreal's architects made the point that buildings used to look like alphabets, to minimize the distance to an exterior wall and maximize natural light and ventilation.

ii. Orientation

Researches have shown that north-south orientation is best for both natural ventilation and daylighting more especially in a hot climate region.

iii. Window to wall ratio (WWR)

There are no daylighting or energy benefits with window-to-wall ratios over 60 percent, and in most cases an area of between 25 and 40% is optimum that is, lowest energy consumption (Straube, 2008).

iv. Colours

A research from the National Association of Realtors (2016) have shown that lighter colours reflect light very well in an interior space while darker colours absorb all types of light colours. Glossy finishes reflect light and change the way the colour looks, whereas flat finishes are less reflective and allow colours to look truer under bright light. Light-coloured walls can reflect the colours of bold carpets: A bright blue rug, for instance, can cast a bluish tone on a white wall (National Association of Realtors, 2016).

v. Floor to floor height ratio for commercial buildings

The height of a floor has a major impact on its performance. Good retail spaces usually need a 15-18-foot (4.5 - 5.5) meter ground floor (Grant, 2014). According to Mekigal, (2012) a standard single story big mall have a ceiling height of 23 foot. (7m).

Depth is also important in commercial building. Retails required spaces 40 feet (12 meter) deep for providing access to daylight. Retail depth is often in tension with the need to provide parking behind (Grant, 2014).

vi. Shading devices

There are many different reasons to want to control the amount of sunlight that is admitted into a building. In warm, sunny climates, excess solar gain may result in high cooling energy consumption and glare. Well-designed sun control and shading devices can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors. Depending on the amount and location of

fenestration, reductions in annual cooling energy consumption of 5% to 15% (Don Prowler, FAIA , Donald Prowler and Associates, 2014).

vii. Ceiling geometry for lighting efficiency

A study by Freewana, Shaob and Riffat (2009) shown that slope ceilings direct more light into a space. Sloping the ceiling away from the fenestration area will help increase the surface brightness of the ceiling further into a space.

viii. Glazing types for energy efficiency

Even at the ratios less than 60%, windows in a low-energy building should generally be high performance (triple-glazed), with high visual transmittance and large thermal breaks over 12.5mm thick and some form of exterior shading (Straube, 2008).

2.9 Effect of forms on energy consumptions

More recent researchers carried well documented study on building form and energy consumption they also appear to focus on issues of cooling, heating, lighting and thermal comfort as a basis for formulating building form utilizing passive strategies in different scale. Shchuchenko, Lie and Harsem (2013) worked on ‘‘Influence of building form of hospital on its energy performance’’; their study focuses on large university hospitals. They investigated the impact of the hospital building geometry on the total energy consumption; in their study, thermal performance of hospital buildings with various geometries were examined. Three types of building forms were investigated: an arcade with glazed roof, a pavilion and a tower on a base. They selected the hospital that are most commonly used in healthcare; and the hospital geometries were first simulated in several steps: beginning from existing (base case) hospital and further applying energy measures to achieve low energy hospital (with better insulated building body and demand controlled ventilation and lighting). The data input for the simulation as the Occupancy,

schedule, internal gains, ventilation rates and fabric data were kept constant for each of the simulated cases. They tested those hospital geometries in both moderate and polar climates. The simulation was carried out using Simien building energy and indoor climate software. At the end of their study, the results show that, in general, geometry of the hospital building has very little influence on its energy use (Shchuchenko, Lie, & Harsem, 2013).

2.10 Shopping malls

A shopping mall is a building or group of buildings that contains stores and the stores are connected by walkways so that consumers can easily walk between (Solis, 2016). as shown in plate 2.1 the shopping mall stores are well connected with the walkway. The National Environmental Agency defined shopping mall as premises which is typically enclosed, climate-controlled and lit, with or without on-site parking facilities, and is used for providing retail services and other commercial establishments (National Environment Agency, 2012). Malls can be built in an enclosed or open-air format (Solis, 2016).



Plate 2-1: The Fashion Centre at Pentagon City, in Arlington, Virginia

Source: Solis (2016)

2.10.1 Building forms of modern shopping malls

Modern shopping malls today are often designed with a concept to suit client demand; that is the reason why most shopping malls today come with different forms and shapes both regular and irregular. A strip mall and a Community mall is configured in a straight line, or have an "L" or "U" shape; but the remaining types of shopping malls can take any desired form and shape (The International Council of Shopping Centers , 1999).

2.10.1.1 Forms of some modern shopping mall buildings

i. Emporia shopping mall

Emporia is a shopping mall and one of the biggest ones in Scandinavia. Its s a free form building shape finished with cladding as shown in plate 2.2 below. Approximately 200 shops are located in Emporia, with a total area of 93,000 m². The mall is three stories topped with a roof terrace measuring 27,000 m². According to Emporia, they have around 25,000 visitors per day (Emporia, 2014).



Plate 2-2: Emporia shopping mall

Source: Emporia (2014)

ii. Las Arenas Shopping Centre Barcelona

Las Arenas Shopping Centre has a circular form with an atrium; its roof dome is finished with a plastic coating as shown in the plate 2.3 below. This helps to reduce glare from reflected sunlight (Lomholt, 2014). The design is based on a series of separate and complementary structural systems, which allows a variety of activities and user requirements to take place on different levels inside the building.



Plate 2-3: Las Arenas Shopping Centre

Source: Lomholt (2014)

2.10.2 Types of shopping malls

The International Council of Shopping Centres has classifies shopping malls into eight basic types: Neighbourhood centre, Community centre, Regional centre, Superregional centre, Fashion/specialty centre, Power centre, Theme/festival centre, Outlet centre. (TRIPinfo, 2012).

a) Neighbourhood Centre: This centre is designed to provide convenience shopping for the day-to-day needs of consumers in the immediate neighbourhood. A neighbourhood centre is typically a straight-line strip with no enclosed walkway or mall area.

b) Community Centre: Community centres (or community malls) are larger than neighbourhood centres, and offer a wider range of goods. They usually feature two anchor stores which are larger than that of a neighbourhood centre's, e.g. a discount department store. They may also follow a strip configuration, or may be L- or U-shaped. Community centres usually feature a retail area of (9,300 to 33,000 m2) and serve a primary area of (4.8 to 9.7 km).

c) Regional Centre: This centre sells a full variety of general merchandise, mostly apparel. Its main attractions are its anchors; they are typically enclosed malls.

d) Superregional Centre: This centre is similar to the regional centre, but it is larger with more anchors and carries a deeper selection of merchandise. Superregional centres draw from a larger population base. Typical configuration is enclosed with multilevel.

e) Fashion/Specialty Centre: Fashion or specialty centres feature upscale apparel shops and boutiques and cater to customers with higher incomes. They usually have a retail area ranging from (7,400 to 23,000 m2) and serve an area of (8.0 to 24 km).

f) Power Centre: Several large anchors, including discount department stores, off-price stores, warehouse clubs or "category killers" (stores that offer huge selection in particular merchandise categories at low prices) dominate. The centre consists of several freestanding anchors and only a few, small specialty tenants.

g) Theme/Festival Centre: Theme or festival centres have distinct unifying themes that are followed by their individual shops as well as their architecture. They are usually located in urban areas and cater to tourists. They typically feature a retail area of (7,400 to 23,000 m2).

h) Outlet centre: Outlet centres usually consist of manufacturers' outlet stores selling their own brands at a discount. They are found in rural or tourist locations. Typical outlet centre designs include enclosed malls, a "village" cluster or a strip configuration.

However, this particular research is will focus more on the Superregional mall design which its configuration is enclosed with multilevel.

2.11 Energy consumption in shopping malls

Among other features, shopping malls utilize large amounts of floor space, tend to be spread out over large expanses of land, and have several separate tenants with varying energy requirements (Young & Buck, 2006). As it was mention, earlier the energy audits and surveys that have been made for four shopping mall buildings conducted by Lam and Li (2003) air-condition account for 47-54% of the total electricity consumption with lighting in the second-place accounting for the 33-38%. In a commercial building electricity use per unit gross floor area ranged from 391 to 454 kWh/m2, with an average of 430 kWh/m2 (Lam & Li, 2003).

A study carried out by Rubio (2001) in a shopping mall located in southern California, indicated that the energy demand in shopping mall is due to the great thermal/internal loads from the lights and the high people densities during the working hours is mainly in early morning or late afternoon hours with bigger needs during the winter months as shown in figure 2.5. On the other hand, cooling demand for the same reasons is peaked during the hours 12:00 to 15:00 with greater effect on summer months (Rubio, 2001).

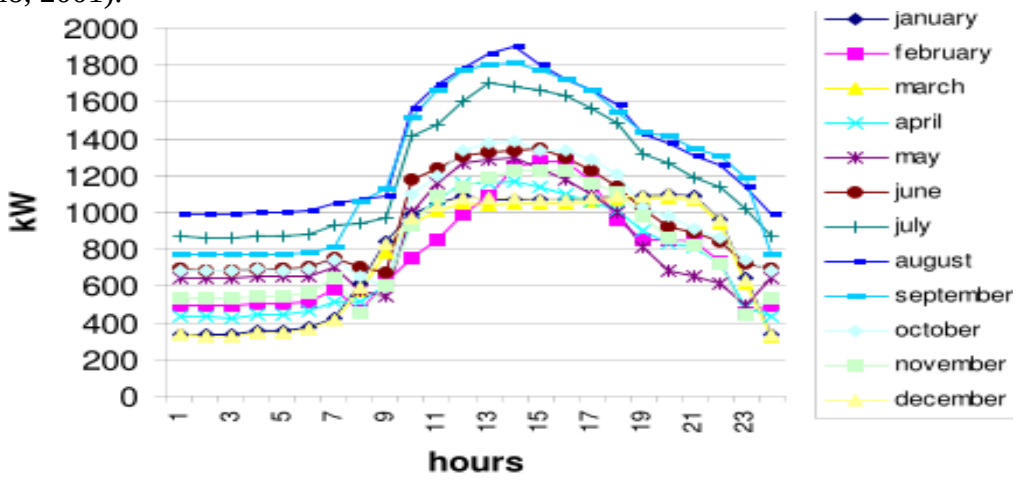


Figure 2.5: Pick load shape in southern California shopping mall

Source: Rubio (2001)

Another study carried out by Lam and Li (2003) the authors investigated the electricity use characteristics in shopping centers in Hong Kong. They selected four fully air-conditioned buildings which were examined in their case studies. The number of storeys of these shopping mall varies from two to four with a total gross floor area (per shopping centre) ranging from 6 550 to 29, 900m2. The shopping mall selected were all modern shopping centres with centralised heating, ventilation and air conditioning (HVAC) plants. Figure 2.6 show the twelve months electricity consumption, the data were collected for each of the four shopping centers. A distinct seasonal variationin electricity use was observed by the researchers. Its was also found that the cooling requirements during mid season are due mainly to the intense internal loads, such as people, electric lighting and office and other electrical equipment.

The total building electricity consumptions of the shopping malls 1 was 12.5, shopping malls 2 was 4.9, shopping malls 3 was 2.5 and the last shopping malls was 3.6 GWh annualy.

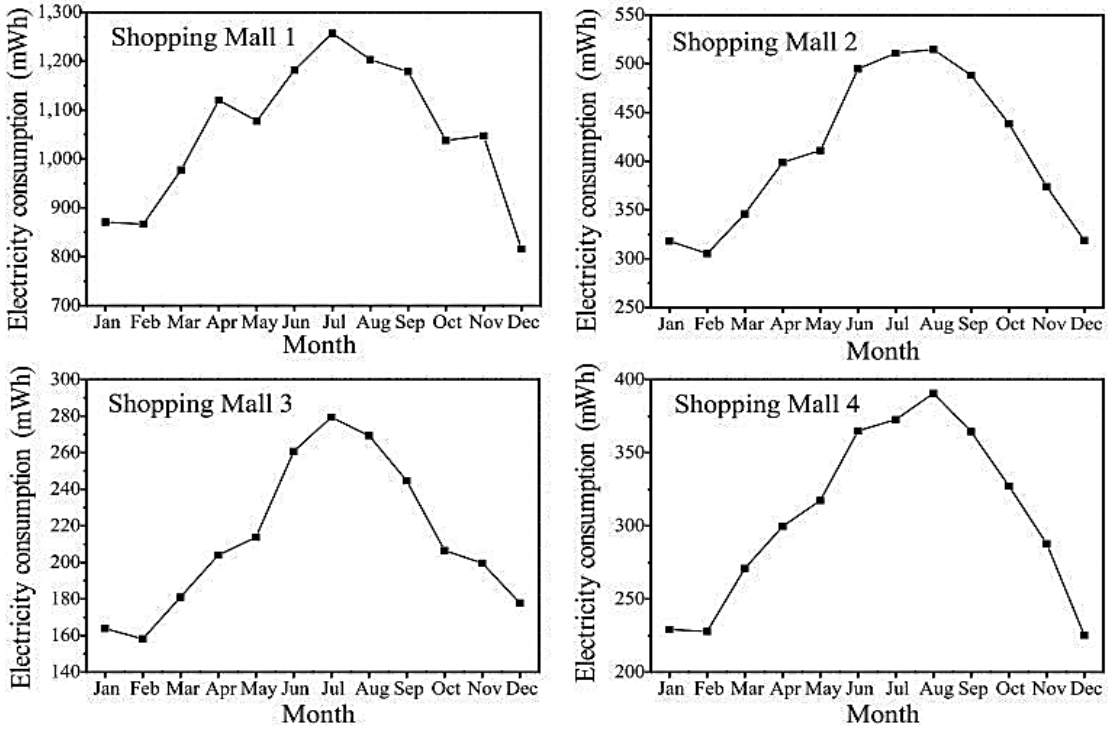


Figure 2.6: Monthly electricity consumption for four shopping malls in Hong Kong

Source: Lam and Li (2003)

2.11.1 Major electricity end uses in shopping malls

In the same study Lam and Li (2003) broke down the total electricity use into four major end uses , namely HVAC, lighting, miscellaneous electrical appliances/equipment and lifts/escalators.

a) For lighting consumption, the number of light fixtures and their corresponding power ratings in both the landlord and tenants areas were surveyed and estimated wherever appropriate.

b) For the electrical appliances consumption a similar approach which were adopted to estimate the energy consumption for lighting implemented.

c) For lifts and escalators, energy analysers (DRANETZ 8000-2) were used to measure the electricity use.

d) For the HVAC (heating, ventilation and air-conditioning) consumption was obtained by subtracting the consumption of those three end uses from the total building electricity use. Figure 2.7 show the percentage break down of electricity use in the four shopping centres. It can be seen that the major end use was HVAC, accounting for 47-54% of the total consumption. Lighting accounted for 33-38% Electrical appliances were ranged between 10-13% and the lift and escalators accounted between 2-5%. On average, HVAC and lighting accounted for about 85% of the total building electricity use.

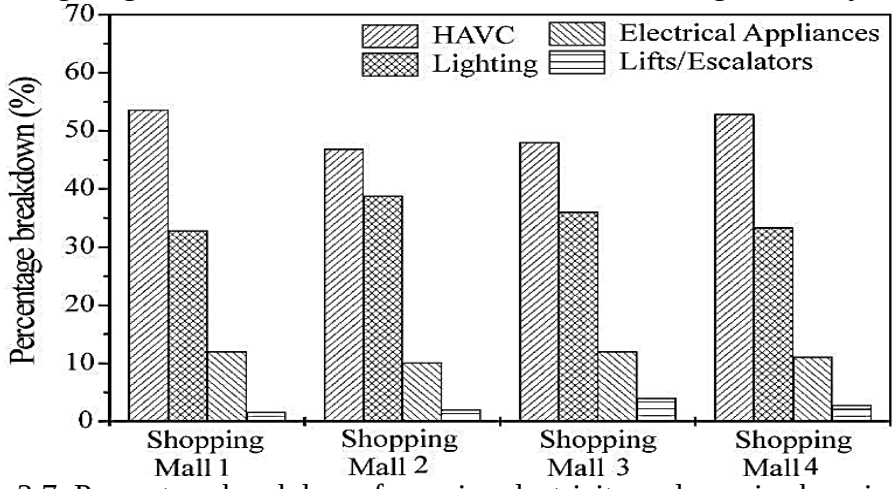


Figure 2.7: Percentage breakdown for major electricity end uses in shopping malls

Source: Lam and Li (2003)

2.11.2 Performance standards for energy consumption in retail mall

Building are encouraged to optimise systems' efficiency; where appropriate, actions should be taken to retrofit systems and upgrade their efficiency to a suitable standard. The ranges of acceptable performance efficiency for the various systems are as given in table 2.1 and table 2.2 (National Environment Agency, 2012). Therefore, building owners are encouraged to work towards a higher performance standard within the given range.

All the ranges given above may be subjected to change.

Table 2.1: Recommended Ranges for the Building Systems' Energy Performance

Systems	Eligibility Requirements	Remarks
Air Conditioning	Plant room efficiency < 0.75 kw/RT	Primary and secondary pumps' consumption in kw should be included in the calculation
Lighting	Lighting power density < 2.7 w/m^2	Code of Practice for Energy efficiency standard for building services and equipment SS 530; 2006 (Table 7)
Mechanical Ventilation	Mechanical Ventilation Power Density < 2.7w/m^2	CP 13, 1999, Clause 5.3.6&7.11.5, for operating units only (stand-by units need not be considered).

Source: National Environment Agency (2012)

2.11.3 Acceptable range for thermal comfort and lighting in commercial buildings

i. Thermal Comfort: The following standards should be met in order to ensure that the building has adequate thermal comfort:

Table 2.2: Acceptable Range for thermal comfort parameters

Parameters	Acceptable range
Dry bulb temperature (DBT)	22.5°C to 25.5°C
Relative humidity	<70%.
Air movement	<0.25m/s
Mean Radiant Temperature (MRT)	MRT-DBT ≤ 2 °C

Source: National Environment Agency (2012)

ii. Illumination levels: the amount or strength of light available in a place or for a purpose (Dictionary.com, 2016). The following standards should be met to ensure that the occupied interior spaces and parking spaces have adequate illumination levels as shown in table 2.3 below.

Table 2.3: Illumination Levels for Various Occupied Interior Space

Space Type	Illumination* (lux)	
Car parks:	Day	Night
Floor and outdoors	20	10
Driving Aisles	100	--
Ramps and corners	100	50
Entrance and exit	300	50
Entrance hall, lobby, waiting room, lift, corridors, escalators	100-200	
Shopping precinct & arcades	100-200	
Enquiry desk	300-750	
Shops, department stores and show rooms	300-750	
Check-out/ payment area	300-750	
Canteen, food court, cafe	80-200	
Restaurant kitchens	300	
Lounge, bar	70	
Cinema:		
Auditoria	50-100	
Foyers	100-200	

Source: National Environment Agency (2012)

2.11.3.1 Effective Temperature for thermal comfort in the tropic

Effective temperature is the temperature in an environment with 100% humidity and no air movements, which will induce the same level of thermal comfort as in the present situation. A study by Ogunsote & Prucnal-Ogunsote (2002) comparing the effective temperature comfort range and effective temperature indicates that 22°C to 27°C are assumed for thermal comfort for the Tropics they have concluded that the most appropriate comfort range should be 20°C to 25°C.

2.12 International case studies

2.12.1 International case study one: ARG Shopping Mall / ARSH 4D Studio

i. Architects: ARSH 4D Studio

ii. Location: Tehran, Tehran, Iran

iii. Architects in Charge: Arsh [4d] Studio- Alireza Sherafati, Pantea Eslami

iv. Design Team: Zahra Ajorloo, Morvarid Malekhosseini, Mina Habibirad, Elnaz

v. Area: 78.0 square meter

vi. Project Year: 2015

vii. Client: Saba Mihan Company



Plate 2-4: ARG Shopping mall

Source: ArchDaily (2016)

2.12.1.1 Background Information

ARG shopping mall has a site area of about 11500 square meter but the whole project area is far bigger than that about 78000 square meter. It is four stories building with basement for parking as shown in the plate 2.4 above. According to the architect, in 2012 they won a competition to design a new facade, landscape, roofs cape, and interior for a shopping centre which was already designed and under construction but the client was not satisfied with the original design.

2.12.1.2 Facilities Available

ARG Shopping mall have various facilities available for the customers: Corridor, toilets, stair case, lobby, restroom, disable restroom, express store, coffee shop, kitchen freight elevator, service room, ramp, mechanical room, mechanical site, electrical room, security, express store storage, retails, administration, lecture hall, waiting room, VIP restaurant, food court, ticket kiosk, wonderland office, performance area, playground, parking spaces (ArchDaily, 2016).

2.12.1.3 Daylighting strategy

Among the different daylighting strategies applicable in shopping mall design, the Side lighting (windows) and atrium method were applied in the building as shown in plate 2.5. Some of the spaces uses one side window lighting while others spaces do not even have access the only source of lighting is the artificial light. However, this has contributed to the availability and variation of light within the interior of the mall.



Plate 2-5: Daylighting strategies of ARG shopping mall

Source: ArchDaily (2016)

2.12.1.4 Design of ARG Shopping mall

i. The building form is irregular with some straight and curve spaces, ARG shopping mall is not properly oriented because the longer axis of the building is facing east

and west this feature has given the building the disadvantage of capturing more daylight while increasing the thermal impact of sunlight on the building.

ii. Concrete was the main building material used in the building follow by the glass as the main envelope material, but the building does not have any form of shading devices to protect the building from unwanted sunlight and glare.

iii. The spaces provided are within the building varies in term of its use, and their depth varies some spaces are not deep and this has helped the spaces achieved a considerable level of daylight for optimum task performance for some spaces.

iv. Most of the interior building elements incorporated in ARG shopping mall have light colour finishes for the walls, roof, ceilings and even the floor. This however, give good reflectance of light within the spaces for the required visual task. Despite the various materials used for ceiling in the mall the geometry of all the ceiling is all flat throughout the building

The glazing type used in ARG shopping mall building is tinted tempered glass with aluminium frame as shown in plate 2.6. To re-compose the facade, the architect decided to simplify the massing and create a smooth and neutral surface to counteract the chaos of the neighbourhood. Glass is used to reflect the old trees of the surrounding area and highlight the mountains to the north and that resulted in its uniqueness in area.



Plate 2-6: Glass facade of ARG Shopping mall

Source: ArchDaily (2016)

Elevation differences of the site is solved by landscape steps (see plate 2.7) turning into long benches provide connections from the sidewalk and create an outdoor auditorium.



Plate 2-7: Public outdoor of ARG Shopping mall

Source: ArchDaily (2016)

For design of the interior, re-connecting the east and south wing, which were previously separated from each other by the central void, has been a key concept as shown in figure 2.8; 2.9 and 2.10. The connection has been achieved via creating continuity in floor and ceiling lines.

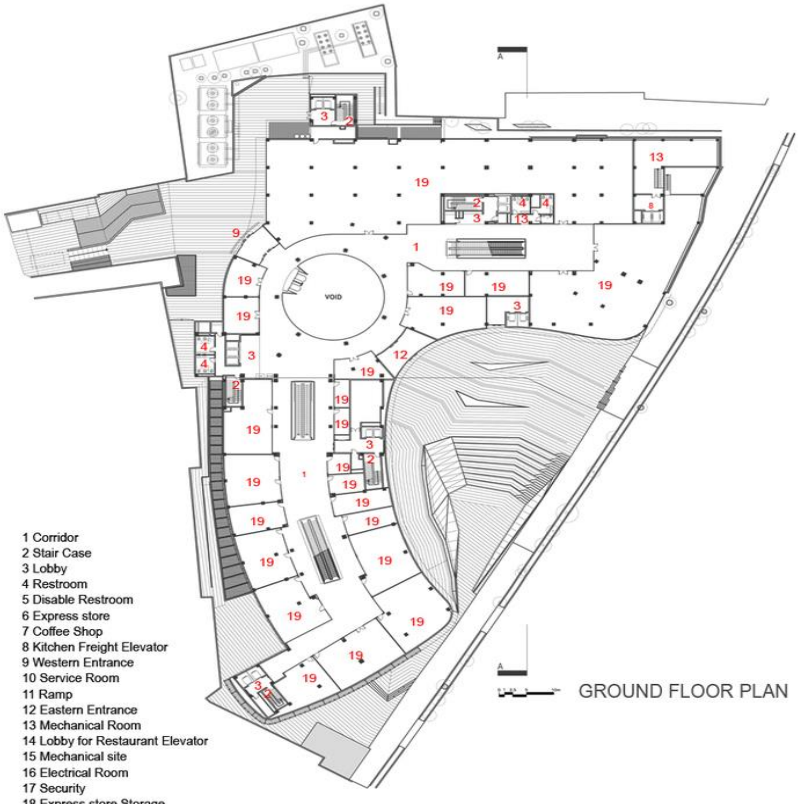


Figure 2.8: Ground floor plan of ARG shopping mall

Source: ArchDaily (2016)

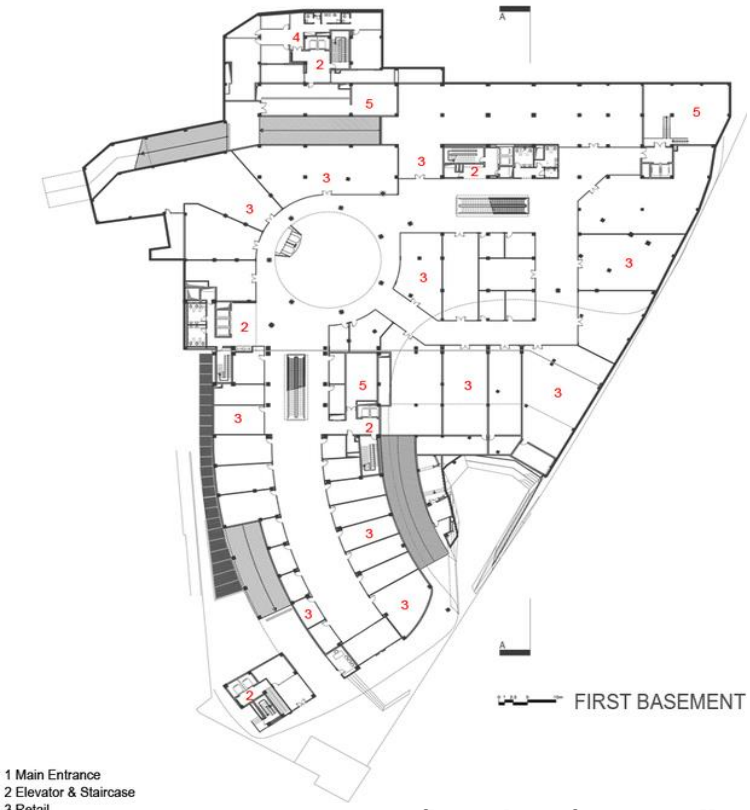


Figure 2.9: First floor plan of ARG mall

Source: ArchDaily (2016)



Figure 2.10: Second floor plan of ARG mall

Source: ArchDaily (2016)

2.12.2 International case study two: Paleet Shopping Center / JVA

i. Architects: JVA

ii. Location: Karl Johans gate 37, 0162 Oslo, Norway

iii. Project Year: 2014

iv. Consultants: RISS AS, Linda Knoph Vigsnæs/LYSSTOFF AS



Plate 2-8: Paleet shopping centre

Source: ArchDaily (2015)

2.12.2.1 Background Information

Paleet is a shopping centre situated on the high-street Karl Johans gate in the very centre of Oslo as shown in plate 2.8 above. It has operated as a shopping mall since 1990, a new building sitting behind retained historical facades from the 1860's. It has an area of about 10100 square meter. In 2014, Paleet has undergone an extensive refurbishment. The aim has been to create a shopping destination with a strong personality. The project seeks to provide an overall experience through exquisite design as well as offering a range of dining venues and high-end boutiques. As a collaboration between Petter Abrahamsen at RISS AS, Linda Knoph Vigsnæs of Lysstoff AS and the architects Jarmund/Vigsnæs Architects, the group had a shared design vision from the outset.

2.12.2.2 Facilities Available

Among the various facilities that a shopping mall should have, Paleet Shopping Centre have many of them to entertain the customers: Retails, toilets, lifts, storage, security room, stair cases, restroom, kitchen, service room, management office, parking spaces restaurant, playground, banking and ATMs (Automatic teller Machine), Optical Services, a dental office, pharmacy, photo studio, children's entertainment, events hall, and Shoprite (ArchDaily, 2015).

2.12.2.3 Daylighting strategy

Side lighting and atrium method were used in the design of Paleet Shopping Centre. Most of the spaces have a side window lighting while just few others spaces do not even have access of daylight the only source of lighting is the artificial light. The ceiling, featuring a suspended see through metal grid, hides the servicing yet gives the impression of a full height space. The soffit with servicing elements is exposed but tinted with a deep red hue. The reflective nature of these gridded surfaces enables light to bounce and animate the space as shown in plate 2.9 below. Nevertheless, this has contributed to the availability and variation of daylight in Paleet shopping centre.

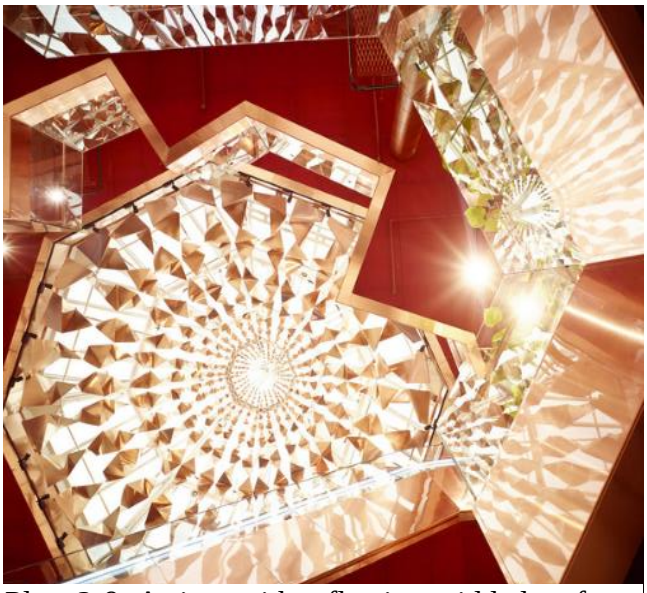


Plate 2-9: Atrium with reflective gridded surfaces

Source: ArchDaily (2015)

2.12.2.4 Design of Paleet Shopping Centre / JVA

The project sought to enable a continuation of the shopping malls original character which was based on exclusive materials and a hospitable atmosphere, translated into a new and contemporary materiality. The goal was to rationalize and modernize the mall, building on the existing atmosphere without copying the old. The brief was to elevate the mall to a high-end shopping destination in way that felt intimate, exclusive with rough feel.

The distinction between shared spaces and individual retailers are important elements in the design of a shopping centre. This distinction took the form of urban walls. The shops retain their individuality through acting as theatrical openings in the wall whilst the restaurants transcend these lines and flow naturally into the shared spaces as shown in figures 2.11 and 2.12 below.

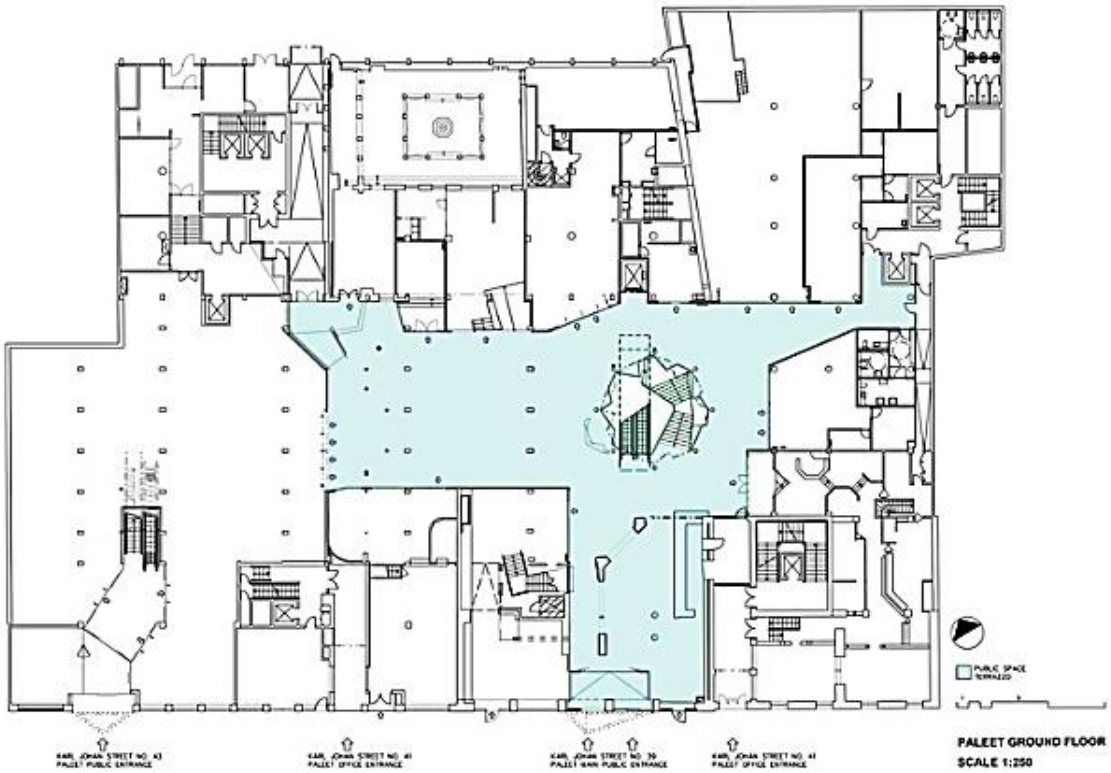


Figure 2.11: Ground floor plan of Paleet shopping centre

Source: ArchDaily (2015)

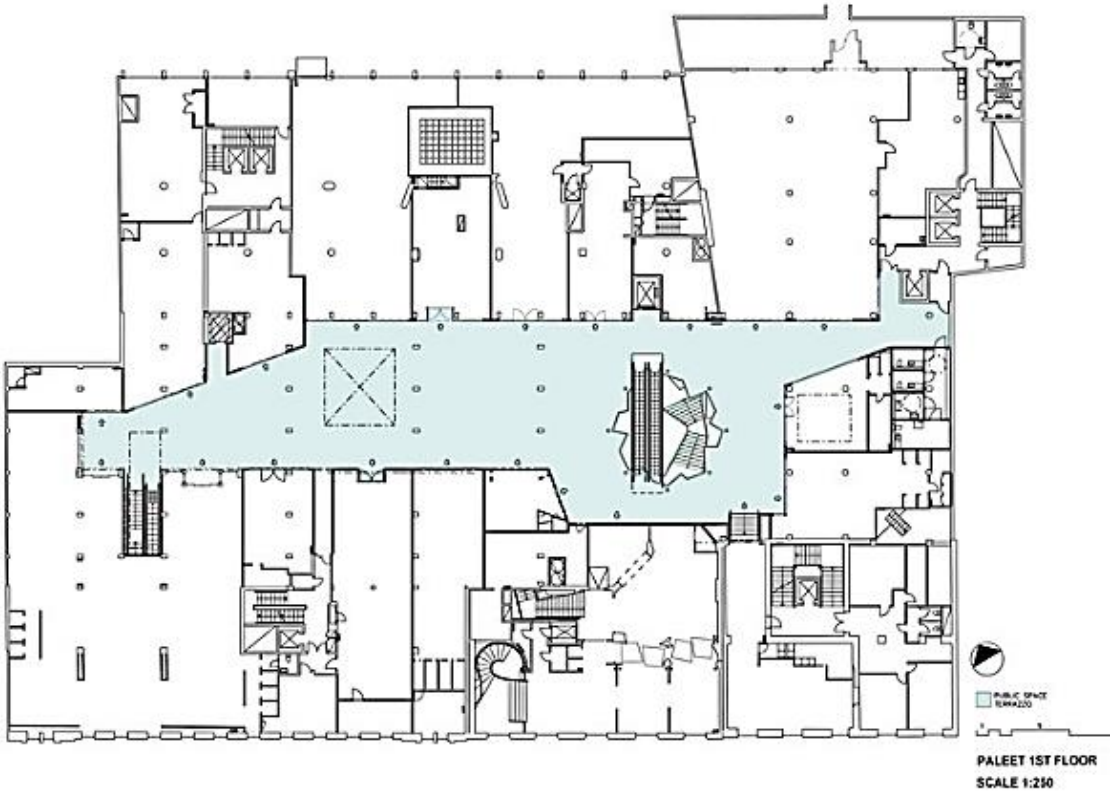


Figure 2.12: First floor plan of Paleet shopping centre

Source: ArchDaily (2015)

The warm and golden palette of the shared spaces retains a level of soberness as not to feel too precious. It has contrasting tactile qualities and a modern appeal with materials that will age gracefully. The choice of materials sets a distinct mood whilst remaining in the background, allowing the shop fronts to take centre stage. The lightly hued terrazzo flooring with golden fragments plays in tandem with the copper and the dryness of the cedar cladding of the walls as shown in plate 2.10 below.

The new chandelier suspended above the main atrium space is a true eye-catcher which creates various light scenarios during the day.



Plate 2-10: Modern appeal materials used in Paleet shopping centre

Source: ArchDaily (2015)

The lightness of the floors, and its slight golden shine, acts as a stage floor, enabling goods and people to be exposed to an optimal degree. Throughout the mall the round columns are upholstered using brown leather with a French seam in a spiral pattern providing a soft tactility among the adjacent harder materials of the palette. The square columns are clad in shiny copper.

Paleet shopping centre have a rectangular form in nature even though some external walls are chamfered, the shopping centre is oriented 315° from North based on it form and location, it is not properly oriented because the longer axis of the building is

facing east and west this feature has given the building the disadvantage of capturing more daylight while increasing the thermal impact of sunlight on the building.

The building material used in the building are concrete, steel, glass, clad in shiny copper, hued terrazzo flooring with golden fragments plays in tandem with the copper and the dryness of the cedar cladding of the walls. However, the building does not have adequate shading devices to protect the building from unwanted sunlight and glare.
The spaces provided are within the building varies in term of its use, and their depth varies some spaces are not deep and this has helped the spaces achieved a considerable level of daylight for optimum task performance for some spaces.

Paleet shopping centre's interior building elements have mostly brown colour for the walls, column and ceilings only the floor have a light colour finishes. This however, does not give good reflectance of light within the spaces for the required visual task. The geometry of the ceiling in the mall some spaces are tilted while some are just flat Even though the various materials they are made.

2.13 Sumary of Findings from the litterature

From the previous studies, the following were observed: First, Simulation tools have become a most common method to address the problem of energy consumption and building forms for Cooling, Heating and lighting simulation. The most common softwares used by the researcher are: eQUEST, Ecotect and Energy plus because of their user friendly interface and the availability. Secondly, the higher the skin to volume ratio, the greater percentage of floor space available for daylighting. Thirdly, most studies focus on only regularly buildings forms, Cubic form, Cuboid form, and L shapes. The major electricity end uses in shopping malls building is generally attributed to the space cooling, heating and lighting; these elements can all be optimized by building forms depending upon the climate, the shape of the building and the materials used in the building envelope are important determinants of energy required. Shopping malls today are built in various forms and sizes. For daylight design, building forms that looks like alphabets minimize the distance to the exterior wall and maximize natural light and ventilation. Building with a large surface area, the internal condition is more influenced by the external climate than in one with less surface areas. Smaller buildings have larger skin/volume ratio than large buildings.

3.0 METHODOLOGY

3.1 Introduction

Having identified the scope and objectives of the study, it is important to follow a suitable research methodology. A methodology is a systematic way to solve a problem (Rajasekar, Philominathan, & Chinnathambi, 2013). It is conceived therefore, as to obtain answers to the research questions**.** This chapter gives the information on how the research was conducted in order to achieve the (research) aim and objectives of the study. The figure 3.3 show the overall summary of the research methodology adopted for this research; It shows the research strategy, research design, Case study selection criteria, sampling method adopted, instrument of data collection and also data analysis and presentations adopted for the research.

For the purpose of achieving the aim of this research, quantitative and qualitative research approach were adopted to investigate the building form effect on energy efficiency and to identify the relationships between variables, and generalizing those results to the world at large.

3.2 Research strategy

Being an evaluative study, the research approach adopted for this study is both quantitative and qualitative. The use of case study and computer simulation for comparing different building forms and by modelling a base case of one of the local case studies, which helped in achieving the aim of the research. Quantitative research is a research based on traditional scientific methods, which generates numerical data and usually seeks to establish causal relationships between two or more variables, using statistical methods to test the strength and significance of the relationships (Encyclopedia, 2012). While qualitative research is aimed at gaining a deep understanding of a specific organization

or event, rather than a surface description of a large sample of a population. It also aims to provide an explicit rendering of the structure, order, and broad patterns found among a group of participants (Qualitative research consultants association (QRCA), 2015).

The building forms are modelled using Autodesk Revit Architecture 2014 and were exported to Autodesk Ecotect 2011 for analysis. The seven (7) different forms involved in the study are Cuboid form, L Shape; T Shape and U Shape; Cubic form; Triangular (isosceles) shape and Cylindrical form as shown in table 3.1. Moreover, the orientation for the Cuboid form, L-Shape, T Shape, U Shape, Cubic form and Triangular shape were decided by simulating them in different positions; and the orientations with the lowest energy loads of each building forms were selected for the comparisons, to give an acceptable result. All the seven 7 building forms have the same floor area, window-floor ratio, floor to floor height, building material and finishes. A valid climate file was obtained for the study location and used for the simulation. Each of the form has a total floor area of 869m^2, and window-floor ratio of 30% is being used for each of the form for an effective result.

The following are assumptions are adopted from the existing building in place:

1. The building forms are assumed to be in a location without a slope.
2. All forms were considered as stand-alone building without overshadow from any adjacent buildings.
3. The occupancy hour of the building used is considered to be from 8:00am-11:00pm everyday including holyday as gotten from the case study. Occupant's activity rate is 110w and 20m2 per occupant.
4. The material properties for the respective forms are the same material as the one used for the base line model (second case). The diagrammatic image of all the forms analysed is shown in figure 3.1 below.

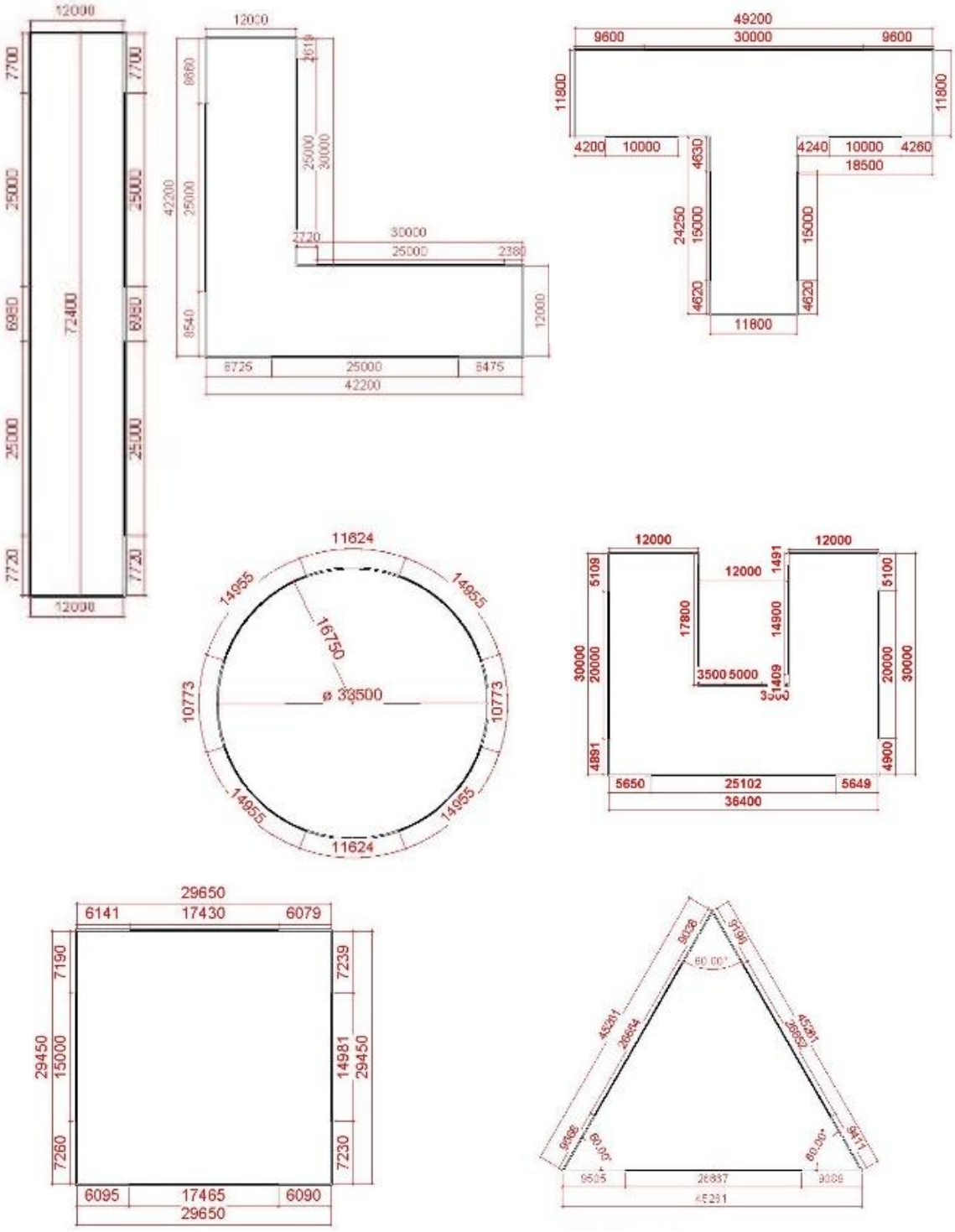
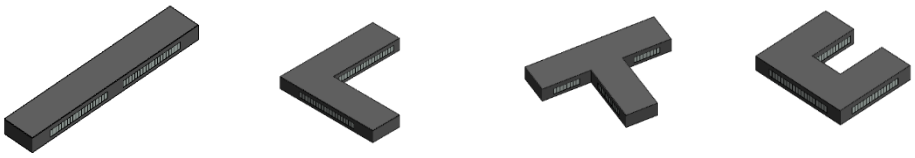
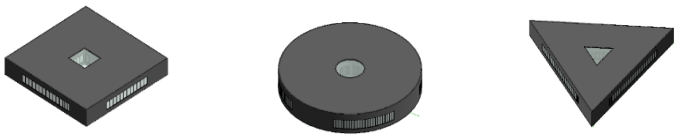


Figure 3.1: Details dimensions of the building forms

Source: Author 2016

Table 3.1: Building forms used in the study

Linear Forms	
Centric Forms	

Source: Author (2016)

3.3 Research design

To achieve the aim and objective of this research, descriptive and quasi-experimental approach were implemented because quasi-experiment provides statistically accepted reliable and valid results. Descriptive research is characterised as simply the attempt to determine, describe or identify a particular situation. Quasi-experiments are studies that aim to evaluate interventions but that do not use randomization its aim to demonstrate causality between an intervention and an outcome (Harris, et al., 2016).

3.4 Case study

Case study research approach excels at bringing us to an understanding of a complex issue or add strength to what is already known through previous research. Yin (2014) defines case study as a form of empirical inquiry. He describes his approach to case study as using a "realist perspective".

For this research, case studies were carried out in some selected shopping malls, a checklist was used to investigate the level at which the factors that determine the choice of building forms was considered in the choice of the existing shopping mall for achieving their efficiency. The building with the lower rating was selected and simulated as it is to

evaluate how much energy could have been saved if the factors affecting energy efficiency was considered in the design.

3.4.1 Sampling

A sample is a number of representative units drawn from the larger population for the purpose of effective studies (Oluigbo, 2014). For this research the type of sampling used for the selection of the case studies is purposive sampling method. This is used because the study is focued more on forms for achieving energy efficiency. Three shopping malls were selected after careful consideration for achivieng the aim of this research base on the following crateria:

a) Buildings form (Most common used forms)
b) Representing of the current design trend in Nigeria's shopping malls.
c) Location (Within the same climate)

The shopping malls selected for the study were: Jabi Lake Mall; Ceddi Plaza and SilverBird.

3.4.2 Variables

A variable is an object, event, idea, feeling, time period, or any other type of category you are trying to measure (Anonymous, 2012). There are two types of variables: dependent and independent. The independent variable it is a variable that stands alone and is not changed by the other variables you are trying to measure while the dependent variable it is something that depends on other factors in other words it is what is being measured in an experiment or evaluated in a mathematical equation and the independent variables are the inputs to that measurement (TechTarget, 2013).

The dependent variables for this study is the energy efficiency and its emphases on cooling, heating load and illumunation level as shown in figure 3.2 below. The independent variables for this study were the building forms. The building forms that are

simulated in this study for their performance were the most commonly used building forms as identified by Astrish, Morris and Walters (n.d.) as stated in the literature but the clustered forms are excluded because they are series of smaller masses in a variety of arrangement and shopping mall nowadays are one big single mass or unite. Sometime shopping malls can be in two or three different masses but they are still link as one big unite.

The forms are:

i. Cuboid form, L Shape, T Shape and U Shape;

ii. Cubic form, Triangular (isosceles) Shape and cylindrical form.

These variables were examined as part of the process of creating base-case models with each of the forms having the same materials properties, same floor area, same floor to floor height and same window-to-wall ratios of 30% to determined the annual cooling, heating load and the illumination level for each of the forms. A checklist's sample to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the existing malls was develop from the literature as part of the descritive research as shown in table 3.2 below.

Quasi-Experimental research

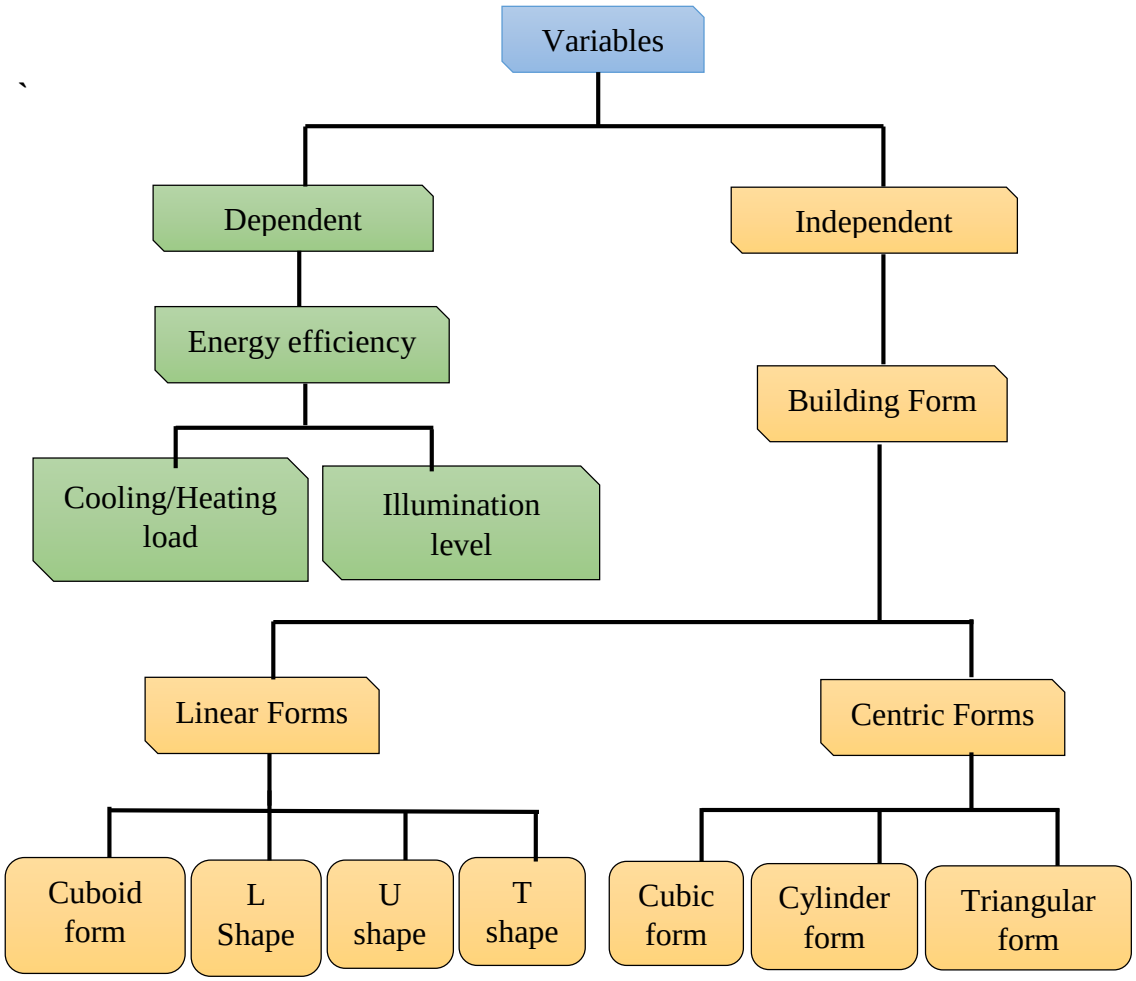


Figure 3.2: Dependent and independent variables for simulation

Source: Author (2016)

Descriptive research

Table 3.2: Sample of checklist to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the existing malls.

Scale Factor: 5=Very Good; 4=Good; 3=Moderate; 2=Poor; 1=Very poor

Variables	Features	Scale Factor	Remarks
Form of buildings			
Orientation			
Window to wall ratio (WWR)			
Colours			
Shadings			
Envelope Material			
Glazing			
Landscape			
Total			

Source: Author (2016)

3.5 Methods and Instruments of Data Collections

3.5.1 Methods

Some of the data collection methods are universal and can be applied across disciplines, while others are more specific to a field (Oluigbo, 2014). Been an evaluative research in nature, this study employed case studies, visual survey and simulation as method of data collection in other to achieved the aim of the study.

a) Visual Survey: This implied the physical observation of the building in order to note its appearance in terms of the building forms, orientation, envelope properties and physical features/ expressions being put in the design.

b) Check list: The check list was developed with the aim to check the rate or extent which the design consideration of daylighting and themal comfort was achieved in the selected case studies. The check list has a ranking scale of 1 to 5 (5=Very Good; 4=Good; 3=Moderate; 2=Poor; 1=Very poor). Each of the consideration will be rated as shown above for each building, and a summation will be done in order to find the building that best apply these considerations.

c) Computer Simulation: In order to evaluate the energy efficiency of the various building forms and the viability of the method/procedure adopted, Computer simulation software is needed.

3.5.2 Instruments

The various instruments used for the collection of data for this research include: check list, photographs, note book, messurement tape, sketch pad and computer softwares.

i. Check list: The check list contained the list of variables gotten from the litterature and they were observed and noted during the field survey.

ii. Photographs: The photographs of relevant areas were taken in order to show the factors that affect the energy efficiency and the extent to which they were applied. They

were taken to support the notes taken during the visit. They also provided a significant source of visual data about the cases to outside observers.

iii. Note book: This instrument of data collection was adopted to back-up information that was observed during the field survey. Comprehensive notes were prepared as an ongoing record of what was happening as the research progressed.

iv. Sketch pad: Sketches were made for the case studies. These sketches were considered vital to form an opinion on the physical setting and spatial organisation of the case studies in order to explain the research.

3.6 Data Analysis and Presentation

For the purpose of this research, descriptive analysis and parametric analysis was used. The aim of the parametric analysis is to observe the response following a modification in a variable. Parametric analyses are conducted for reasons including the need to determine (Hamby, 1994) as cited in (Batagarawa, 2013). The analysis were carried out using computer simulation Ecotect as similar studies were succesfully done using the software as found in the litterature.

A general documentation of the case studies was done and analysed based on the factors that determines the choice of building forms of the selected cases, after which conclusions were drawn out of the analysis. The case with lowest rating is simulated, as is it, to check its efficiency and performance based on cooling load and illumination level; then the same building was simulated again by applying the factors that determines the choice of building forms to compare the energy consumption of the two cases and their interior lighting level. The data were analyzed and represented in the following ways: Graph; Tables and Figures follwed by descriptive statistics analyses. They are presented in next chapters.

3.6.1 Building simulation software ecotect.

The purpose of using the ecotect software for conducting this research is that, similar studies were carried successfully using the software and Ecotect is a comprehensive concept to detail sustainable design analysis tool, providing a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs, it is also user-friendly graphical interface. Online energy, water, and carbon-emission analysis capabilities integrate with tools visualize and simulate a building's performance within the context of its environment. It calculates heating and cooling loads for models and analyze effects of occupancy, internal gains, infiltration, and equipment. In addition, it visualize incident solar radiation on glazed surface and surfaces, over any period. It displays the sun's position and path relative to the model at any date, time, and location.

3.7 Summary of the research methodology

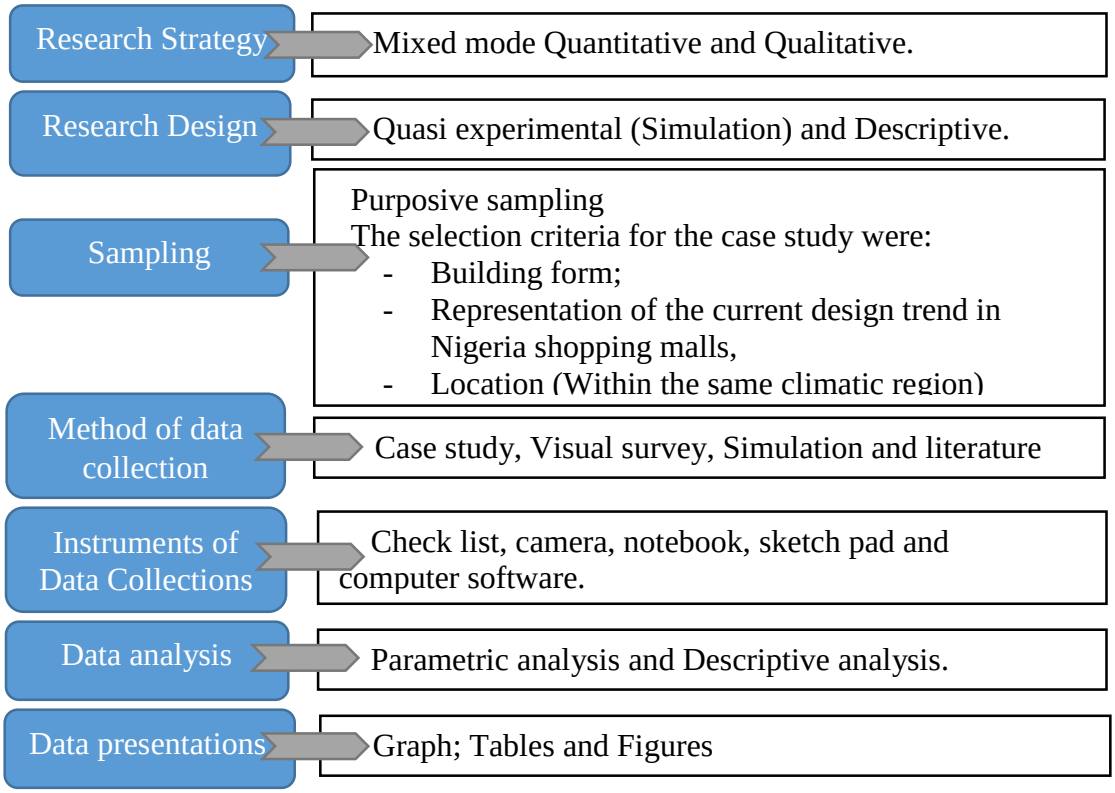


Figure 3.3: Overall research methodology

Source: Author (2016)

4.0 FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents how the data collected were analysed in order to achieve the aim of the research which is evaluating the effect of building forms for enhancing energy efficiency in shopping malls in a composite climate of Abuja. The analysis was carried out in line with the research questions and it was conducted in four stages process below.

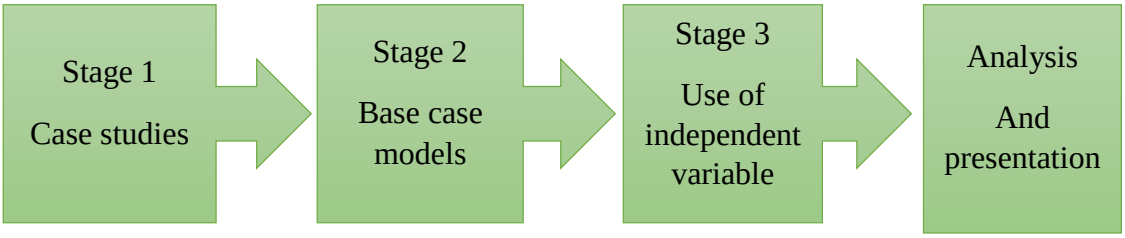


Figure 4.1: Stage process during the analysis

Source: Author (2016)

All the information collected from first stage served as data input for the creation of the base case model on which various factors that determine the choice of building forms were applied and simulated for an alternative energy saving. Different building forms involve in this study were evaluated for their energy efficiency with the information collected from first stage which served as data input also. The last stage involves analysis and presentation of the various results in in form of tables and graphs.

4.2 Case Studies

This section, the results of the case studies conducted are presented. Three case studies were conducted in three shopping mall buildings: Jabi Lake Mall; Ceddi Plaza and Silverbird all located in Abuja under the same climatic zone. The results focused on the variables as described in the methodology of this study. These variables of study were developed from review of the literature and similar studies that were done before. The case study focuses on the factors that determine the choice of building forms.

4.3 Case study one: Jabi Lake Mall

i. Location: Abuja

ii. Developed by: Actis Ltd

iii. Style: contemporary architecture

iv. Facility Manager: Mr Paul Banton

v. Opened: 26th Nov 2015



Plate 4-1: Jabi Lake Mall view form the South entrance

Source: Author's Fieldwork (2016)

4.3.1 Background Information

The Shopping mall provides a one-stop shopping experience comparable to world-class standards, with an excellent lakefront location with great visibility and easy accessibility off the main highway as shown in plate 4.1 above. The mall is located just within 8 km of Abuja Business District. The Jabi Lake Mall project is a mixed-use shopping mall consisting of two floors the ground floor plan has an area about 7214 m2 while the first-floor plan has an area of 6409m2. It has in total 124 shops and can take about 10000 people at a time. The Mall is the largest shopping centre to date in Abuja and is part of the Jabi Lakefront Master Plan proposal, a large, multi-purpose, multi-use scheme. The Mall is designed to be a unique shopping, entertainment and relaxation centre and

comprise numerous shops on both levels with outdoor seating areas for convenience and choice as shown in figure 4.2.

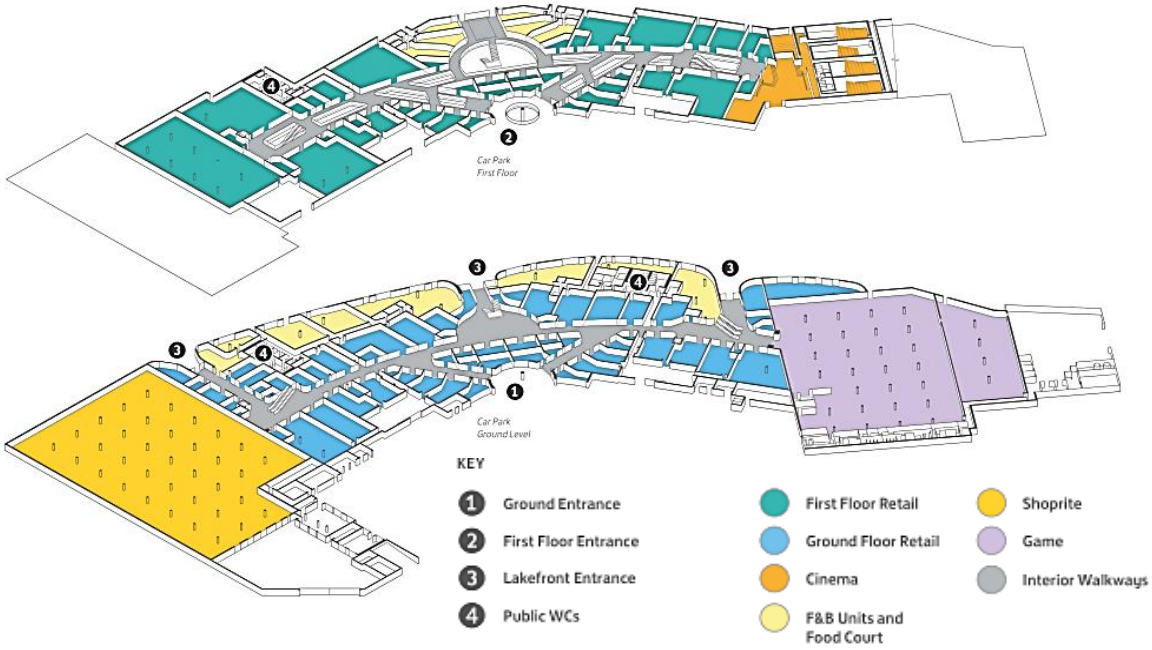


Figure 4.2: Layout of Jabi Lake Mall

Source: jabilakemall (2013)

4.3.2 Energy consumptions of Jabi Lake mall

Monthly, about 1000 to 2000 kWh of energy is consumed by the building; that is about 12000 kWh to 24000 kWh annually and according to the Operation Manager of Jabi lake mall 80 to 90% percent of the electricity of the whole mall is powered by the generators because of the electricity shortage in the country. The total shopping mall have a power load is 5100 kilowatts. There are two main anchors tenants (Shoprite and Game) but there is also a Cinema (Silverbird). Because of their sizes four (4) Air handling unit with compressor each, have been provided there are also four (4) lifts and four (4) escalators for the whole building. The entire lighting fixture provided are energy efficient they are all less than 60Watt. To keep the whole shopping mall running every day, seven (7) generators are in place: three (3) generators of a capacity of 2000 kva for the mall (shops), and two (2) generators of a capacity of 1100 kva for the Shoprite and game, which make it in total seven (7) generators. The design power load of the whole building is 5100

kilowatts, but at the present moment for the mall only one 2000 kva generator can power the mall and for the Shoprite and game 1100 kva for each.

4.3.3 Accessibility

An exit from Shehu Yar Adua Way allows a direct access to the mall. From an easterly direction, access is via a link road with Soloman Lar Way. There are two main access gate the north and south gate. The north gate will lead you straight to the first level while the south gate to the ground level. A vehicle drops off area, bus stop and pedestrian footpaths connecting the mall to the main road make Jabi Lake Mall easily accessible.

4.3.4 Facility Available

The Jabi Lake Mall has Shoprite and Game as its anchor tenants, as well as other line shops to cater for fashion, Centre management offices, security offices, Shoprite, home décor, hairdressing and beauty, banking, telecommunications, three public toilet blocks featuring male and female toilet facilities, disabled facilities, baby change facilities and parent and child facilities, Specialist retailing and a 5-screen cinema. The mall also offers dining and fast food, cafés and bars, children's play area and ample parking spaces of 733 parking spaces. The plate 4.2 and 4.3 below show some of the interior facilities of Jabi.



Plate 4-2: The interior facilities of Jabi Lake mall

Source: Author's fieldwork (2016)



Plate 4-3: The interior View of Jabi Lake mall

Source: Author's Fieldwork (2016)

4.3.5 Daylighting strategy

Among the different daylighting strategies applicable in shopping mall design, Side lighting method was mostly applied within the spaces in the building. Most of the shops do not have access to daylight the only source of lighting is the artificial ones. However, this has contributed to the availability and variation of light within the spaces.

4.3.6 Design of Jabi Lake Mall

Jabi Lake Mall's design is unique. According to the Operation Manager of Jabi Lake, vertically shopping mall with multiple floors three, four, five, six levels or more are somehow difficult for shoppers to circulate and do the shopping easily. However, Jabi Lake Mall's design is just two floors ground floor and the first floor to reduce vertical circulation. There are two main access gate the north and south gate. The north gate will lead you straight to the first level while the south gate to the ground level. The upper floor is kept open so that someone can see over the shops below. This attracts people to move up and down. There are escalator and lift for shoppers to easily slide up and down the mall.

4.3.6.1 Form of building

Being a cluster form and shape in nature, Jabi Lake Mall consist of many irregular shapes inter-connected together to form its unique form as shown in plate 4.4 below. The building has a ground and first floor and various facilities are taken place on each floor as shown in figure 4.3 and 4.4 below.



Plate 4-4: Jabi Lake Mall view from the North entrance

Source: Author's Fieldwork (2016)



Figure 4.3: Ground Floor plan of Jabi Lake Mall

Source: jabilakemall (2013)



Figure 4.4: First Floor plan of Jabi Lake Mall

Source: jabilakemall (2013)

4.3.6.2 Orientation

The Jabi Lake influences Jabi Master Plan. The master plan was design is such a way that its follow the Organic pattern of the Lake as shown in figure 4.5 below. Therefore, this has made Jabi Lake Mall's Orientation not proper base on its location and climate because the longer axis of the building is facing east and west this feature has given the building the disadvantage of capturing more daylight and increasing the thermal impact of sunlight on the building.



Figure 4.5: Google image showing the Jabi Lake Mall

Source: Google earth (2016)

4.3.6.3 Building Envelope/materials

The main building materials used for the construction are sandcrete block wall, reinforced concrete, glazed aluminium windows and porcelain floor tiles on floor.

1. Door: laminated glass with aluminium frame to all mall shops
2. Window: glazed aluminium windows
3. Ceilings: Concrete slab,
4. Wall: Sandcrete block and reinforced concrete
5. Floor material: Marble, porcelain floor tiles to first floor mall area

4.3.6.4 Shadings

There are two type of external shading devices provided in the Jabi Lake Mall, the vertical and horizontal shading. The shading devices helped in reducing the heat gain in the mall. However, the horizontal shading devices are placed high therefore leads to direct incident solar radiation reaching the stores facing outside without any form of obstruction. This will lead to high internal temperature and glare effects to occupants of the building as shown in plate 4.5 below.



Plate 4-5: Vertical and Horizontal shading devices

Source: Author's field work (2016)

4.3.6.5 Size and depth of spaces

The spaces provided within the Jabi Lake mall some are square, rectangular but most of them are irregular in nature and they are being lighted from one side from the corridor. Most of spaces provided do not have window just a fully glaze front.

The depth of most of spaces are less than 12 meter which is very good the and this has helped in achieving a considerable level of daylight for optimum task performance while most of the spaces without the help of artificial light it will be impossible to perform tasks.

4.3.6.6 Colours

Most of the building elements incorporated the use of light colour finishes for the walls, roof, ceilings and even the floor. This however, give good reflectance of light within the spaces for the required visual task.

4.3.6.7 Glazing

The main material for the glazing used in the Jabi Lake Mall is the single clear glazed with aluminium frame. The Plate 4.6 below shows the types of glazed used and the major source of daylight in the Mall, And the used high level fixed windows along the corridor.



Plate 4-6: Single clear glazed window

Source: Author's fieldwork (2016)

Table 4.1: Checklist to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the choice of building form of Jabi Lake Mall.

Scale Factor: 5=Very Good; 4=Good; 3=Moderate; 2=Poor; 1=Very poor

Variables	Features	Scale Factor	Remarks
Form of buildings	Use of cluster building form.	2	The building has different building shape inter connected facing different direction to form its unique architectural form.
Orientation	Position of building in relation to its location and climate	2	The longer side of the building is facing east-west and it is not proper because of the heat gain.
Window to wall ratio (WWR)	No use of window.	3	There is no any side window in the building because they wwant to reduce the heat gain trough window and make the building more secure.
Colours	Use of brighter colour	4	Material with Light finishes with very high level of reflectance was used with various colours.
Shadings	Use of shading devices to direct sun glare and heating.	3	Horizontal and vertical shading devices were used to reduce glare and solar heating on some walls and entrances.
Envelope material application	Use of common building material for each of the elements.	3	Use of Hollow sandcrete block for the wall, aluminium roofing sheet was used in the roof, concrete floor while all the doors and windows made use of glass.
Glazing	Use of clear tempered glazing system.	3	Clear Tempered single glazed system are used its allow natural daylight into the building and has more durability.
Landscape	The level of usage of soft and hard landscape around the building.	4	Almost 60% of the mall is surrounded by the lake and soft landscape, while 40% with hard landscape.
Total		24	

Source: Author (2016)

4.3.7 Discussion of case study one

From the case study conducted, it was observed that, the factors that determines the choice of building form to achieve energy efficiency was considered about 60% in Jabi Lake Mall as shown in table 4.1 above. The building form, which is a cluster form, is not suitable for the location; the elongated side of the building is facing the sunrise and sunset exposing the most of the building surface to the heat gain. The building could have been well oreiented so that the amount of solar radiation reaching the building's surface will reduce but it is not the cases.

The absence of window in Jabi Lake Mall help in reducing the heat gain but stoping natural light into the shops making the use of artificial light unavoidable which increases the light bill. Even the building material used in the mall are not insulated, they were mostly the commontly building material found in Nigeria market non-insulated materials are not as efficient as the insulated onces. Building materials have the highest impact on energy consumption of a building.

Jabi Lake Mall is expose to direct sun radiation with no any obstruction like natural shadings (trees) even the artificial shading availables are not enough horizontal and vertical shading devices were used to reduce glare and solar heating on some walls and entrances only. Most of the building is not shaded may be it is because the absence of the windows.

4.4 Case study two: Ceddi Plaza

i. Location: Abuja

ii. Owners: Ceddi Corporation

iii. Manager: Mrs Folake

iv. Style: Ultra-modern shopping mall

v. Construction Started: 2001-2003

vi. Opened: November 2005



Plate 4-7: Exterior view of Ceddi Plaza

Source: Author's Fieldwork (2016)

4.4.1 Background Information

Ceddi Plaza is owned by Ceddi Corporation and is located in the Central Business Area of Abuja as shown in plate 4.7 above. Daily, Ceddi Plaza receive averagely between 2000 to 3000 visitors it has a capacity of 120 parking cars according to the Operation Manager. The Plaza consists of 10,000 square meters of retail and office space. The Basement to the 2nd second floor are occupied by retails spaces (eateries, fashion boutiques, entertainment and services) and two floors of corporate office spaces in the 3rd floor Netco Dietsmann and 4th floor which has Mansel Hyson. The facility is managed by Cluttons International. It is opened everyday even on holiday from 7 am to 11 pm; and its pick

time is always around 12 to 6 pm. The Plaza is celebrated as the premiere Centre for Shopping & Entertainment in the City of Abuja.

4.4.2 Energy consumptions of Ceddi Plaza

In a month about 230000 kWh is consumed on electricity including diesel for generator that is about 2760000 kWh in a year. Due to the number peoples that visit Ceddi plaza daily for their comfort; two (2) central air conditioning, sixty-two (62) fans coil unit and eighteen (18) Air handling unit is provided just to maintain a good indoor temperature. For lighting each shop have a required number of light bulb in addition to the natural daylight. The fluorescent light varies from 15-20 Watt and some other types are about 20-40 Watt. For the vertical circulation within the building, three (3) lifts and three (3) escalators are also provided.

4.4.3 Accessibility

From Tafawa Balewa Way, you can have a direct access Ceddi Plaza through the south-east gate. There is only one main access gate for security reason. There is a drops off in front of the building that give you access to the main building. The location of Ceddi plaza made its accessibility very easy.

4.4.4 Facility Available

Ceddi Plaza has about 55 shops, including offices and service providers consisting of movie theatres, a bookstore, Wine Shop, Grocery, the Atrium at Ceddi Plaza, restaurants, cafes, fashion boutiques, shoes, accessories, home interior design stores, furnishings, health and beauty salons, gift shops, telephones, banking and ATMs (Automatic teller Machine), dry cleaning services, Optical Services, a dental office, pharmacy, photo studio, Telecommunication, children's entertainment, events hall, and Shoprite etc. The plate 4.8 below show some facilities.



Plate 4-8: Interior View of Ceddi Plaza

Source: Author's Field work (2016)

4.4.5 Daylighting strategy

Atriums and Windows are the basic means for daylight to both the offices and retails spaces as shown in the plates 4.9 and 4.10 below. The windows have almost 50% of window to wall ratio with tinted glazing which does not allow proper penetration of daylight to the spaces, but provide good privacy for the administrative areas. There are three atriums within the building that provides good lighting within the building.



Plate 4-9: Atriums as Daylighting strategy in Ceddi plaza

Source: Author's Field work (2016)



Plate 4-10: Windows as daylighting strategy in Ceddi Plaza

Source: Author's field work (2016)

4.4.6 Design of Ceddi Plaza

Ceddi Plaza have a simple design with it rectangular shape it has six 6 floors and a basement; the attraction for this shopping centre include the first multi-screen cinema in Abuja, a multimedia store, the restaurants, specialist retailers, bank cash office, airline ticket office as shown in figures 4.6 and 4.7. There are two glass lifts from the main entrance to every floor in the building, there is also a straight fly staircase on the right and another customized one at the left side. The main entrance foyer opens into the giant circular atrium, traversing the entire six floors with two panoramic lifts framing the grand staircase. The second and third floors are open plan offices with provision for voice and data outlets as shown in figure 4.8. The penthouse on the fourth floor is designed for maximum visibility.

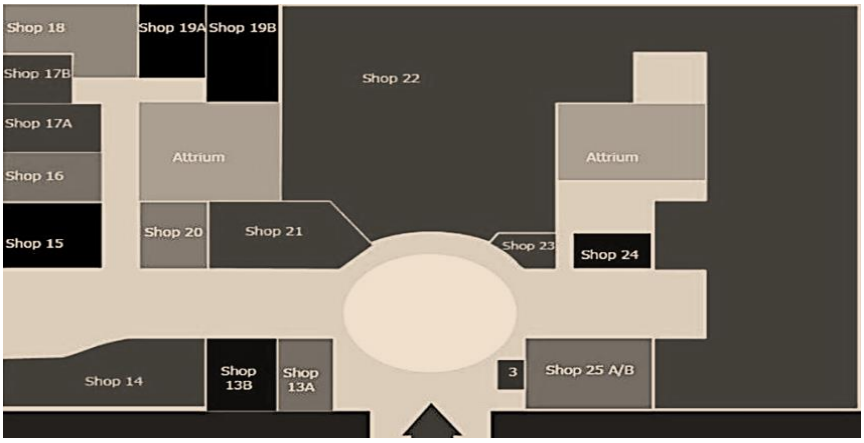


Figure 4.6: Spatial organisation of ground floor plan, Ceddi plaza Abuja

Source: Ceddicorporation (2013)

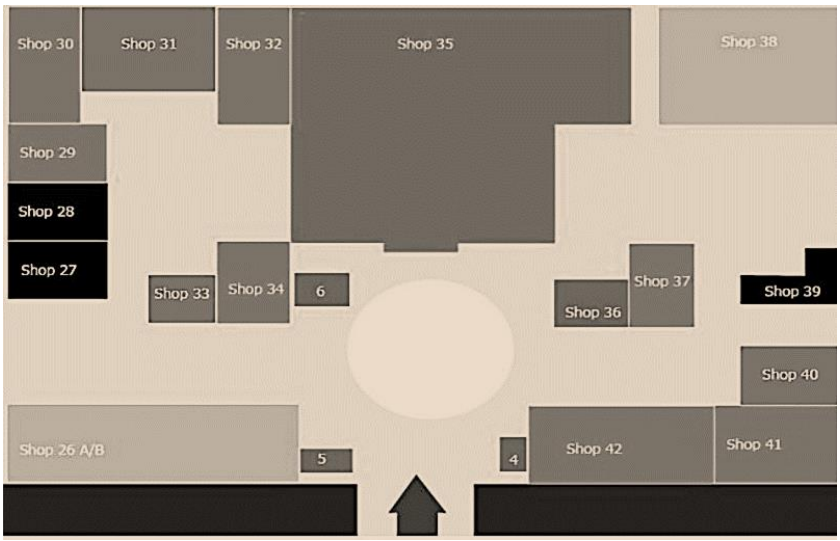


Figure 4.7: Spatial organisation of first floor plan, Ceddi plaza Abuja

Source: Ceddicorporation (2013)

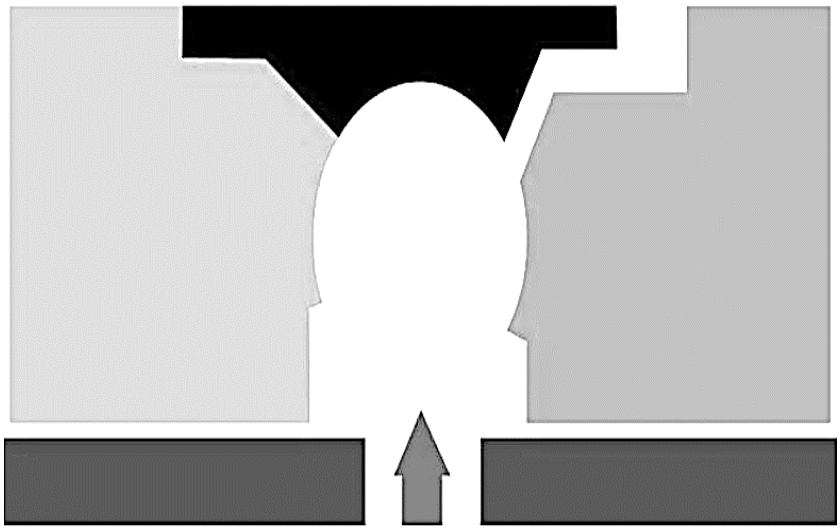


Figure 4.8: Spatial organisation of second floor plan, Ceddi plaza Abuja

Source: Ceddicorporation (2013)

4.4.6.1 Building Form

The building has rectangular form; it has three atriums and its consist of many rectangular and square shape on the plan even though some spaces have an irregular shape. The building has a basement for parking, and electrical rooms.

4.4.6.2 Orientation

The building is oriented North-West and South-Est. The building was oriented with its longer axis facing the East and West direction increasing the solar heat solar heat gain on the building and this eventually lead to a very high cooling load as shown in figure 4.9 below.



Figure 4.9: Google image showing Ceddi Plaza

Source: Google earth (2016)

4.4.6.3 Building Envelope/materials

The main building materials used for the construction are sandcrete block wall, reinforced concrete, glazed aluminium windows and marble floor tiles on floor.

1. Door: laminated glass
2. Window: glazed aluminium windows
3. Ceilings: Concrete slab, celotex, plasterboard
4. Wall: Sandcrete block and reinforced concrete
5. Floor material: Marble, Tiles

4.4.6.4 Shadings

Most of the windows at Ceddi Plaza do not have shading devices. This therefore leads to direct incident solar radiation reaching the building surface without any form of obstruction. Only the glazed façade of the ground and first floor is shaded with the top slab supported with column, which help to cast shadow on the glazing surfaces as shown in plate 4.11 like a self-shading building. The lack of adequate shading devices leads to high internal temperature, operation cost and glare effects.



Plate 4-11: Absence of adequate shading devices in Ceddi Plaza

Source: Author's fieldwork (2016)

4.4.6.5 Size and depth of spaces

Most of the spaces within the building are rectangular and square in nature and they are lighted from one sides mostly. The atriums also help in providing adequate light within the building and mostly along the corridor areas.

4.4.6.6 Colours

Most of the building elements like walls, roof, and ceilings incorporated the use of light colour finishes. This however, reflect back heat into the atmosphere and gives good reflectance of light within the spaces for the required visual task. However, the floor colours are dark colour (mostly brown) finishes.

4.4.6.7 Glazing

The primary material for glazing used in Ceddi Plaza is the single glazing system with all aluminium frame. Windows are found in opposite sides of the building mostly front and back. Nevertheless, the glazing material used for the atrium is fibreglass which reduces glare within the interior of the building. Tinted Window are introduced to prevent glare and internal heating as shown in plate 4.12 below.



Plate 4-12: Showing tinted glazing used in Ceddi plaza

Source: Author's field work (2016)

Table 4.2: Checklist to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the choice of building form of Ceddi Plaza.

Scale Factor: 5=Very Good; 4=Good; 3=Moderate; 2=Poor; 1=Very poor

Variables	Features	Scale Factor	Remarks
Building form	cuboid form	3	The building has a rectangular plan with three atriums as one of the major source light.
Orientation	Position of building it is elongated North-West and South-Est.	3	Most of the building envelope is exposed to solar radiation which result in high heat gain.
Window to wall ratio (WWR)	Use of efficient WWR for buildings.	4	The wall to window ratio is about 40% which is efficient according to the literature.
Colours	The most dominant colour used is light yellow, follow by brown and white.	4	It does not absorb much heat and it has a very good light reflectance into the interior spaces.
Shadings	Use of a little of vertical and horizontal shading devices	2	The ground and second floor's windows are protected, horizontal shading were used to reduce glare and solar heating.
Envelope material	Use of the common building material.	3	Use of Hollow sandcrete for the wall, aluminium roofing was used in the roof, concrete floor while all the doors and windows are made of glasses.
Glazing	Use of single and tinted glazing system.	3	The glazeing used are single tinted glass its reduices the heat gain.
Landscape	The level of usage of soft and hard landscape around the building.	3	Almost 75% of building surrounding are hard landscape while the remaining 25% are soft landscape.
Total		25	

Source: Author (2016)

4.4.7 Discussion of case study two

The level of application of the factors that determines the choice of building form to achieve energy efficiency was considered is almost the same as the one of Jabi Lake Mall as shown in table 4.2. Even though the building form is a cuboid form in nature, it is still not suitable for Abuja climate The orientation of building it is elongated North-West and South-East with the location of Ceddi Plaza in Abuja climate (Composite climate Hot humide/Hot dry climate) this building form is not suitable base on the litterature carried out.

The window in Ceddi Plaza are tinted help in reducing direct solar radiation into the shops and also reducing the heat gain but daylight transmittance into the building is reduced critically. The good thing is that lighting is not the major issue in the tropic, the major issue is cooling. The building material used for Ceddi plaza are not insulated, they are also the common building material found in Nigeria market; and non-insulated materials are not as efficient as the insulated ones. This surely has a lot effect on energy consumption of Ceddi Plaza The Plaza is expose to direct sun radiation with natural shadings, the artificial shading are availables only from the grounf floor to the second floor and that is because of the balcony. Horizontals and vertical shading devices when it is properly used in a building it can reduce glare and solar heat gain which will ultimately reduce its energy consumption.

4.5 Case study three: SilverBird

i. Location: Abuja

ii. Owners: Silverbird Group

iii. Chairman of Silverbird Group: Ben Murray Bruce

iv. Style: Modern architecture

v. Constructed in: 2009



Plate 4-13: Exterior View of Silverbird

Source: Author's field work (2016)

4.5.1 Background Information

The Silverbird Galleria building is located in Abuja central district area. It opens every day from 8 am to 11:30 pm including holydays and the pick time is mostly around 12 pm to 11:30 pm. The building has seven floor and a basement, with a total site area of 35,000square meter as shown in plate 4.13 above. Its includes 12 screen multiplex cinemas, eight VIP lounges, game arcades, retail shops, stores and administrative offices. The building form is rectangular elongated on the north-south axis. All the windows are made of tampered glass. The roof is partly decked and drained with pipes at the exterior, while other areas are covered with fibreboards. Its interior floors are covered with decorative tiling with dark colours.

4.5.2 Energy consumptions of Silverbird mall

Annually about 15 to 20 million Naira is spend on electricity including diesel for generators that is about 1080000 to 1450000 kWh/Year. There are three (3) generators 2000, 1500 and 500 Kva. The 2000 and 1500 Kva are used simultaneously when there is not power source during the day, but during the night when the shops are close; the 500 Kva generator is used. Silverbird uses the central AC for cooling about 40 chillers because the window is fix windows to achieve the comfort of its 5000 visitors daily. The artificial light wattage rages form 15-25 Watt. There are ten 10 escalators and four (4) lift.

4.5.3 Accessibility

An exit from Sani Abacha way give an access to M Dr. Road that allows a direct access to Silverbird mall. Its location does not favour the people without private. There is only one main access gate (south-west gate) which help for proper control.

4.5.4 The Facility Available

Silverbird has about 64 shops, including offices and service providers consisting of cinema halls, Shoprite, banking etc. as shown in plate 4.14. There is an excellent bookshop a pharmacy, retail space for various goods, luxury shopping, 12 screen cinemas, VIP balconies, Photography, Food court, clothing, supermarket, lifestyle, restaurants toilets, restroom etc.

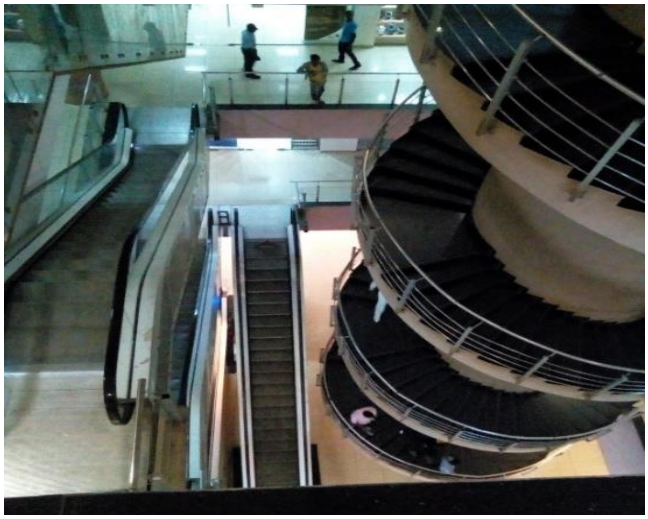


Plate 4-14: Interior views of the Silverbird showing the escalators

Source: Author's field work (2016)



Plate 4-15: Interior views of the Silverbird

Source: Author's field work (2016)

4.5.5 Daylighting strategy

Windows are the major means daylighting for the offices and retails spaces and others facilities as shown in the plate 4.16. The windows to wall ratio is between 30-40%. It is tinted and does not have a good visual transmittance into the spaces, but provide good privacy for the administrative areas.

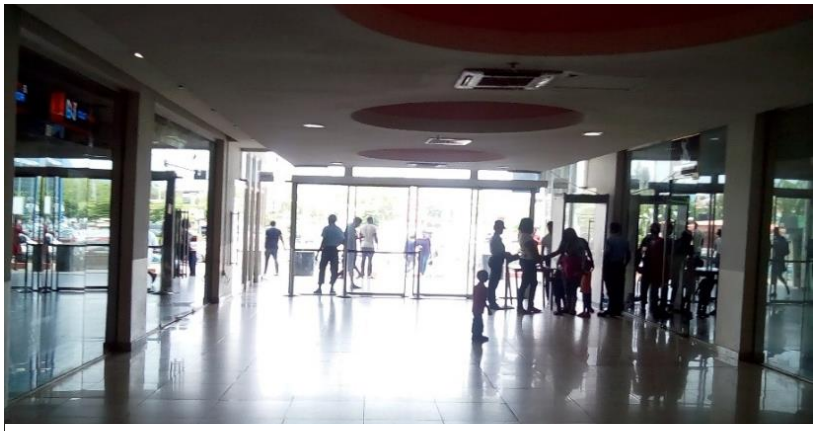


Plate 4-16: Daylighting in Silverbird Mall

Source: Author's field work (2016)

4.5.6 Design of SilverBird

Silverbird mall have seven (7) floors and a basement as shown in figure 4.10. There are 64 shops including offices and other facilities. In the basement, ATM, Shoprite and others facilities are located, from ground to 3rd floor it is allocated for retail shops but the management offices are located at the 3rd floor and from 4th to 6th floor there are the movie

halls while the 7 floor which is the last is private. There are 4 lift, 2 for the customers, 1 private lift and another one for goods. There are also 10 escalators form the ground to fourth floor with 2 escalators. Two staircases are also provided within the building.

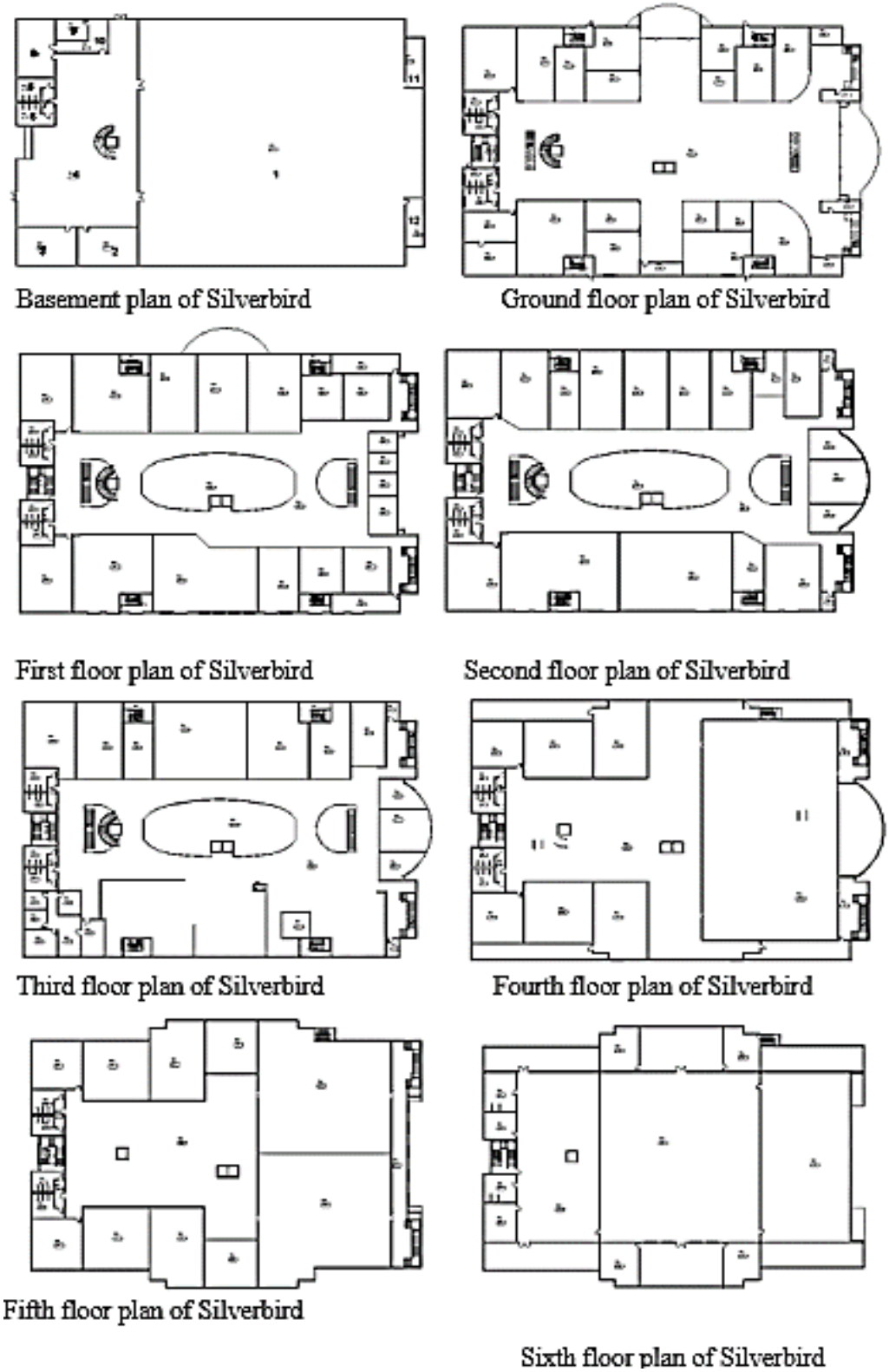


Figure 4.10: Floor plans of Silverbird

Source: Author's sketch (2016)

4.5.6.1 Building form

Silverbird mall has a cuboid form; the walls are straight without balcony obstruction, which changes building forms. The interior space also consists of many rectangular and square shapes even though some spaces have an irregular shape. The building has a basement ground to seven floors and various facilities are taken place on each floor.

4.5.6.2 Orientation

Based on the climate of Abuja city, Silverbird is not proper oriented because it is positioned at an angle of about 315° degrees away from the north as shown in Figure 4.11. The longer axis of the building is facing east and west even though the building looks almost square. This orientation has given the building the disadvantage of capturing more daylight while increasing the thermal impact of sunlight on the building, which increases cooling load.



Figure 4.11: Google image showing Silverbird

Source: Google earth (2016)

4.5.6.3 Building materials

The main building materials used for the construction are sandcrete block wall, reinforced concrete, aluminium and marble.

1. Door: Clear glass
2. Window: tinted glass
3. Ceilings: celotex, concrete slab
4. Wall: Sandcrete block and reinforced concrete
5. Floor material: Marble, Tiles, and concrete

4.5.6.4 Shadings

All the windows on the building do not have any shading devices. This therefore leads to direct incident solar radiation reaching the building surface without any form of obstruction as shown in plate 4.17. The lack of shading devices leads to high gain of heat and solar radiation; but the tinted glass used in the building help in reducing the effect of glare.



Plate 4-17: Lack of shading devices on Silverbird Mall

Source: Author's fieldwork (2016)

4.5.6.5 Size and depth of spaces

The spaces provided within Silverbird are mostly square, rectangular but few of them are irregular. Most of spaces provided have window only one side. The floor-to-floor height is about 3 meter and the depth of most of the retails spaces are about 8 to 12 meter with various length. The depth of some spaces like the management offices and security surveillance room are not deep this is because they are small in size when compared with the shops and this helped in achieving a considerable level of daylight for optimum task performance while most of the spaces without the help of artificial light it will be impossible to perform task.

4.5.6.6 Colours

The most dominant colour used in Silverbird is light yellow; follow by grey and white. The roofing colour is red. The floor colour is composed of various colours same thing for the ceiling. This however, reflect back heat into the atmosphere and gives good reflectance of light within the spaces for the required visual task.

4.5.6.7 Glazing

The main material for glazing used in Silverbird is tinted single glazed with aluminium frame. The Plate 4.18 below show the materials in details.



Plate 4-18: Glazing used in Silverbird

Source: Author's fieldwork (2016)

Table 4.3: Checklist to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the choice of building form of Silverbird.

Scale Factor: 5=Very Good; 4=Good; 3=Moderate; 2=Poor; 1=Very poor

Variables	Features	Scale Factor	Remarks
Building Form	cuboid form	3	The building has a rectangular plan with no shading devices to enhance efficiency of the building.
Orientation	It is positioned at an angle of about 315° degrees away from the north.	2	The building envelope is exposed to the sun rise and sun set which result in high heat gain.
Window to wall ratio (WWR)	The wall to window ratio is about 40% which is efficient.	4	Use of efficient window to wall ratio (WWR) for buildings.
Colours	Light finish material with high level of reflectance was used with various colour.	3	The most dominant colour used in Silverbird is light yellow, followed by grey and white.
Shadings	No shading devices to direct sun glare and heating.	1	The building does not have any kind of shading even trees to reduce glare and solar heating.
Envelope material application	Use of the commonly building material available in the country.	3	Use of Hollow sandcrete block for the wall, aluminium-roofing sheet was used in the roof, concrete floor while all the doors and windows made use of glass.
Glazing	Use of single tinted glazing system.	3	The glazed are single tinted glaze its allow natural daylight into the building and reduces heat transmitance.
Landscape	Use of soft and hard landscape around the building.	2	Almost 85% of building surrounding are hard landscape while the remaining 15% are soft landscape.
Total		21	

Source: Author (2016)

4.5.7 Discussion of case study three

Among the three cases studies conducted Silverbird has the lowest level of consideration the factors that determines the choice of building form to achieve energy efficiency just about 50% as shown in table 4.3. It has a Cuboid form with totally no shading devices exposing the building to solar heat gain. Research have shown that Cuboid form is more suitable for hot dry climate but Abuja has a composite climate (Hot humid/ hot dry climate). The orientation of the building is 45 degree from North exposing all the building surface to the sun rise and sun set which result in high heat gain. The window in Silverbird are tinted this actualy help in reducing the heat gain into building while at the same time reducing the amount of natural light into the shops making the use of artificial light inevitable.

The building material used in Silverbird are not efficient as other insulated with high termal mass. Thermal insulation in buildings is an important factor to achieving thermal comfort for its occupants. Insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling systems. Thermally massive materials absorb heat and slowly release it when there is a temperature deference between the mass and the surrounding space. The materials used in the mall can be found in the local markets.

Silverbird it is not surrounded with natural shadings like trees or other natural features. This therefore leads to direct incident solar radiation reaching the building surface without any form of obstruction. This lead to high internal temperature of the building.

4.6 Comparative assessment of the case studies

The figure 4.12 below show the Assessment of performance efficiency of the three shopping malls conducted with the checklist; to investigate the level at which the factors that determines the choice of building form to achieve energy efficiency was considered in the choice of building form for existing shopping malls with consideration to the design requirements needed to provide energy efficiency based on variables identified from the literature review.

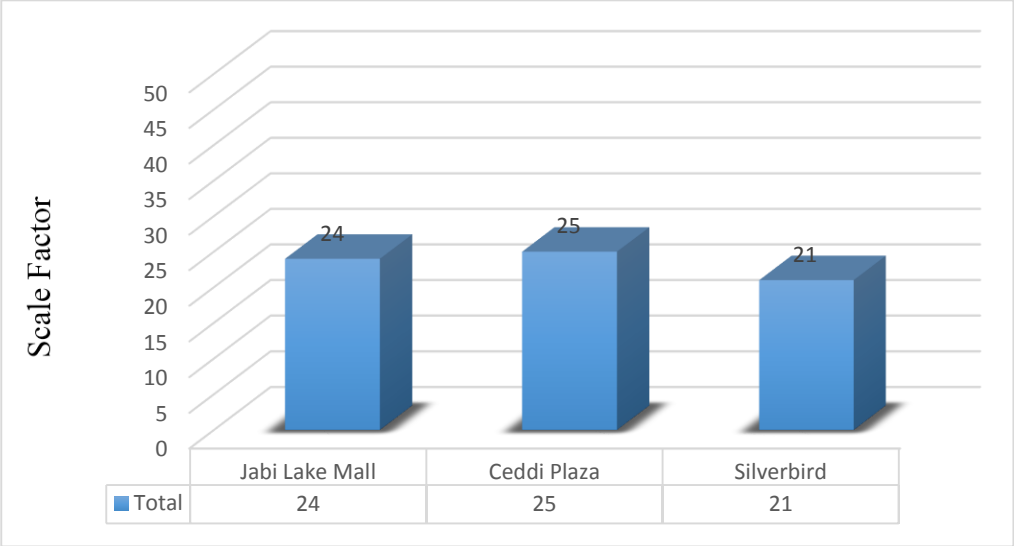


Figure 4.12: Assessment of performance efficiency of the three shopping malls

Source: Author (2016)

The basis for the comparison of the three cases studies is that, they are all shopping malls and they also represent the current design trend in Nigeria shopping malls; they are also located within the same climatic region; same operation hours and their buildings forms are the most commonly used forms in the building industry. The design considerations were greatly considered in Ceddi plaza, followed by the Jabi Lake mall and lastly that of Silverbird.

i. From the local case studies, it is observed that from all the cases the window to wall ratio is less than 60% and based on the literature review it is the recommended percentage for efficient buildings.

ii. The floor-to-floor height of the buildings varies between 3 to 4-meters high.

iii. Use of top and side light for daylight strategies

iv. The material finishes of the buildings are mostly brighter colour, light finishes reflect the heat into the atmosphere and has good reflectance of light.

v. Use of horizontal and vertical shading device strategies

vi. Use of commonly used building material concrete, steel and glass.

vii. The glazing use are both tinted and clear glasses.

viii. Smart use of hard and soft landscape on the site plan.

ix. Use of mostly rectangular building form.

4.7 Simulation of the case study (Silverbird)

As stated earlier, from the information given by the management of Silverbird about ₦15,000,000 to ₦20,000,000 million Naira is spent annually on electricity including diesel for the generators. Based on the current electricity tariffs electricity by the Abuja Electricity Distribution Company (AEDC), the tariffs are about ₦13.91 per kilowatt-hour (Kwh), the calculation shows that the electricity consumption is about 1,080,000 to 1,450,000 kWh/Year.

First case: the building is model using Autodesk revit 2014 and was exported in Autodesk Ecotect Analysis 2011. It is simulated as it is with its existing construction materials as shown in table 4.4 and orientation (315° from North). as shown in figure 4.13 to validate the findings from the case study base on its annual energy consumption. The simulation result indicated that the total annual cooling is about 1,483,362.128 kWh/Year.

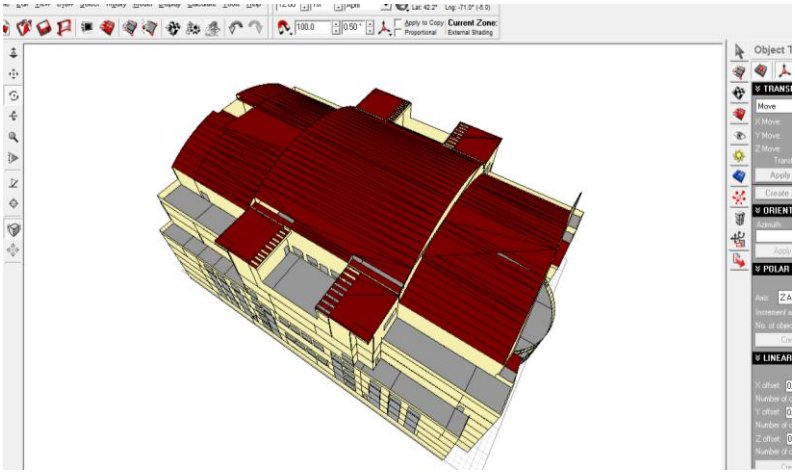


Figure 4.13: Existing building (first case) simulated as it is

Source: Author (2016)

Table 4.4: Detail of the Building materials used for the existing building as it is

Building envelope Details	Description	Thickness (mm)	U-Value (W/m² °C)	Colours	Solar absorption
Floor	Concrete floor	150	2.90	Brown (reflectance 0.65)	0.414
Wall	Hollow Sandcrete block	230	3.11	Butter colour (reflectance 0.72)	0.301
Roof	Corrugated roofing sheet	0.75	7.14	Red colour (reflectance 0.62)	0.439
Ceiling	plasterboard	10	4.32	Milk (reflectance 0.70)	0.365
Window	Single-tinted Glazed reflective	-	5	35% of visible light transmitted VT= 0.35	78% of soar heat transmited SHGC=0.78

Source Author (2016)

Second case: The same existing building is modelled and simulated with the independent variables that are important in the choice of building form for affecting energy efficiency was considered in the existing case as the proper orientation, shading devices, glazing material, and colour of finishes as shown in table 4.5 which were gotten from the litterature were applied on the second model as shown in figure 4.14. The simulation is carried out in 8 eight different orientation to select the orientation with the lowest annual

energy. The results were observed and recorded with comparisme of the first model to validate the findings from the case study. The simulation result indicated that the total annual energy consumption is about 1,381,045.504 kWh/Year.

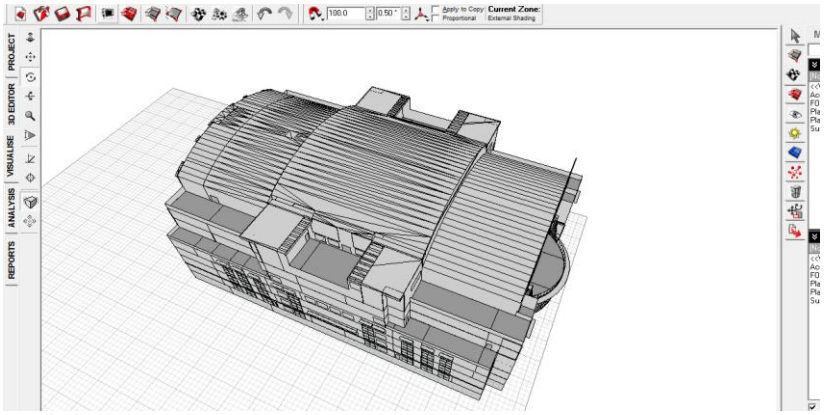


Figure 4.14: Second case simulated with the application of some variables

Source: Author (2016)

Table 4.5: Detail of material used for the existing building (second model)

Building envelope Details	Description	Thickness (mm)	U-Value (W/m² °C)	Colours	Solar absorption
Floor	Concrete floor	150	2.90	White (reflectance 0.80)	0.276
Wall	Hollow Sandcrete block	230	3.11	White (reflectance 0.80)	0.276
Roof	Corrugated roofing sheet	0.75	7.14	Grey colour (reflectance 0.75)	0.364
Ceiling	plasterboard	10	4.32	Milk (reflectance 0.70)	0.365
Window	Double-Glazed, Low-solar-gain Low-E Glass with argon gas fill			72% of visible light transmitted VT= 0.72	26% of soar heat transmited SHGC=0.26

Source Author (2016)

4.7.1 Discussion of simulation from the case study (Silverbird) Finding

First model: From the simulation, the total annual energy for the existing building required for heating is 0 kW and the total annual cooling is about 1,483,362.128 kWh/Year as shown in table 4.6. It is almost the same as the amount of the total energy

consumption gotten from the case study (1,080,000 to 1,450,000 kWh/Year) which validate the result of the simulation.

Table 4.6: Result of monthly energy load of the first model building as it is

	HEATING	COOLING	TOTAL
MONTH	(kWh)	(kWh)	(kWh)
Jan	0	143086.528	143086.528
Feb	0	152122.768	152122.768
Mar	0	181119.512	181119.512
Apr	0	147509.872	147509.872
May	0	130792.944	130792.944
Jun	0	99047.288	99047.288
Jul	0	92517.976	92517.976
Aug	0	86940.344	86940.344
Sep	0	79166.568	79166.568
Oct	0	115041.352	115041.352
Nov	0	125861.216	125861.216
Dec	0	130155.856	130155.856
TOTAL	0	1483362.128	1483362.128
PER M²	0	75.472	75.472
Floor Area:	19654.496 m2		

Source: Author (2016)

From the result, the three hottest months are the ones with high-energy demand and March has the pick of about 181,119.512 kWh. The lowest monthly energy demand is recorded in September with 79,166.568 kWh as shown in the Figure 4.15 below.

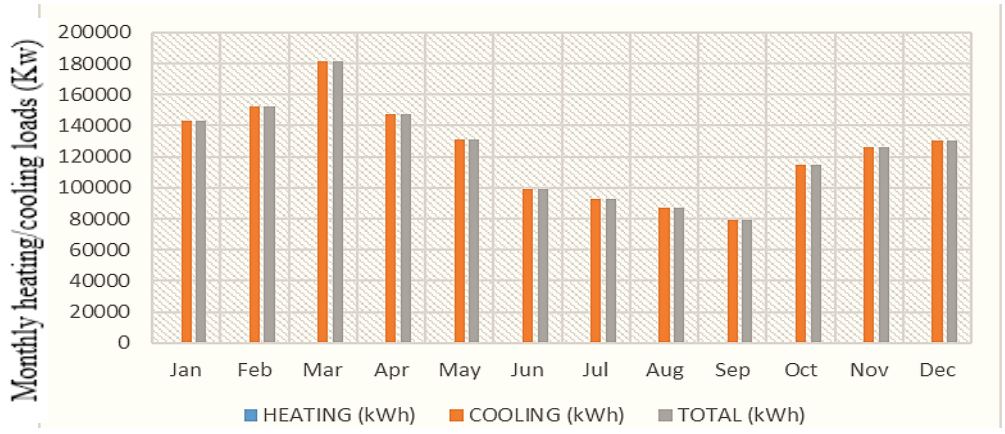


Figure 4.15: Monthly heating/cooling loads of the first model

Source: Author (2016)

Second model: The orientation with the lowest annual energy demand is the 0 ° degree from North (1,381,045.504 kWh/Year) as shown in the figure 4.16 below. the value is compared with the first model. The total annual energy required for heating is 0 kWh and the total annual energy required for cooling for second model building is about 1,381,045.504 kWh/Year as shown in table 4.7 which is 102,316.624 kWh/Year lower than the first model.

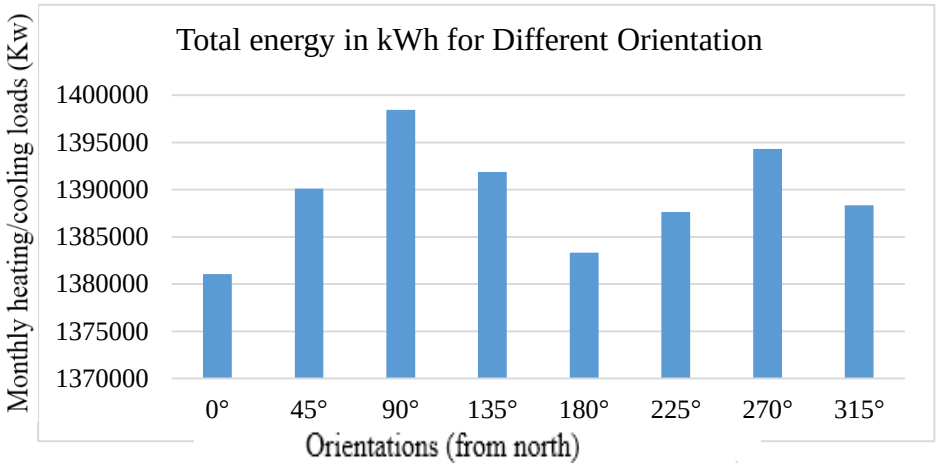


Figure 4.16: Orientation with lowest energy demand of the second model

Source: Author (2016)

Table 4.7: Result of monthly and annual energy load of the second model building

	HEATING	COOLING	TOTAL
MONTH	(kWh)	(kWh)	(kWh)
Jan	0	134110.168	134110.168
Feb	0	138666.768	138666.768
Mar	0	162018.144	162018.144
Apr	0	133465.296	133465.296
May	0	120341.392	120341.392
Jun	0	93742.424	93742.424
Jul	0	88826.52	88826.52
Aug	0	83703.504	83703.504
Sep	0	76676.984	76676.984
Oct	0	107871.856	107871.856
Nov	0	118563.208	118563.208
Dec	0	123059.384	123059.384
TOTAL	0	1381045.504	1381045.504
PER M²	0	70.266	70.266
Floor Area:	19654.4976 m2		

Source: Author (2016)

From the result of the second model, the three hottest months are the ones with high-energy demand and March has the pick of about 162018.144 kWh. The lowest monthly energy demand is recorded in September with 76676.984 kWh as shown in the Figure 4.17 below.

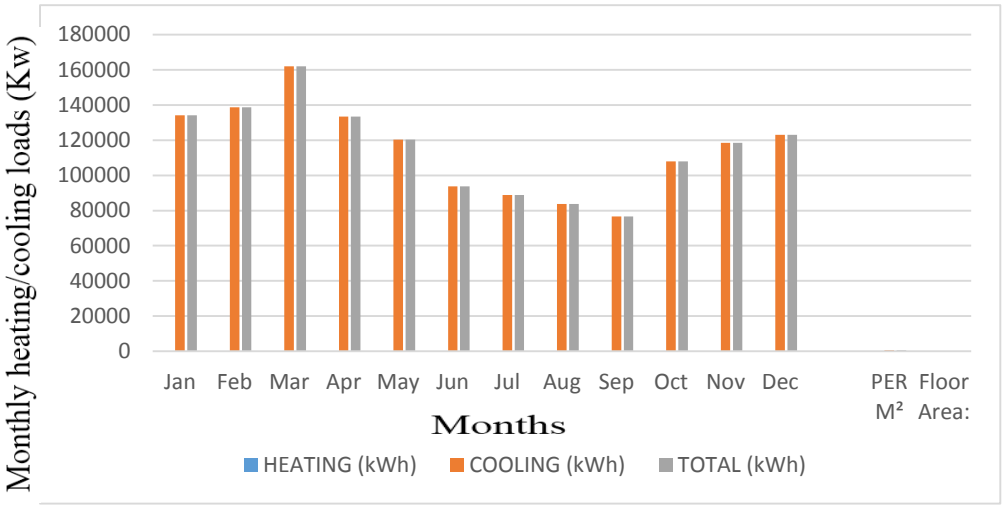


Figure 4.17: Monthly heating/cooling loads of the second model

Source: Author (2016)

4.7.2 Comparison of the two cases simulated

From the two cases simulated the first case is simulated as it is with its existing construction materials, shading, finishes and orientation (315° from North), the simulation result indicated that, the total annual energy consumption is about 1,483,362.128 kWh/Year, while in the second case, the annual energy consumption is about 1,381,045.504 kWh/Year which is 102,316.624 kWh/Year lower than the existing building (first case model).

Finally, it is concluded that the factors that determines the choice of building forms to achieve energy efficiency as the Orientation, shading devices, glazing material, and colour of finishes that were applied on silverbird building have reduced the annual energy consumption by 7.41% which can save about ₦ 1,422,201.0736 annualy and in 20 twenty years time that is about ₦ 28,444,021.472 that can be invested in a different business and for a comercial building that is a lot of money.

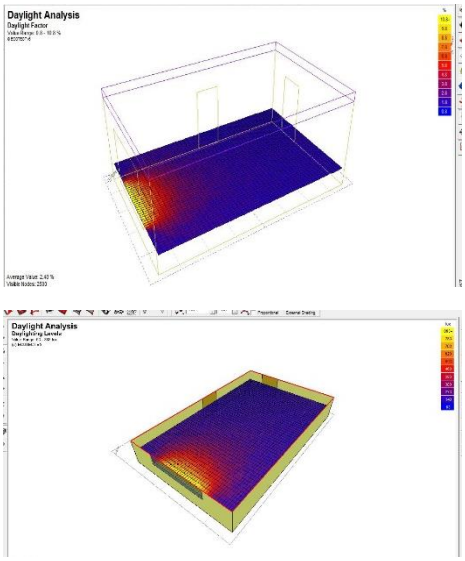
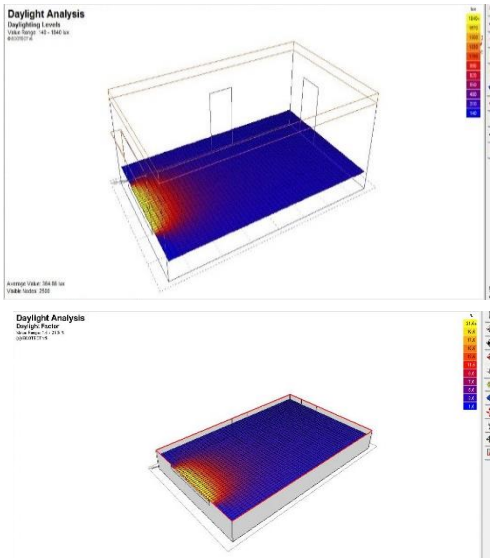
4.7.3 Simulation of two cases for the illumination level

The simulation is carried out with Ecotect analysis software, using with these settings: 1st April at 12:00 in Abuja with a design sky illuminance of 8500lux. To perform an effective analysis; a single room is selected for the simulation. The room selected is the waiting room in the management area and the simulation was done in two phases:

First, the room is simulated as it is with its existing construction materials finishes and orientation (315° from North) to check the range of illumination level and the average value of the light level in the building.

Secondly, the room is simulated again with some independent variables of the factors that determines the choice of building forms for achieving energy efficiency like the orientation, shading system, glazing material, and colour of finishes which were gotten from the litterature were applied on the second case to check the range of illumination level and the average value of the light level in the new case as shown in table 4.8 below.

Table 4.8: Evaluation for the two cases simulated for illumination level

Evaluation of the two model for their effective daylight	
Existing building (First case)	Base line model (Second case)
Daylight Factor	**Daylight Factor**
Value range: 0.8 – 10.8%	Value range: 1.5 – 21.5%
With an average value of 2.48%	With an average value of 4.29%
Daylight levels	**Daylight levels**
Value range: 63 - 863 lux.	Value range: 140 – 1840 lux.
With an average value of 210.51 lux.	With an average value of 364.86 lux.
	

Source: Author (2016)

4.7.4 Discussion Simulation of two cases for the illumination level

Finally, it is established that the factor affecting energy efficiency in the choice of building form like the Orientation, shading devices, glazing material, and colour of finishes if they are well applied on a building will optimize the daylight level in the interior space of a building. From the literature, the mininum light level in all conners required for a commercial buiding should be 100 lux in a waiting area. So, for the two cases simulated, the minimum lux level recorded for the existing waitng area (first case) is 63 lux while the the minimum lux level recorded for the second case is 140 lux. So

based on the analysis, of the waiting area for silverbird its was noticed that the daylight level have increased by 73%.

4.8 Simulations of the different building forms for energy load

The forms have the following details in table 4.9:

Table 4.9: Details of building forms involved in the study

S/N	Building form	Floor Area	Floor Height	Volume	Wall area
1	Cuboid form	869m^2	4.5m	3910.5 m^2	761.4m^2
2	L Shape	869m^2	4.5m	3910.5 m^2	763.2m^2
3	U Shape	869m^2	4.5m	3910.5 m^2	763.2m^2
4	T Shape	869m^2	4.5m	3910.5 m^2	609.35m^2
5	Cubic form	869m^2	4.5m	3910.5 m^2	639.5m^2
6	Cylindrical form	869m^2	4.5m	3910.5 m^2	569.2m^2
7	Triangular shape	869m^2	4.5m	3910.5 m^2	737.928m^2

Source: Author (2016)

4.8.1.1 L Shape simulation

The L Shape is simulated in different positions and the result has shown that the lowest annual cooling load is the South-West orientation 225° from North; with an annual cooling load of 97,549.891 kWh/Year as shown in figure 4.18. There is no any Heating load and the maximum Cooling 39.541 kW at 16:00 on 17th March with the highest load in March 10,142.868 kWh and the lowest in September 6,530.794 kWh as shown in the figure 4.19 below.

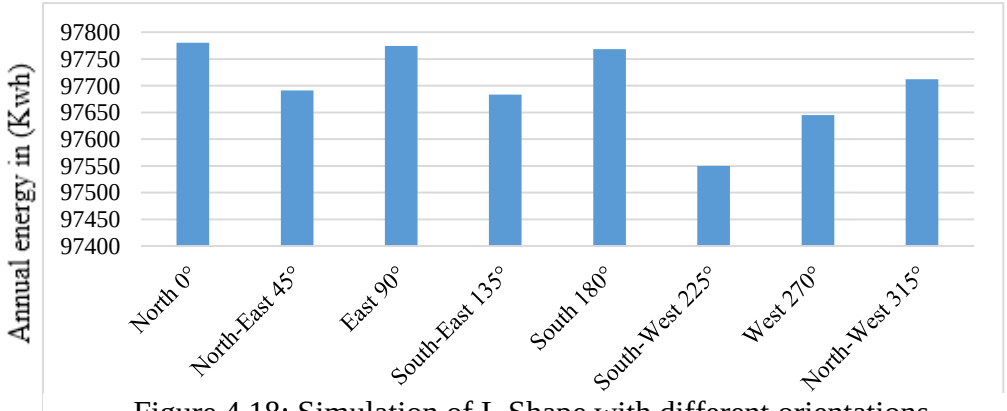


Figure 4.18: Simulation of L Shape with different orientations

Source: Author (2016)

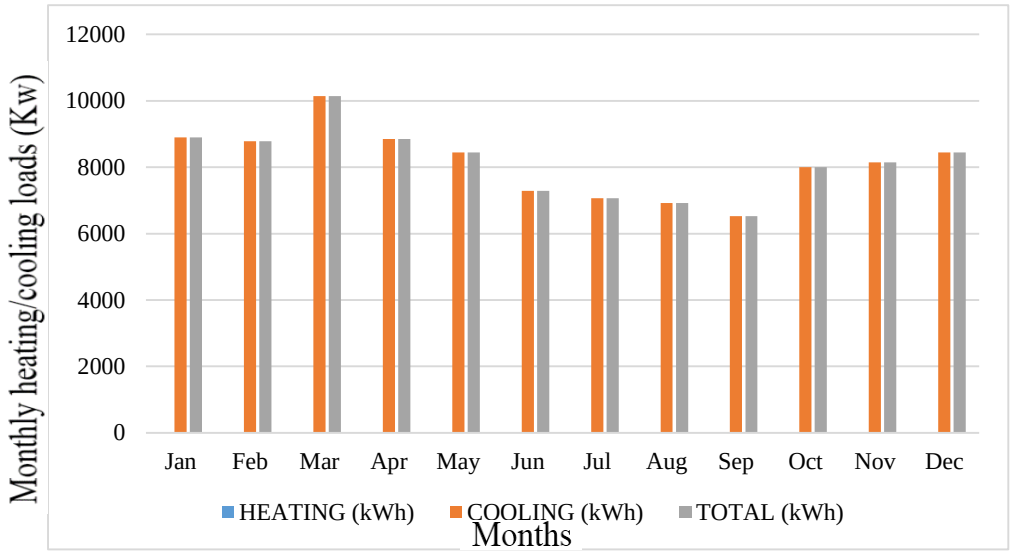


Figure 4.19: Monthly heating/cooling loads for L Shape

Source: Author (2016)

4.8.1.2 T Shape simulation

The T Shape is also simulated in different positions and the result has shown that the lowest annual cooling load is the North orientation 0° from north, with an annual cooling load of 94,663.359 kWh/Year as shown in figure 4.20. There is no Heating load and the maximum Cooling is 38.124 kW at 16:00 on 22nd February with the highest load in March 9,675.469 kWh and the lowest in September 6,284.425 kWh as shown in the figure 4.21 below.

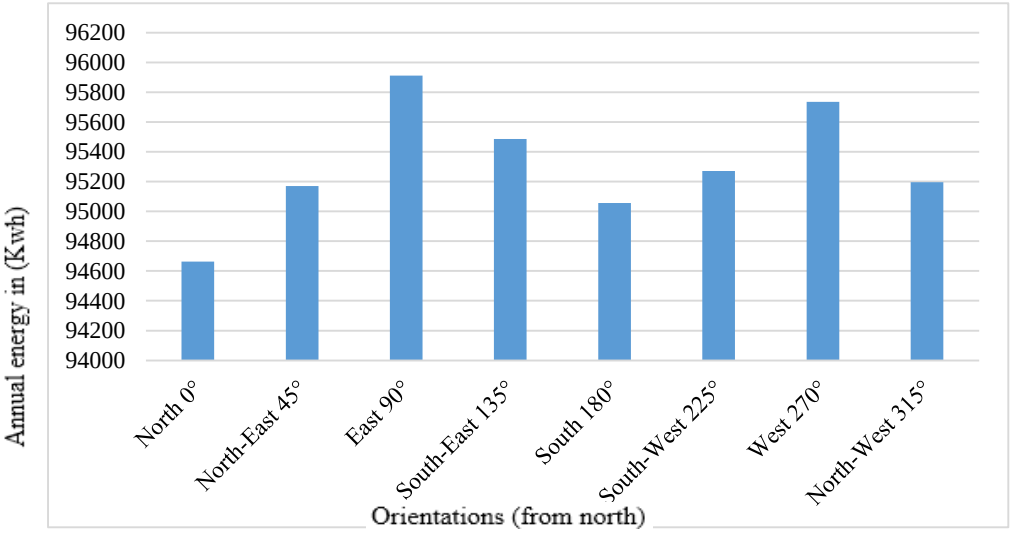


Figure 4.20: Simulation of T Shape with different orientations

Source: Author (2016)

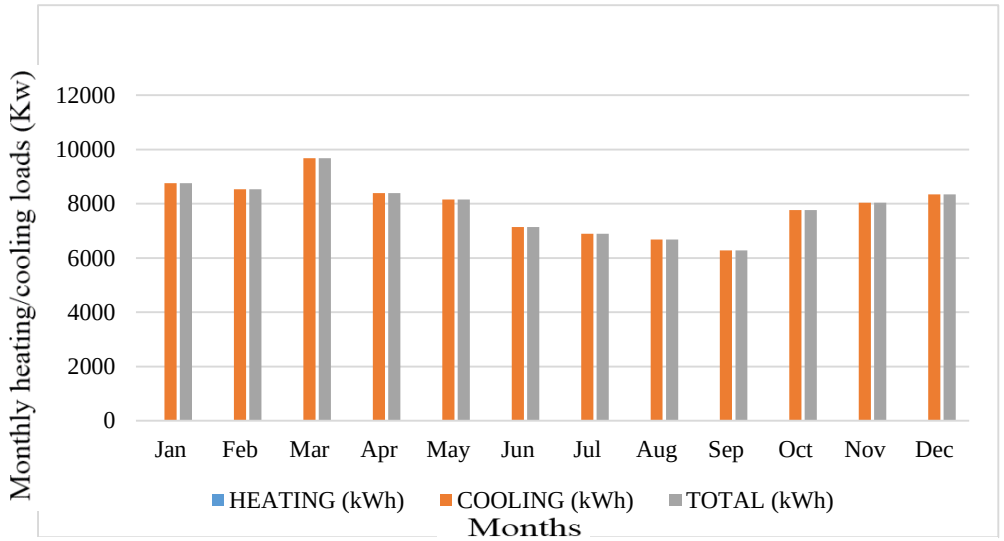


Figure 4.21: Monthly heating/cooling loads for T Shape

Source: Author (2016)

4.8.1.3 U Shape simulation

The U Shape is simulated in different positions also and the result has shown that the lowest annual cooling load is the East orientation 90° from the North with an annual cooling load of 93,616 kWh/Year as shown in figure 4.22 below. There is no Heating load and the maximum Cooling load is 38.863 kW at 16:00 on 22nd February with the highest load in March 9,661.636 kWh and the lowest in September 6,075.781 kWh as shown in the figure 4.23 below.

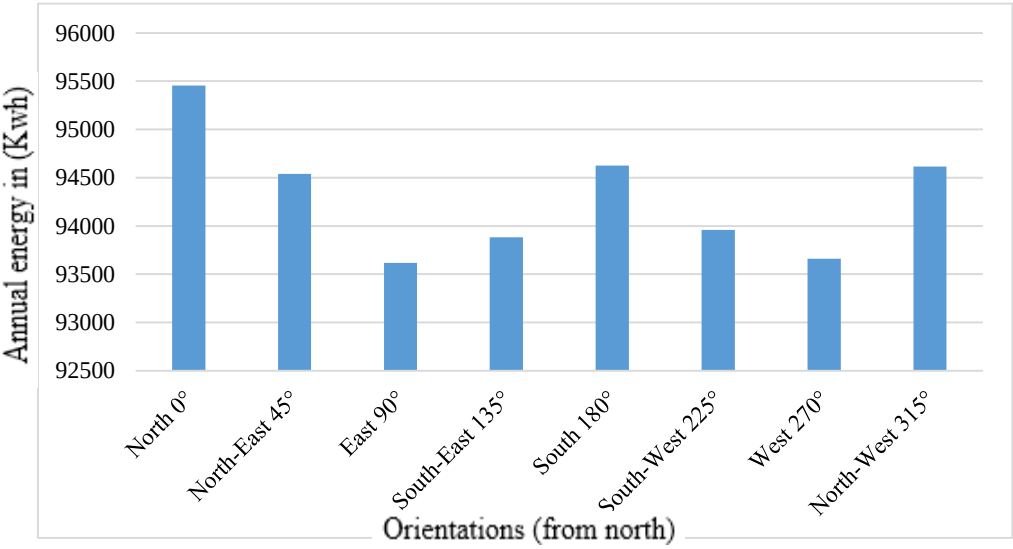


Figure 4.22: Simulation of U Shape in different positions

Source: Author (2016)

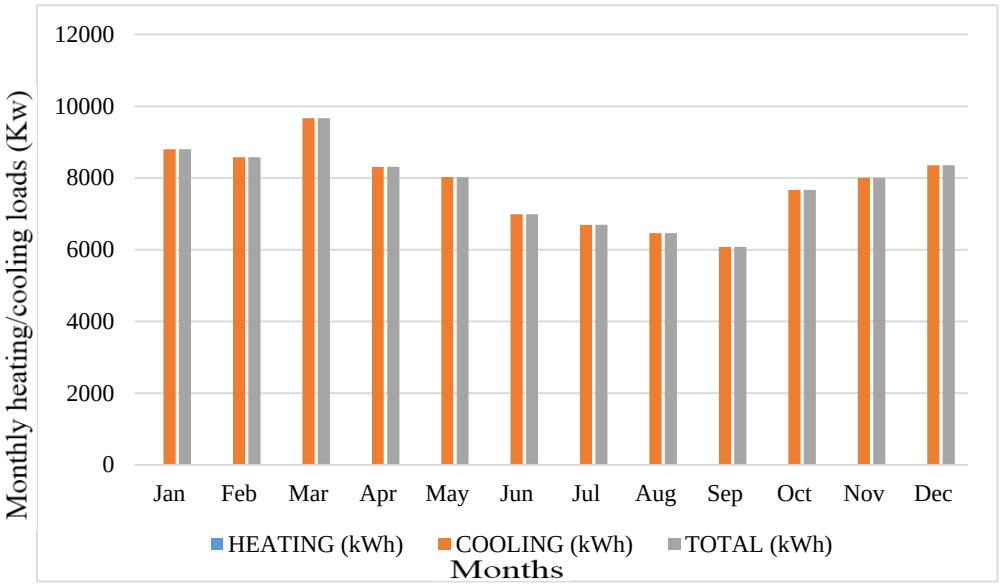


Figure 4.23: Monthly heating/cooling loads for U Shape

Source: Author (2016)

4.8.1.4 Cuboid form

The Cuboid form is simulated in different positions and the result has shown that the lowest annual cooling load is the North-south orientation 270° from north; the longer axis is facing North-South with an annual cooling load of 96,703.875 kWh/Year as shown in figure 4.24. There is no Heating load and the maximum Cooling is 38.705 kWh at 16:00 on 22nd February with the highest load in March 9,764.404 kWh and the lowest in September 6,340.876 kWh as shown in the figure 4.25 below.

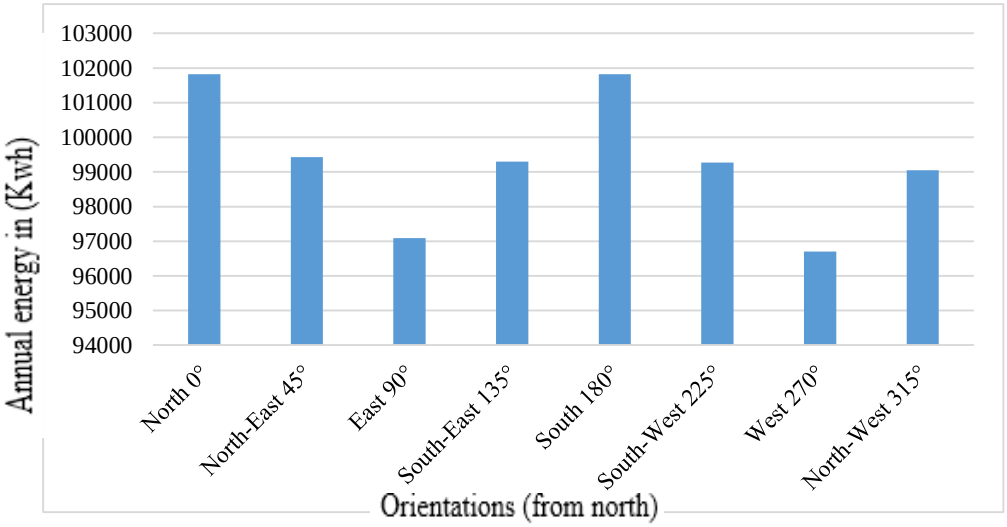


Figure 4.24: Simulation of cuboid form in different positions

Source: Author (2016)

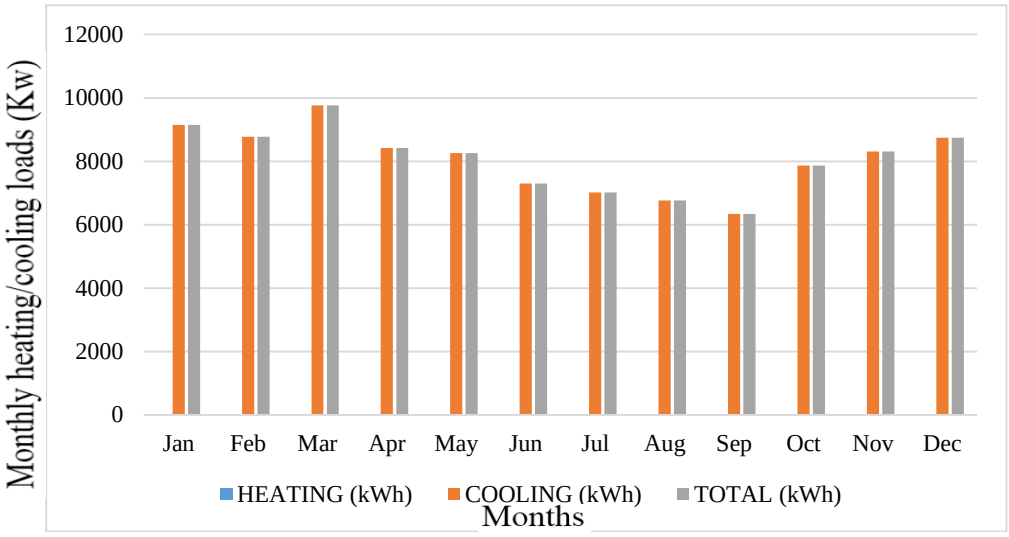


Figure 4.25: Monthly heating/cooling loads for the cuboid form

Source: Author (2016)

4.8.1.5 Cubic form

The Cubic form is simulated in two different positions because of its square shape in nature same dimension in all the side. The result has shown the lowest annual cooling load is the North orientation 0° from north, with an annual cooling load of 85,335.352 kW/Year as shown in figure 4.26 below. There is no Heating load and the maximum Cooling 32.657 kW at 16:00 on 22nd February with the highest load in March 8,646.765 kWh and the lowest in September 5,752.22 kWh as shown in the figure 4.27 below.

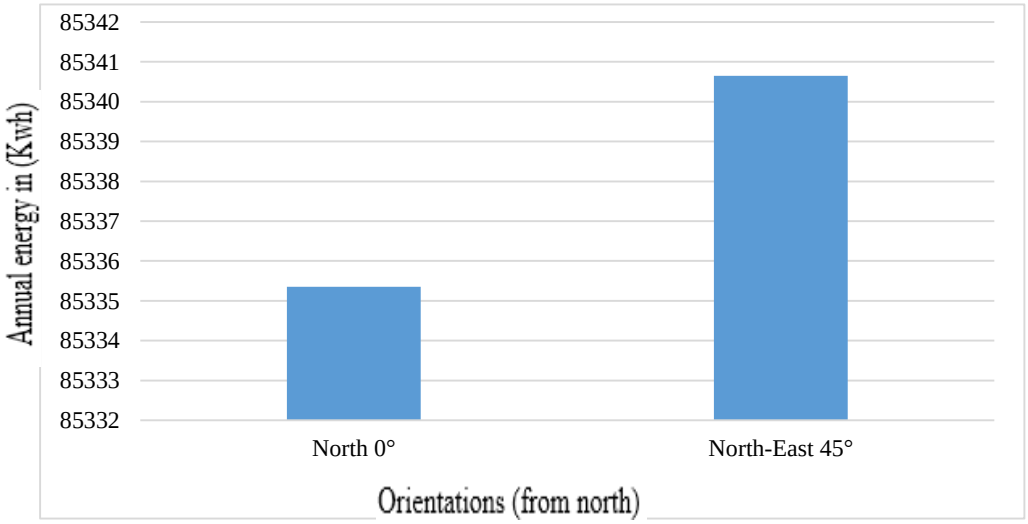


Figure 4.26: Simulation of Cubic form in different positions

Source: Author (2016)

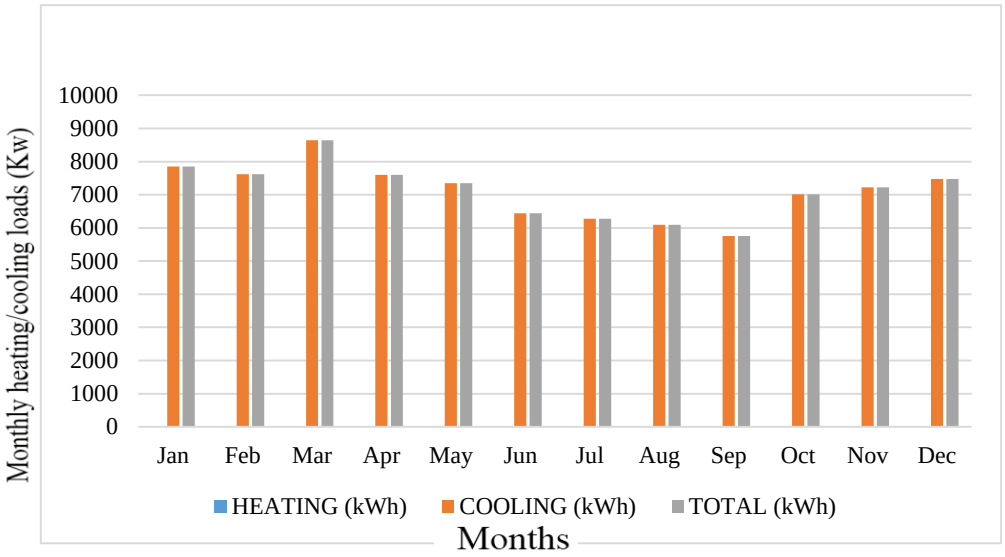


Figure 4.27: Monthly heating/cooling loads for the Cubic form

Source: Author (2016)

4.8.1.6 Cylindrical form

The Cylindrical form is simulated in one positions because of its circular shape in nature and the result has shown that the Cylindrical form have an annual cooling load of 75,345.039 kWh/Year. There is no Heating load and the maximum Cooling 49.685 kW at 16:00 on 22nd February with the highest load in March 10,403.593 kWh and the lowest in September 2,137.861 kWh as shown in the figure 4.28.

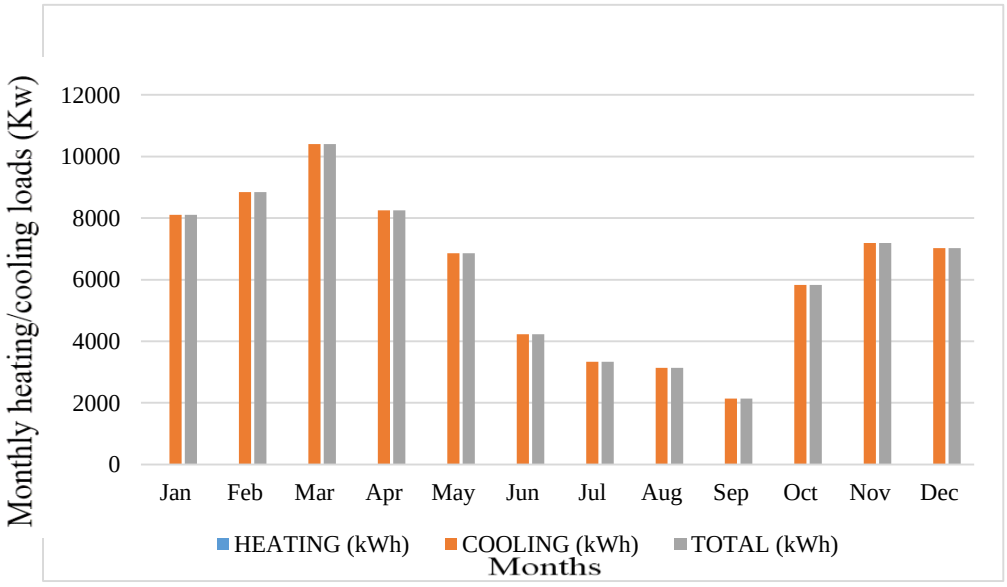


Figure 4.28: Monthly heating/cooling loads for the Cylindrical form

Source: Author (2016)

4.8.1.7 Triangle shape

The Triangular shape is simulated in two positions because of its an isosceles triangle (three equal sides); and the result has shown the lowest annual cooling load is the North-East orientation 45° away from north; with an annual cooling load of 108,753.844 kWh/Year as shown in figure 4.29 below. The maximum Cooling 39.665 kW at 13:00 on 22nd February with the highest load in March 10,859.134 kWh and the lowest in September 7,590.752 kWh as shown in the figure 4.30.

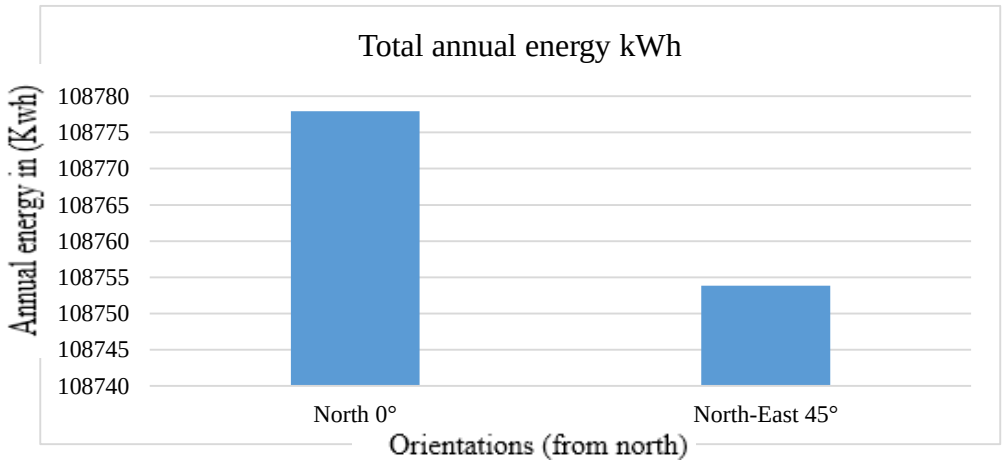


Figure 4.29: Simulation of Triangular shape in different positions

Source: Author (2016)

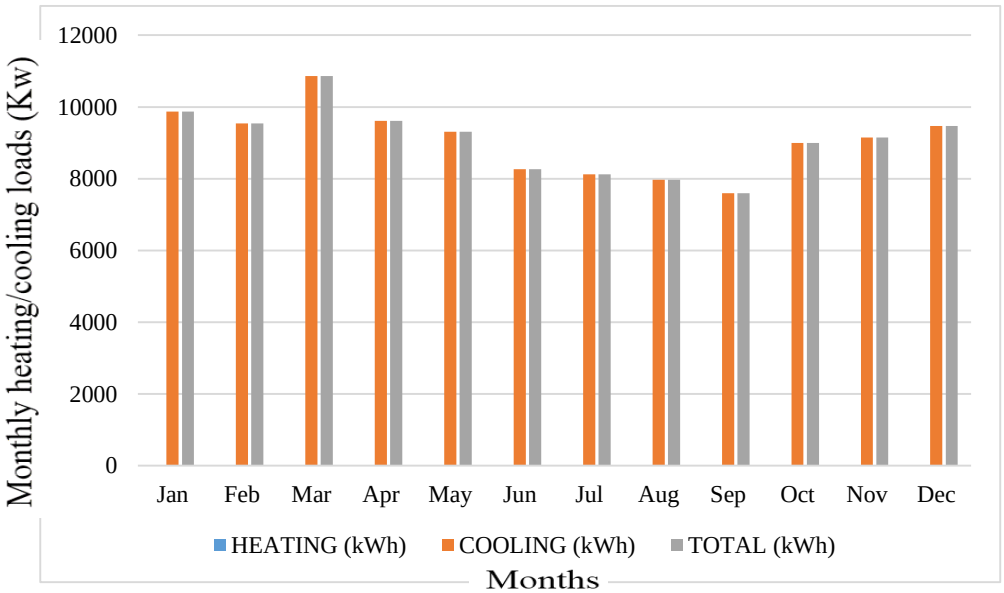


Figure 4.30: Monthly heating/cooling loads for the isosceles triangle shape

Source: Author (2016)

4.8.2 Discussion of Finding from the building forms simulated

After the simulations, it was observed that the cylindrical form has the lowest annual energy consumption as shown in Figures 4.31 below. The second observation is that throughout the year all the forms involved in the study do not required heating at any time of the year and this is because of the geographical location and climatic of Abuja which is a composite climate (hot humid and hot dry climate). The monthly energy consumption of each forms has shown that the highest consumption load is always in March. However, in the other hand, the lowest energy consumption is recorded in September for all the building forms. Finally, it is established that:

i. In a composite climate (Hot humid and hot dry climate), a cylindrical form will save more energy compared to an L Shape; T Shape, U Shape, cuboid form, Cubic form and the triangular shape.
ii. Cylindrical form will save 29.47% of the total annual energy consumption compared with an L Shape.
iii. Cylindrical form will save 25.64% of the total annual energy consumption compared with a T Shape.
iv. Cylindrical form will save 24.25% of the total annual energy consumption compared with a U Shape.
v. Cylindrical form will save 28.35% of the total annual energy consumption compared with a cuboid form.
vi. Cylindrical form will save 13.26% of the total annual energy consumption compared with a cubic form.
vii. Cylindrical form will save 44.34% of the total annual energy consumption compared with a triangular shape.

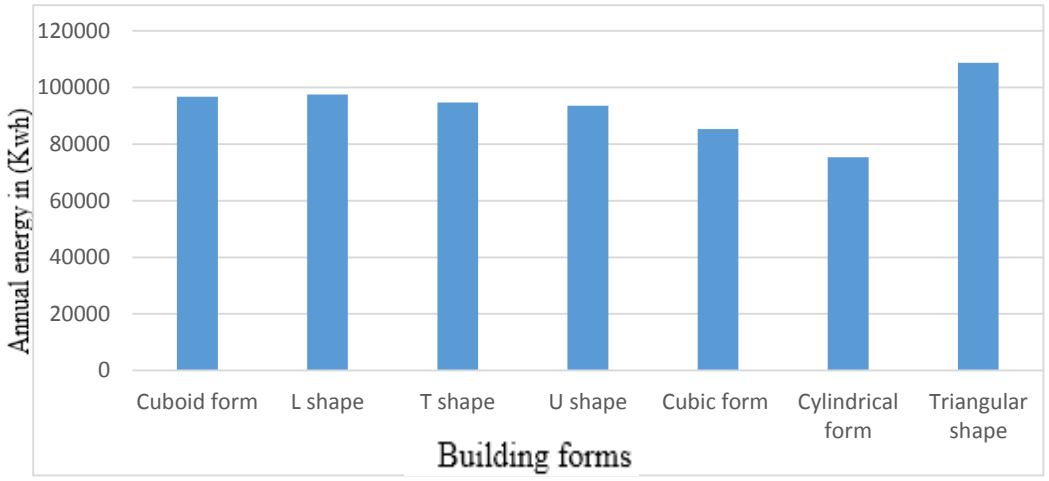


Figure 4.31: Assessment of the building forms simulated

Source: Author (2016)

4.9 Simulations of the building forms for the illumination level

The same building forms simulated for their annual cooling and heating load above were also simulated for their illumination level to access which building form at this point has the highest amount of daylight level in it interior space. The simulation was carried out on 1st April at 12:00 pm in Abuja with a design illuminance of 8500 lux. The building forms used are the same forms simulated for the cooling and heating load with the same material properties in table 4.10.

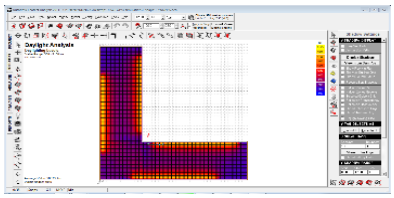
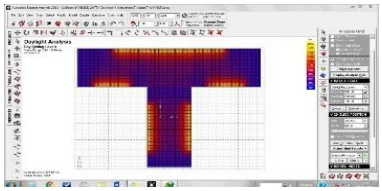
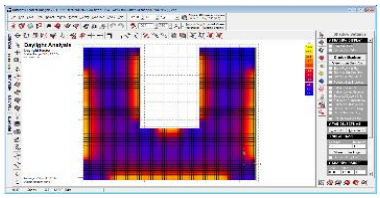
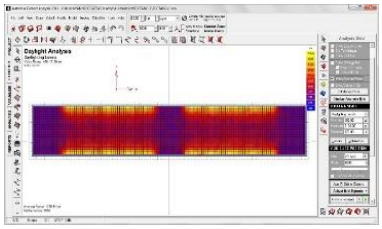
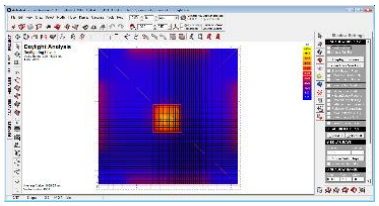
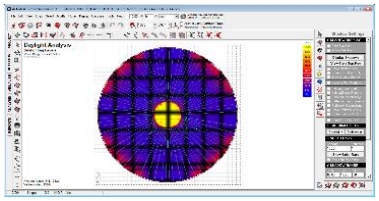
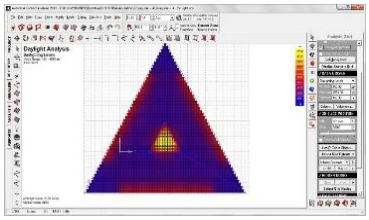
Table 4.10: Materials properties of the building forms

Building envelope Details	Description	Thickness (mm)	Colours	Solar absorption
Floor	Concrete floor	150	White (reflectance 0.80)	0.276
Wall	Hollow Sandcrete block	230	White (reflectance 0.80)	0.276
Roof	Corrugated roofing sheet	0.75	Grey colour (reflectance 0.75)	0.364
Ceiling	plasterboard	10	Milk (reflectance 0.70)	0.365

Source: Author (2016)

The simulation result is shown in table 4.11 below.

Table 4.11: Simulation result for illumination of the seven different building forms

Daylight level (lux)				
	Building forms	Minimum Value range (lux)	Maximum Value range (lux)	Average value (lux)
1-L Shape		350	2150	983.27
2-T Shape		280	2080	825.08
3-U Shape		480	2080	961.14
4-Cuboid form		400	2100	1120.84
5-Cubic form		320	6320	1058.65
6-Cylindrical form		72	4772	946.10
7-Triangular shape		150	4550	1029.73

Source: Author (2016)

4.9.1 Findings from the simulation for the illumination level

From the simulation, the first observation was that, the building forms having the highest number of minimum value range of lux are the linear forms (L Shape, T Shape, U Shape and the cuboid form); this is due to their narrow shapes in nature. While the Cubic form, Cylindrical form, and Triangular shape in the other hand have more daylight at the atrium part, this lead us to conclude that top light system introduces more daylight compare to side light system as the result of the simulation shown in table 4.11 above. The second observation is that, among all the building forms involved for the assessment for illumination level, cuboid form is the most suitable for daylight design for the climate of Abuja because it has the highest average lux value compared to the others building forms.

4.10 Discussions of findings

From the results, it was noticed that under the same conditions, as same operation hours, Occupant's activity rate at 110w and 20m2 per occupant, location without a slope, building forms not shaded, comfort band between 20-25ºC and Heating, ventilation and air-conditioning (HVAC) is Mix mode system and same climatic condition as a typical shopping mall there are still some interesting findings.

First, the cylindrical form has the lowest cooling and heating load and this is because of its smallest surface exposure to the environment compared to the others building forms. The cuboid form has the highest illumination level compared to the others building forms; it is interesting to investigate the reason for this in the future work. However, since in this part of the world in commercial buildings cooling is the major issue not lighting, that is because a lot of money is actually spent on cooling than lighting as it was verified from the literature and from the case studies so, having a cylindrical building form will save more energy and money than the others building forms involved

in the research. Buildings having simple or uncomplicated form or shapes are typically more efficient than the buildings with complex or irregular shapes.

Secondly, the trend of diagrams between cooling demands of most of the forms are very small it could be almost negligible. However, these slight differences mean a lot of money when it is kept for a long period.

Thirdly, This Study has also shown that the factors affecting energy efficiency in the choice of building form such as, orientation, glazing material, shading system, and material finishes can help greatly in reducing the amount of cooling load while at the same time increasing the illumination level of a building.

These three elements: cooling, heating and lighting, as stated from the literature review they are the major source of energy consumption in a shopping mall regardless of the climate. The properties of building materials also have adverse effect on cooling, heating, daylight requirement of an interior space with respect to the climatic factors of the region; the colour of the wall, ceiling, window, floor and roof can also significantly improve the efficiency of the building.

Fourthly, From the three local case studies conducted, it is also noticed that the tenant attempt to modify the interior of the retail stores, the tenants tend to obstruct the inflow of lighting by using shelves to cover the windows provided and making use of more artificial light. In this case, the window meant to serve for lighting fails and only contributes to the heat gained in the interior space. It is therefore advised to reduce the large glazing and provide lighting by sustainable means that do not contribute to heat gain. The window to wall ratio of shopping mall building in a hot humid hot dry climate should be less than 60% for a more efficient building. Nevertheless, the orientation will depend on the type of building form and it location.

Efficient appliances can improve the energy efficiency of a building. This can be achieved by using renewable energy as well as energy saving appliances. Renewable energy such as solar energy is abundance in Abuja climate. Photovoltaic cells with the aid of an inverter can solely provide sufficient electricity for buildings thereby eliminating use of turbines and diesel engine generators used conventionally in Nigeria.

5.0 DESIGN PRELIMINARIES

5.1 Introduction

The chapter discusses the preliminary study on the design and it is arranged under the following headings: the brief; the study area; site location and selection; site analysis; and site implication on the proposed design.

5.1.1 Clients Brief

Silverbird Group aimed at building a new shopping mall that seek to empower young and growing business owners acquire shops contrary to the current trend of renting shops at a very expensive rate so, they decided to expand their business by providing an avenue for buying. The design should explore means of achieving sustainable design through the three pillars environmental, socio-cultural and economic sustainability. It should also abide by development regulation. This Shopping mall is to take advantage of the Abuja city especially the Abuja face two (II).

5.1.1.1 Design Research and Development of Design Brief

a. Shopping mall
b. Local planning considerations
c. Vehicular and pedestrian circulation
d. Parking requirements
e. Functional flow and relationships
f. Schedule of accommodation
g. Materials and structural considerations
h. Architectural expression
i. Services (water, electricity, waste disposal, fire safety etc.)
j. Site planning/landscaping/recreational facilities

5.1.1.2 Case Studies

a. Local case studies (Documented in chapter four)

b. Foreign case studies (Documented in chapter two)

5.1.1.3 Site Analysis and concept development

a. Site analysis

b. Determining the limitations and assets of the site

c. Record exiting vegetation

d. Take note of condition around the site and in the locality

e. Take note of the utilities

f. Record other noticeable features of the environment

5.1.1.4 Full Scale Presentation Drawing and 3Ds

a. Site plan

b. Floor plan

c. Roof plan

d. Minimum of 2 sections

e. Minimum of 4 elevations

f. Perspectives and model

g. Details

5.1.1.5 Working drawings

a. Complete working drawing

b. Details of unique/sustainable design features

c. Material specifications

5.2 The study area

The site for the proposed project is located in the Federal Capital Territory, which is centrally located, lying above the hot humid lowlands of Niger/Benue trough but below the hot dry parts of the savannah to the north. Abuja is located in the park savannah region of Nigeria Lying between latitudes 8°25" and 9°20' north of the equator and longitudes 6°45" and 7°30" east of the Greenwich meridian, Abuja is geographically located in the centre of the country.

The Federal Capital Territory has a landmass of approximately 7,315 km2 and it is situated within the Savannah region with moderate climatic conditions hot dry hot humid climate zone as it is shown in figure 5.1. It is bounded by Kaduna state to the north, Nassarawa state to the East and south east, Kogi state to the south west and Niger state to the west.

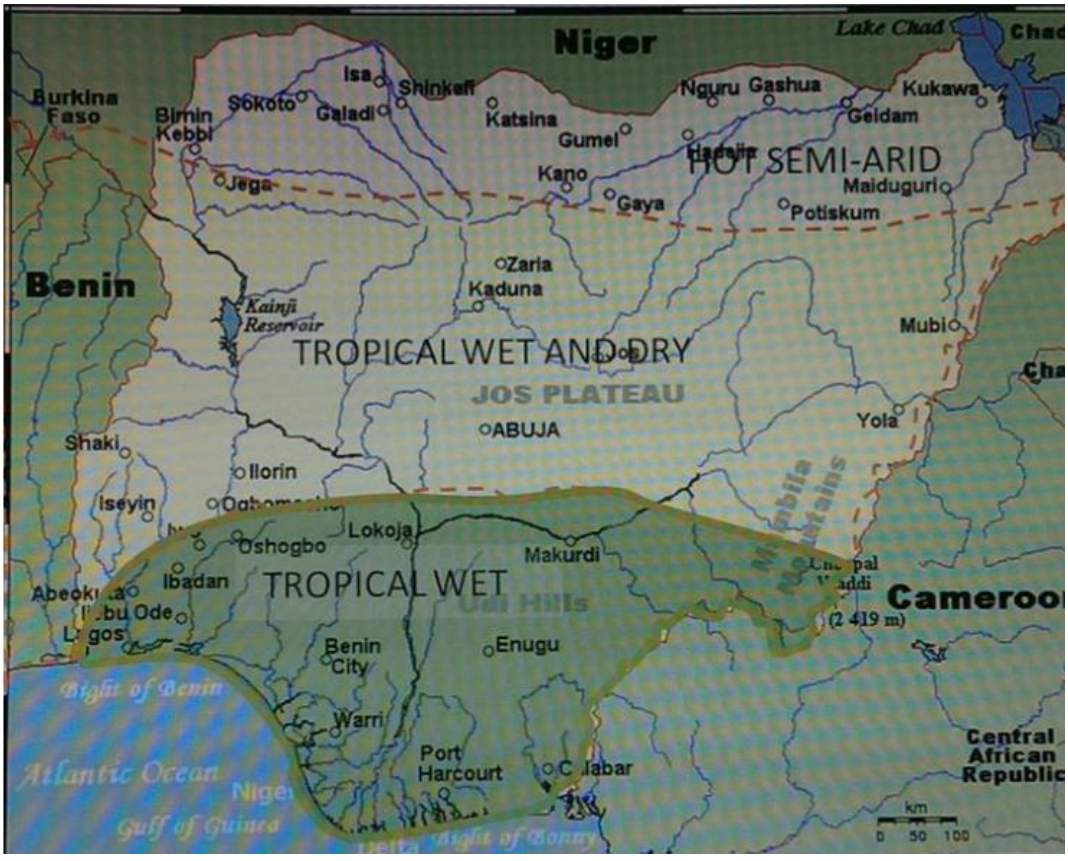


Figure 5.1: Map of Nigeria showing the Three Climate Zones

Source: Koppen-Trewatha-Horn classification scheme (2012)

5.2.1 Site selection criteria

Shopping malls are the new public space. The continuous sophistication of the city dwellers and the need for a comfortable space to shop and relax after work or a busy week is paramount with respect to time. The increase of population of an urban city will required additional residential, recreational area and commercial facilities. Therefore, Architects make decision in selecting site for new development; this decision affects which tenant will be interested in locating in the mall. In facts, the decision will basically determine the success or failure of the project.

Therefore, for the purpose of this study, five sites were chosen as shown in figure 5.2 below.



Figure 5.2: Location of the five-sites selected in Abuja

Source: Google earth (2016)

The list below are the criteria established by some researchers along with specific questions that were considered when evaluating the sites:

a. Closeness to Residential area.

b. Potential for expansion for future needs.

c. Compatible with current and probable future zoning regulations of FCT.

d. Commercial potential of surrounding area

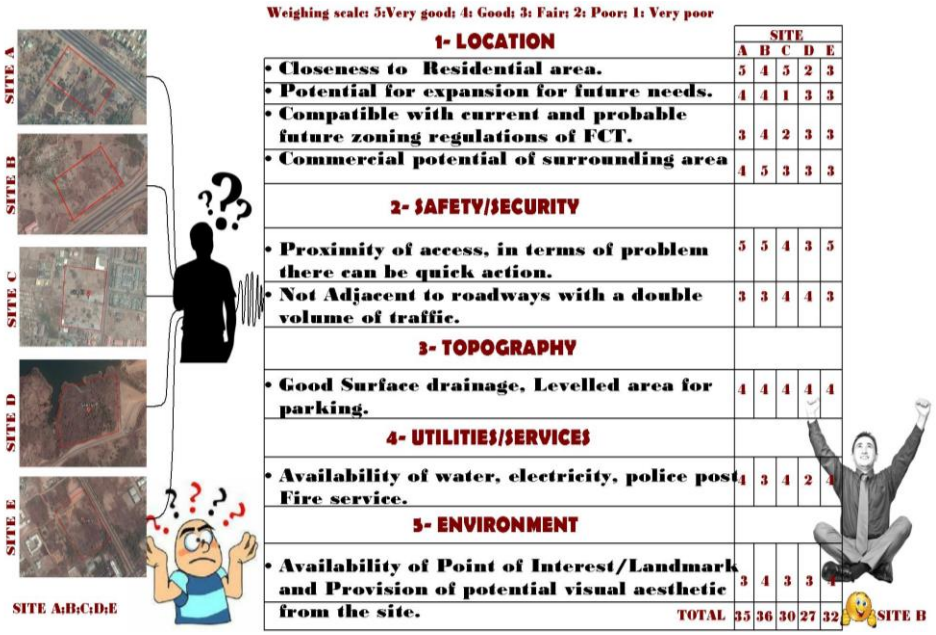
e. Proximity of access, in terms of problem there can be quick action.

f. Not Adjacent to roadways with a double volume of traffic.

g. Good Surface drainage, Levelled area for parking.

h. Availability of water, electricity, police post Fire service.

i. Availability of Point of Interest/Landmark and Provision of potential visual aesthetic from the site.



Weighing scale: 5:Very good; 4: Good; 3: Fair; 2: Poor; 1: Very poor

	SITE				
	A	B	C	D	E
1- LOCATION					
• Closeness to Residential area.	5	4	5	2	3
• Potential for expansion for future needs.	4	4	1	3	3
• Compatible with current and probable future zoning regulations of FCT.	3	4	2	3	3
• Commercial potential of surrounding area	4	5	3	3	3
2- SAFETY/SECURITY					
• Proximity of access, in terms of problem there can be quick action.	5	5	4	3	5
• Not Adjacent to roadways with a double volume of traffic.	3	3	4	4	3
3- TOPOGRAPHY					
• Good Surface drainage, Levelled area for parking.	4	4	4	4	4
4- UTILITIES/SERVICES					
• Availability of water, electricity, police post Fire service.	4	3	4	2	4
5- ENVIRONMENT					
• Availability of Point of Interest/Landmark and Provision of potential visual aesthetic from the site.	3	4	3	3	4
TOTAL	35	36	30	27	32

Figure 5.3: Showing the weighing scale for the site selection

Source: Author (2016)

Based on the above criteria and analysis the site B is most suitable and it is selected for the design.

5.2.2 The Proposed Site

The proposed site is located in Abuja phase II Area within the Federal Capital Territory, which still have a lot to be done based on infrastructures and facilities as shown in figure 5.4 below. The site is Along UMARU MUSA YAR'ADUA road; it is precisely located in between Handcraft Village Park and Wonderland Park just adjacent to Millipat Plaza. It has an area of 52960 m2 and a perimeter of 934 meter.



Figure 5.4: Selected Site for Proposed Design

Source: Google earth (2016)

5.2.3 Analysis of the proposed site

The site characteristics and analysis is based on the following factors and their associated to the basement complex geology of central Nigeria.

The site analysis is divided into three aspects:

1. Site analysis (climatic data)
2. Site analysis (services and topography)
3. Site analysis (surrounding views)

5.2.3.1 Site analysis (climatic data)

i. Vegetation

The site has few existing scattered randomly trees, shrubs and grass; but for a more efficient site design, proper landscape will be provided to enhance the site present condition.

ii. Noise

The main source of noise to the site come from the major road due to vehicular circulation. So, site zoning should be well considered for each of the facilities that is provided.

iii. Sun-set

Its occurs in the afternoon, sun rays may cause glare and heat gain for the users. Therefore, opening along this side should be minimized or well shaded with shading systems.

iv. Sun-rise

Its occurs around 6:30-7:30am. The early morning sun is pleasant and bright, good for lighting but shading will be used to prevent solar radiation into the building.

v. North-East Wind

It is between November and March it is cold dry and dusty. Window should be minimized on north-east side. Trees and shrubs should be used to filter the wind and serve as shield.

vi. South-West Wind

It is between April and October its brings rain and cool breeze. Good construction methods and materials specification will be applied in the shopping mall to resist any kind of wind.

vii. Temperature

The highest temperatures are recorded during the dry season 40 degree. And its minimum from November to January as low as 12 degrees.

viii. Relative Humidity

The relative humidity for the first quarter of the year is 25% average due to harmattan. The humidity increases during the rainy season up to 77% reaching its peak in august 84%.

ix. Rainfall

The rainfall data indicates that rainfalls in months of May to October with august having the peak fall. January to march are usually dry. Therefore, the exterior of the mall should be cover with efficient materials.

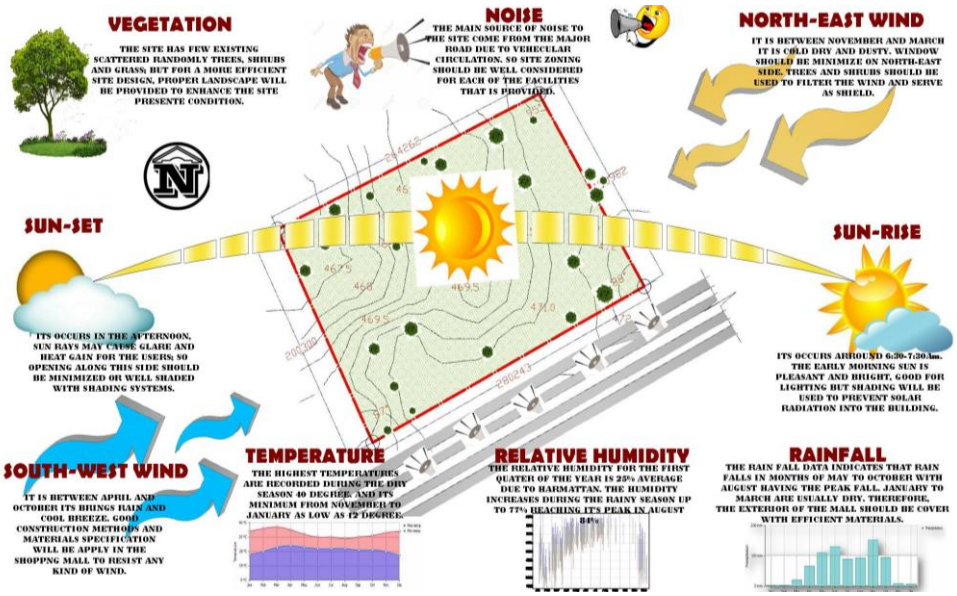


Figure 5.5: Site analysis climatic data

Source: Author (2016)

5.2.3.2 Site analysis (services and topography)

i. Water

The main source of water to the site is the water from the f.c.t water board or possibly of having a water tank located at the highest point of the site.

ii. Telecommunication

Mobile telecommunication mask is available not too far from the site. This indicates that there is good network strength in the site.

iii. Accessibility

There is only one access road to the site its can be safely accessible from the karmu road.

iv. Electricity

The major source of electricity to the site is from the Nigerian electricity regulatory company, (NERC) and it is distributed using high-tension cables passing in front of the site.

v. Sewage disposal

The sewer collection would be channelled towards the Eastern part of the site. To connect with central sewage collection points for easy collection and evacuation of solid waste from the site.

vi. Topography

The site is sloping gently toward the west. The site drainage will take the direction of the slope to utilize the force of natural gravity and ground gutters will be provided for a more effective water drainage. Water supply also will run from the highest point of the site to the lowest, to ease flow through gravity.

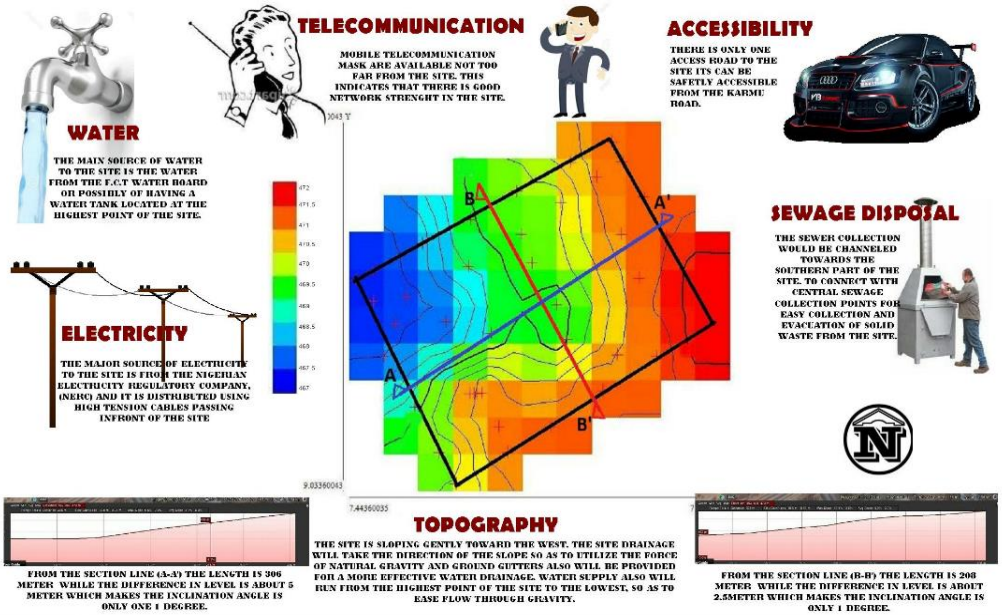


Figure 5.6: Site analysis services and topography

Source: Author (2016)

5.2.3.3 Site analysis (surrounding)

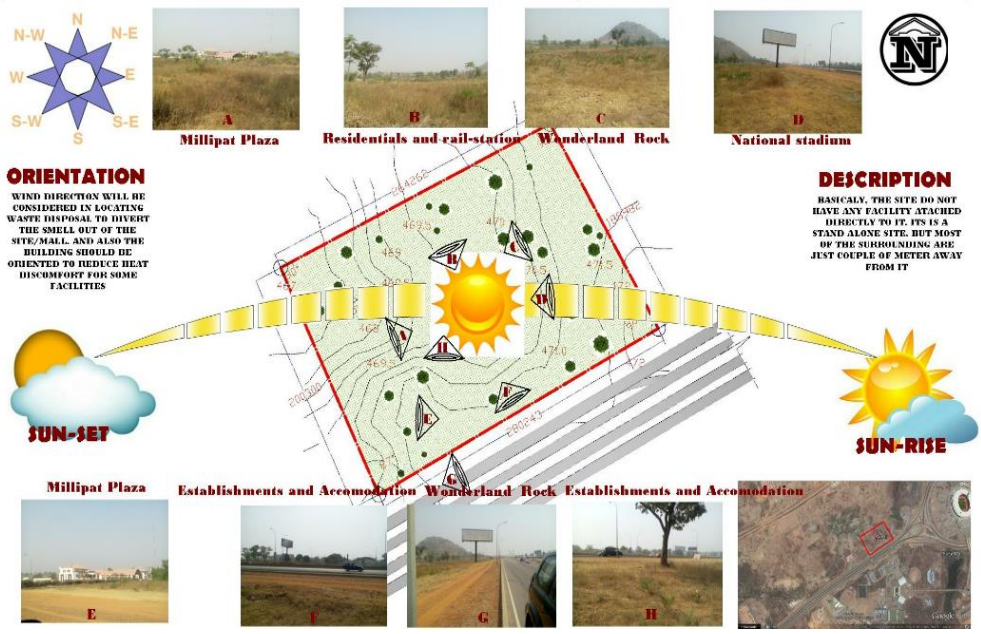


Figure 5.7: Site analysis surrounding

Source: Author (2016)

5.3 Site implications on design

Design parameter shall be drawn based on the effect of the above-analysed site and climate factors to see how best they can be utilized to achieve required effects on the final design proposal.

5.3.1 Site plan

The site plan aimed at integrating strategies that will minimise solar heat gain by creating various planting on the site. The trees around the building and within the site will provide adequate shading to the environment. This will create a microclimate that is favourable for the shopping mall.

5.3.2 Roofing

Based on the site analysis, the volume of rain in Abuja is quite reasonable but the winds are high. Therefore, roofs with relatively low pitch could be used or even flat roofs. However, parapet walls should be provided to prevent wind blowing off roofing

materials. In addition, roofing materials with reflective properties should be used reduce effect of solar radiation penetrating the building.

5.3.3 Foundation

The structural engineer will take care of the foundation design specification. However, the soil is relatively stable. However, attention should be paid to prevention of rising water as soil has high water retaining ability, especially after heavy rainfall.

5.3.4 Finishing

The finishing should be bright and glossy to reflect direct solar radiation from building and air spread of natural lighting within the building. Brighter colours are more efficient compared to the darker ones.

5.3.5 Lighting

Abuja has abundance sunlight its last mostly up to 8-10 hours. So, it should be maximized achieve maximum natural lighting in the mall. Fenestrations should be placed abundantly but with close attention to the sun path. This is to reduce direct sunlight from penetrating the interior of the building.

5.3.6 Ventilation

Ventilation is one of the key point in shopping mall. To achieve maximum thermal comfort for the customers, the methods of ventilation applied in both hot humid and hot arid regions should be employed. This would mean providing large voluminous spaces with high head rooms to allow for stack effect. Cross ventilation should be provided were ever possible.

6.0 DESIGN REPORT

6.1 Introduction

This chapter incorporates the report of the architectural design of the proposed shopping mall. In this chapter, key design requirements and how the research findings have been incorporated into the design are discussed. The chapter is arranged under the following headings: The Design Brief; Schedule of accommodation; Major Functional Divisions; Functional Organization and Design Consideration.

6.2 Major functional divisions

The functional spaces in the shopping mall are grouped into various functional divisions based on the nature of the activities carried out in the spaces. All the related spaces are grouped together. The major functional divisions are four, namely: Anchor store (Shoprite); Anchor store (Game); Let able shops spaces and the management's offices. The two-anchor tenant are on the ground floor, the let able shops are in all the floors, while the managements are in the last floor.

6.3 Functional organization

The design of shopping malls involves three basic concepts which are used to determine the organization of the functional spaces. These concepts are listed below:

i. Linear Concept: This concept is characterized by locating the display area at the façade of the building, and the service area at the rear end.
ii. Introverted Concept: The introverted concept has the shopping activities taking place at the core of the structure while service is carried out at its periphery.
iii. Extroverted Concept: In this arrangement, the main shopping activity takes place at the periphery of the structure while the services take place at the core. This

concept is usually used in most western shopping areas where a covered street flanked by shops is the main shopping enclave.

For the purpose of this design, the Linear Concept shall be adopted. The purpose of this is to make access for maintenance easy and to open up the interior space for more flexibility.

6.4 Schedule of accommodation

The different areas required for the different activities that take place in a shopping mall varies. The table below summarizes the areas that will be adopted for the different functional spaces in the mall. The table 6.1 compares the space requirements as observed from the case studies; the standard requirements and that adopted for the design.

Table 6.1: Schedule of accommodation

S/N	Functional Space	Unite area	No	Total Area m2
1	Entrance area	154	1	154
2	Security post	36	2	64
3	Shops	30	--	--
4	Shoprite	755	1	755
5	Games	755	1	755
6	Events hall	698	1	698
7	Movie theatres	550	1	550
8	Free Wi-Fi	82	1	82
9	Electronics	250	1	250
10	Home décor	164	1	164
11	Hairdressing	80	1	80
12	ATM	32	1	32
13	Pharmacy	40	1	40
14	First aid	40	1	40
15	Bookstore	40	1	40
16	Dry cleaning	32	1	32
17	Toilet male	2	12	24/96
18	Toilet female	2	12	24
19	Food court	633	1	633
20	Photo studio	66	1	66
21	Chines Restaurant	142	1	142
22	Fast food	1124	1	1124

S/N	Functional Space	Unite area	No	Total Area m^2
23	Communication	20	1	20
24	Snack/cakes	38	1	38
25	Children's shop	80	1	80
26	Popcorn/Ice-cream	--	4	--
27	DVD/CD shop	40	1	40
28	Gift shop	40	1	40
29	Secretary/waiting	66	1	66
30	General manager	44	1	44
31	Meeting room	77	1	77
32	Operation manager	27	1	27
33	Accountant	42	1	42
34	Architect and Lawyer	27	1	27
35	Facilities team	38	1	38
36	Security manager	37	1	37
37	Control room	79	1	79
38	Cleaning team	80	1	80
39	Cafés	91	1	91
40	Sport wear shop	40	1	40
41	Parking spaces	$75m^2/1$	188	$75m^2/1$
Total unit area m^2: 13416				
Total site area m^2: 52960 m2				

Source: Author, (2016)

6.5 Design Considerations

The proposed shopping mall is environmentally friendly; it has technology and abundant natural resources to develop a model, which show cases energy efficiency. The mall is designed using the findings from the literature and from the simulations. The strategies employed are based on the variables gotten from the literature review. The proposed design will tremendously reduce the energy consumption given the owner high benefits.

6.5.1 Climate

The climate of the site played a significant role in the design of the proposed building. In a hot dry and hot humid region, such as F.C.T, which is characterized by high humidity and hot discomfort, building materials, considerations and construction techniques are

such that they should keep off heat rather than absorbing it thereby reducing the building interior temperature and running time of the air conditioning systems

6.5.2 Site consideration

Openings on all sides of the building were shaded with horizontal and vertical shading devices and trees. The proposed building was placed in the centre of the site and drainages were placed on the lower points of the site, this will help for easy drainage during peak periods of rainfall. The site incorporated native plants and wild grasses to reduce direct sun from striking and heating up the building surfaces, this will prevent reflected light carrying heat into the building from the ground to other surfaces. Impervious landscaping surfaces was minimized to achieve maximum drainage. Deciduous planting provided for shading during summer and allows desirable solar gains during winter and added aesthetic to the shopping mall.

6.5.3 Building Envelope

It is known that roof receives significant amount of solar radiation and plays an important role in heat gain/losses and illumination, hence light colours paint was used on the concrete roof to reflect light that will heat up the surface. Atrium was introduced in order to allow adequate passage of daylight and escape of hot air from the building. Single tempered glazing, low emittance coatings, blue tints have become very important means of energy conservation and durability in modern construction to reduce both thermal losses and heat gain, hence it was used in this design while for the walling material, and hollow sandcrete block was used.

6.5.4 Building shape and form

In a composite hot humid/hot dry climate of Abuja, a cylindrical building form is more efficient it can help in reducing a tremendous amount of cooling load required to cool up the entire building; the computer simulation have proven that. This influenced the shape

and form of the proposed shopping mall. Therefore, cylindrical building form is incorporated in the design.

6.5.5 Spatial Organization

The general planning of the site and facilities are such that the activity relationship is well co-ordinated to create a harmonious grouping and ease of circulation.

6.5.5.1 Accessibility

Accessibility to site is convenient and free from all obstruction. Two separate accesses were provided, the main access that is for the customers and staff, while the other is strictly for services. The main access is complimented with a pedestrian walkway on the both side.

6.5.5.2 Site Drainage

The site drainage is positioned at the lowest point on the site; this is to allow easy flow and collection of running water during rainfall.

6.5.5.3 Main Facilities

The shopping mall consist of eight floors, all floors are designed to have an open plan circulation in order to encourage free movement of air and users. The entrance of the building leads to the security post by the right, which is directly before the central atrium. Staircases, lift are also provided for vertical movement of user including the disables.

6.6 Simulation of the proposed design

The building is modelled using Autodesk revit 2014 and was exported in Autodesk Ecotect Analysis 2011 as the previous simulation. It is simulated as it is with the construction materials used in the second case of silverbird as shown in figure 6.1 to validate to compare the cooling loads per floor area of the new proposed shopping mall to the existing silverbird mall.

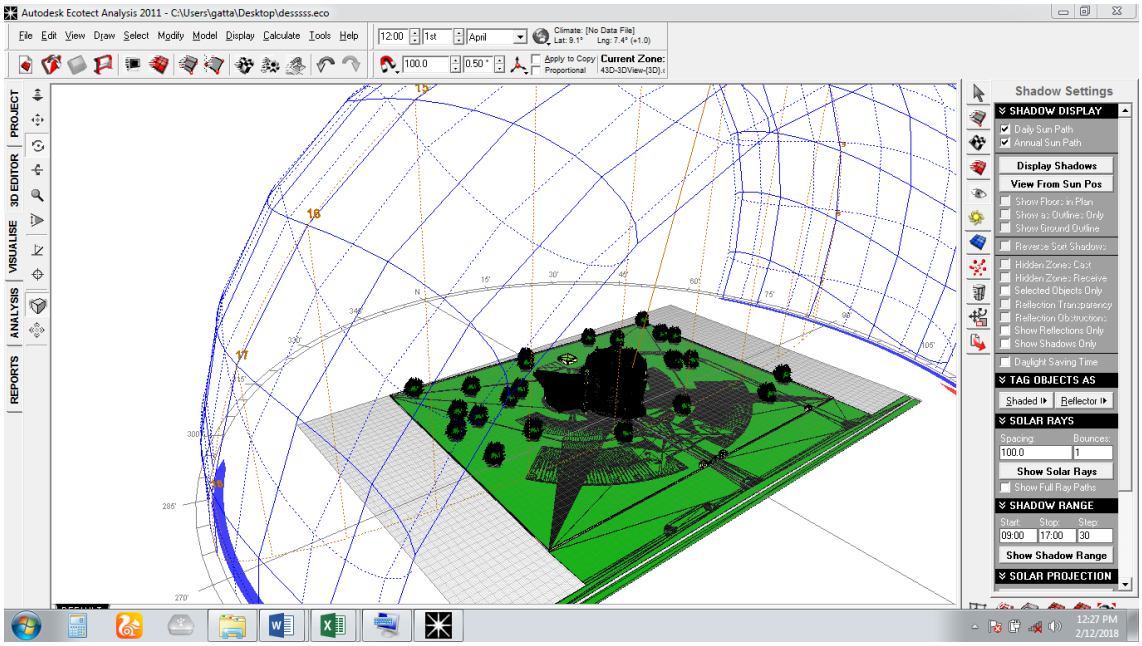


Figure 6.1: Energy simulation of the proposed shopping mall

Source: Author (2017)

As reported earlier in chapter four, the simulation result of silverbird as it is indicated that the total annual cooling is about 1,483,362.128 kWh/Year while the cooling per meter square (PER M²) was 75.472. The proposed design has a total annual cooling of about 312177.594 kWh/Year while the cooling per meter square (PER M²) was 52.706 as shown in the table 6.2 below.

Table 6.2: Monthly energy load of the proposed shopping mall

	HEATING	COOLING	TOTAL
MONTH	**(kWh)**	**(kWh)**	**(kWh)**
Jan	0	32763.964	32763.964
Feb	0	43857.046	43857.046
Mar	0	56601.118	56601.118
Apr	0	40448.964	40448.964
May	0	29820.702	29820.702
Jun	0	12771.354	12771.354
Jul	0	10664.998	10664.998
Aug	0	7976.878	7976.878
Sep	0	5247.404	5247.404
Oct	0	20887.45	20887.45
Nov	0	12378.964	12378.964
Dec	0	26379.78	26379.78
TOTAL	**0**	**312177.594**	**312177.594**
PER M²	**0**	**56.604**	**56.604**
Floor Area:	**48435.143 m2**		

Source: Author (2017)

This show that the proposed design is more energy efficient than silverbird as the cooling per meter square is 25.61% lower than silverbird. Annualy that is about N5,000,000.00 (Naira) saved on cooling compared to silverbird.

7.0 CONCLUSION AND RECOMMENDATION

7.1 Conclusion

In a modern architectural practice, building forms have definitely a lot to say about it energy consumption, irrespective of the location or the building envelope. It is concluded that with the shortage of power supply in Nigeria, the cost of energy on the rise and the issue of global climate change, optimization of building energy performance during the early design phase is vital for the whole building design process; its guarantees the environmental quality. It is a very important factor for achieving energy efficiency in building. This research has added to the literature on building forms in shopping mall in hot humid and hot dry climates in general as it contains recent information on the concept. Hopefully, this research will serve as a guide for students, to various professionals involved in building industry and as well as government agencies making policies on environmental control and sustainable design. Efficient design is our hope and the hope for our future generations.

7.2 Recommendations

The study established the following recommendations:

i. Architects and others proffessional (Builders, Engineers etc…) involves in the building industry should consider building form as one of the key aspect when aiming at reducing the energy load of a building.

ii. The window to wall ratio of shopping mall building in a hot humid/hot dry climate should be less than 60% for a more efficient building.

iii. In this part of the world for commercial buildings, cooling is the major issue not heating or daylight that is because a lot of money is spent on cooling than lighting so, having a building form that will help in keeping the heat out will save more

energy and money than a building forms that can introduce high amount of daylight.

iv. Soft landscape coverage on site can help in reducing cooling requirement of any types of building. Therefore, proper landscape should be integrated in any type of design.

v. Efficient appliances can be used to improve the energy efficiency of a building.

vi. If your major concerns are to provide day lighting in a building, then the Cuboid building form is one of the best choice for the Abuja climate.

7.3 Contribution to knowledge

The study established that:

i. In a composite climate of Abuja, cylindrical building form is more suitable in reducing energy-cooling load by up to 44.34%.

ii. Factors that determine the choice of building forms to achieve energy efficiency such as, orientation, glazing material, shading system, and material finishes reduces the cooling load by up to 7.41%.

iii. Factors that determine the choice of building forms to achieve energy efficiency such as, orientation, glazing material, shading system, and material finishes can increase the illumination level of an interior building by up to 73%.

iv. Atrium introduces more daylight into a building compared to the side light system.

v. Cuboid building form is the most suitable for day lighting design for the climate of Abuja.

vi. Cylindrical form will save 44.34% of the total annual energy consumption compared with a triangular shape.

7.4 Areas of Further Research

The challenge for this dissertation has been to design a Shopping mall building that will be energy efficient and respond to the climate of Abuja. Therefore, further research can be:

i. Others building forms should be evaluated in the same climate to find out other suitable building form.
ii. This same study should be carried out totally in another different climate to find the suitability of these building forms.
iii. The cuboid form amazingly has the highest illumination level; so, it is interesting to investigate the reason for this in the future work.

REFERENCES

Advance Lighting Guideline (ALG). (2010, November 10). *Daylighting*. Retrieved August 23, 2016, from Advance Lighting Guideline: https://algonline.org/index.php?daylighting-strategies

Alter, L. (2009, October 7). *Architects: Go Back To The ABCs and Design Buildings Like Letters Again*. Retrieved July 16, 2016, from treehugger: http://www.treehugger.com/sustainable-product-design/architects-go-back-to-the-abcs-and-design-buildings-like-letters-again.html

Anonymous. (2012). *What are independent and dependent variables?* Retrieved May 17, 2016, from GraphinTutorial: https://nces.ed.gov/nceskids/help/user_guide/graph/variables.asp

ArchDaily. (2015, December 19). *Paleet Shopping Center / JVA*. Retrieved August 29, 2016, from ArchDaily: http://www.archdaily.com/778738/paleet-shopping-center-jva/

ArchDaily. (2016, March 11). *ARG Shopping Mall / ARSH 4D Studio*. Retrieved August 29, 2016, from ArchDaily: http://www.archdaily.com/783535/arg-shopping-mall-arsh-4d-studio/

Astrich, B., Morris, A., & Walters, B. (n.d.). Daylight Performance in Mid/Large Buildings. *UTSoA - Seminar in Sustainable Architecture* (p. 5). Texas: Center for Sustainable Development. Retrieved June 19, 2016, from https://soa.utexas.edu/sites/default/disk/preliminary/preliminary/5-Astrich_Morris_Walters-Daylight_Performance_in_Mid_Large_Buildings.pdf

Batagarawa, A. (2013). *Assessing the thermal performance of phase change materials in composite hot humid/hot dry climates. An examination of office buildings in Abuja-Nigeria.* School of Architectue, planning and landscape, Newcastle Universty, Newcastle Universty. Retrieved from https://theses.ncl.ac.uk/dspace/bitstream/10443/2146/1/Batagarawa,%20A.%2013.pdf

BioclimaticX. (2016, 1 8). *Bioclimatic X*. Retrieved 3 22, 2016, from What is Bioclimatic Architecture: "http://bioclimaticx.com/xmlrpc.php">

Canada Mortgage and Housing Corporation (CMHC). (2014, November). Impact of Architectural Form on the Potential Energy Performance of Multi-Unit Residential Buildings. *Research Highlight, 4*, 11-14. Retrieved April 2016

Catalina, T., Virgone, J., & Iordache, V. (2011). Study on the impact of the building form on the energy consumption. *12th Conference of International Building Performance Simulation Association* (pp. 1726-1729). Proceedings of Building Simulation. Retrieved April 11, 2016

Community Research and Development Centre (CREDC). (2009). *Energy Efficiency Survey in Nigeria.* (E. Uyigue, Ed.) Edo State.

Department of Energy and Climate Change. (2012). *The Energy Ef¿ciency Strategy: The Energy Ef¿ciency Opportunity in the UK*. London: Department of Energy and Climate Change. Retrieved September 15, 2016, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65602/6927-energy-efficiency-strategy--the-energy-efficiency.pdf

Dictionary.com. (2016). *Define Air quality*. Retrieved April 14, 2016, from Dictionary.com: https://www.Dictionary.com

Don Prowler, FAIA , Donald Prowler and Associates. (2014, December 18). *Sun Control and Shading Devices*. (M. E. Joseph Bourg, Editor) Retrieved September 11, 2016, from WBDG Whole BuildingDesoign Guide : https://www.wbdg.org/resources/suncontrol.php -->

Du, L. (2012). *The Impact of Building Morphology on Energy Consumption.* Norwegian university of science and technology, Faculty of Architecture and Fine Art. Norwege: Norwegian university.

Emporia, O. (2014, February 26). Retrieved from Emporia shopping mall: http://se.club-onlyou.com/Emporia

Encyclopedia. (2012). *quantitative research*. Retrieved May 17, 2016, from encyclopedia.com: http://www.encyclopedia.com/doc/1O62-quantitativeresearch.html

Energy Commission of Nigeria and United Nations Development Programme (ECN-UNDP). (2005). *Federal Republic of Nigeria Renewable Energy Master Plan.* The Energy Commission of Nigeria and the United Nations Development Programme. Retrieved July 24, 2016, from http://www.iceednigeria.org/REMP%20Final%20Report.pdf.

Erdim, B., & Manioglu, G. (2011). Impacts of building form on energy efficient heat pump applications. *Proceedings of the Eleventh International Conference Enhanced Building Operations* (pp. pp.10-28). New York: ESL-IC. Retrieved June 23, 2016

European Expertise centre (EPEC). (2013). *The Benefits of Energy Efficiency.* EPCE. Retrieved September 16, 2016, from http://www.eib.org/epec/ee/documents/factsheets-energy-efficiency-en.pdf

European Standard 15232. (2012). *Energy performance of buildings – Impact of Building Automation, Controls and Building Management.* European Standard.

eXtension. (2013, November 13). *How the Exterior Architectural Features of a Home, Built in a Warm Climate, Affect its Energy Efficiency*. Retrieved June 09, 2016, from eXtension.org: http://articles.extension.org/pages/25670/how-the-exterior-architectural-features-of-a-home-built-in-a-warm-climate-affect-its-energy-efficien

Freewana, A. A., Shaob, L., & Riffat, S. (2009). Interactions between louvers and ceiling geometry for maximum daylighting performance. *Renewable Energy, 34*, 223–232. doi:doi:10.1016/j.renene.2008.03.019

Granadeiro, V., Correia, J. R., Leal, V. M., & Duarte, J. P. (2013, February 6). Envelope-related energy demand: A design indicator of energy performance forresidential buildings in early design stages. *Energy and Buildings, 61*, 215–223. doi:http://dx.doi.org/10.1016/j.enbuild.2013.02.018

Grant, B. (2014, June 03). Designing at Ground Level. *Urbanist Article*(534). Retrieved Sptember 11, 2016, from http://www.spur.org/publications/urbanist-article/2014-06-03/designing-ground-level -->

Hamby, D. (1994). A review of techniques for parameter sensitivity analysis of environmental models. *Environmental Monitoring and Assessment, 32(2)*, 135-154.

Harris, A. D., McGregor, J. C., Perencevich, E. N., Furuno, J. P., Zhu, J., Peterson, D. E., & Finkelstein, J. (2016, January). The Use and Interpretation of Quasi-Experimental Studies in Medical Informatics. *Journal of American Medical Informatics Association*, 16–23. doi:10.1197/jamia.M1749

HomeEnergy. (2013, November 13). *How the Exterior Architectural Features of a Home, Built in a Warm Climate, Affect its Energy Efficiency*. Retrieved May 1, 2016, from Home Energy: http://articles.extension.org/pages/25670/how-the-exterior-architectural-features-of-a-home-built-in-a-warm-climate-affect-its-energy-efficien -->

IEA. (2015). *Energy efficiency*. Retrieved September 19, 2016, from International Energy Agency: http://www.iea.org/topics/energyefficiency/ -->

Industries/GaugeTech., E. (2016, 4 21). *How Shopping Malls Can Benefit From Power Monitoring Systems*. Retrieved from Electro Industries/GaugeTech.: https://electroind.com/tag/shopping-mall-energy-consumption/ -->

International Energy Agency (IEA). (2012). *International Energy Agency.* Paris, France: International Energy Agency. Retrieved May 12, 2016

Jeff, M. (2000). Design and Analysis of Hybrid Solar Lighting and Full Spectrum Solar Energy Systems. *SOLAR 2000 conference* (p. 9). United States: American Solar Energy Society's . Retrieved from https://digital.library.unt.edu/ark:/67531/metadc719062/m2/1/high_res_d/788614.pdf

Kadir, A. A., Ismail, L. H., & Kasim, N. (2015). optimization of daylighting system by using light pipe system in a building. Retrieved July 15, 2016, from http://eprints.uthm.edu.my/7281/1/13._OPTIMIZATION_OF_DAYLIGHTING_SYSTEM_BY_USING_LIGHT_PIPE_SYSTEM_IN_A_BUILDING.pdf

Kartal, S., & Chousein, Ö. (2015). Utilization of Renewable Energy Sources in Bioclimatic Architecture in Greece. *Recent Advances on Energy, Environment, Ecosystems, and Development*, pp.26. Retrieved April 29, 2016, from http//www.inase.orglibrary2015barcelonabypaperEEEDEEED-04.pdf

Kocagila, I. E., & Oral, G. K. (2015). The Effect of Building Form and Settlement Texture on Energy Efficiency for Hot Dry Climate Zone in Turkey. *Energy Procedia, 78*, 1835 – 1840. Retrieved May 18, 2016

Kocaili, b. e. (2010). *Evolution of shopping malls: Recent trends and the question of regeneration.*

Lam, J. C., & Li, D. H. (2003, june 9). Electricity consumption characteristics in shopping malls in subtropical climates. *Energy Conversion and Management, 44*(9), 1391–1398. doi:doi:10.1016/S0196-8904(02)00167-X

Lomholt, I. (2014, March 06). *Las Arenas Shopping Center Barcelona*. Retrieved june 22, 20106, from e-architect: http://www.e-architect.co.uk/barcelona/las-arenas-shopping-center

Macromedia. (2005). Macromedia (version 8) [computer software] . Retrieved from www.macromedia.com

McCarty, D. (2014). Guide for redesigning an urbans city. pp.13-49. Retrieved March 3, 2016

Media studio. (2013, September 05). *Form -Architecture*. Retrieved June 15, 2016, from bbamediastudio.wikispaces: https://bbamediastudio.wikispaces.com/Form+-Architecture?

Mekigal. (2012, July 13). *Floor-(ceiling)-Height-Standards-In-Construction*. Retrieved September 11, 2016, from lofi.physforum.com: https://lofi.physforum.com/Floor-(ceiling)-Height-Standards-In-Construction_40340.html -->

Mushs, J. D. (2000). Design and analysis of Hybrid solar Lighting and full-Spectrum solar energy systems. *Proceeding of American Solar Energy Society "Solar200 Conference"*. Madison: Wisconsin.

National Association of Realtors. (2016). *Houselogic*. Retrieved September 11, 2016, from That Paint Color Looked Great Until You Got It Home. Here's Why.: https://www.houselogic.com/remodel/painting-lighting/choosing-paint-colors-how-light-affects-color/ -->

National Environment Agency. (2012). *Technical guide towardsenergy smart retail mall.* Singapore: National University of Singapore Department of Building. Retrieved June 2016

National Mirror. (2015, May 22). *Abuja population will rise to 10m in 2018 –minister*. (O. IFOH, Editor) Retrieved March 2016, from National mirror: http://nationalmirroronline.net/new/abuja-population-will-rise-to-10m-in-2018-minister/ -->

Ogunsote, O., & Prucnal-Ogunsote, B. (2002). Defining Climatic Zone for Architectural Design in Nigeria. *Journal of Environmental Technology, vol.1*, pp.1-14. Retrieved June 2016, from http://sdngnet.com/Files/Papers/Journal%20Publications/Defining%20Climatic%20Zones%20for%20Architectural%20Design%20inNigeria.pdf

Olgyay, V. (1963). *Towards an evaluation framework for sustainability in retail design COBRA 2004 L M University NE1, UK,*. Leeds Metropolitan University. pp. 6-7.

Oluigbo, S. N. (2014). *Lecture eight: population and sampling.* Course notes. Zaria: Ahmadu Bello University. pp.1. Retrieved 2016

Oral, & Yilmaz. (2002). The limit U values for building envelope related to building form in temperate and cold climatic zones. *Building and Environment, 37*, 1173–1180. Retrieved June 4, 2016

Praharaj, M. (2014, March 14). Effect of Building Form for Low energy Architecture: Evaluation of Bio- Climatic Design, Bhubaneswar. *Elixir International Journal*, pp.22492-22495. Retrieved May 1, 2016, from https://www.academia.edu/7967451/Effect_of_Building_Form_for_Low_energy_Architecture_Evaluation_of_Bio-_Climatic_Design_Bhubaneswar?auto=download

Premium Times. (2016, May 19). *Nigeria has capacity to generate 12,000 MW of electricity - Fashola*. Retrieved July 22, 2016, from Premium Times: http://www.premiumtimesng.com/business/business-news/203683-nigeria-capacity-generate-12000-mw-electricity-fashola.html

Public Works and Government Services Canada. (2002). *Daylighting Guide for Canadian Commercial Buildings.* Canada: August. Retrieved 2016

PWC. (2016, March 09). *South African Property Giant Invests In Abuja*. Retrieved May 27, 2016, from PricewaterhouseCoopers: http://www.africa.com/south-african-property-giant-invests-abuja/

Qualitative research consultants association (QRCA). (2015). *What is Qualitative Research?* Retrieved May 19, 2016, from Qualitative research consultants association: http://www.qrca.org/?page=whatisqualresearch

Rajasekar, S., Philominathan, P., & Chinnathambi, V. (2013). *Research methodology.* Tamilnadu, India: Department of Physics. Retrieved June 05, 2017, from https://arxiv.org/pdf/physics/0601009.pdf

Roberts, D. L. (2012, September 28). *No Brainer — Commercial Buildings Should Save Money by Becoming More Energy Efficient*. Retrieved September 16, 2016, from CleanTechnica: https://cleantechnica.com/2012/09/28/commercial-building-energy-efficiency-strategies/ -->

Rubio, J. (2001). *CERTS Customer Adoption Model.* California: Lawrence Berkeley National Laboratory. Retrieved April 27, 2016, from https://gig.lbl.gov/sites/all/files/rubio_certs_customer_adoption_model_03-2001.pdf

Samuel, K. D. (2015, February). Evaluating The Effects Of Building Forms On Thermal Comfort In Office Buildings In Hot Humid Areas. Retrieved Juy 15, 2016, from http://kubanni.abu.edu.ng:8080/jspui/bitstream/123456789/7003/1/EVALUATING%20THE%20EFFECTS%20OF%20BUILDING%20FORMS%20ON%20THERMAL.pdf

Shchuchenko, V., Lie, B., & Harsem, T. T. (2013, December). Influence of building form of hospital on its energy performance. *European Scientific Journal, 3*, 286-295. Retrieved January 31, 2016

Siemens. (2013). *Energy efficiency in building automation Application guide for ventilation and air conditioning.* Switzerland: Siemens Switzerland Ltd,. Retrieved September 16, 2016, from https://www.downloads.siemens.com/download-center/d/Energy-efficiency-in-building-automation-and-control-Application-guide-for-ventilation-and-air-conditioning_A6V10389375_hq-en.pdf?mandator=ic_bt&segment=HQ&fct=downloadasset&pos=download&id1=A6V10389375

Solis, K. T. (2016, April 2). *What are Shopping Malls?* (B. Harris, Editor) Retrieved april 27, 2016, from wiseGEEK: http://www.wisegeek.org/what-are-shopping-malls.htm#comments

Straube, J. (2008, SEPTEMBER 11). *BSI-006: Can Highly Glazed Building Façades Be Green?* Retrieved June 30, 2016, from Building Science Corporation: http://buildingscience.com/documents/insights/bsi-006-can-fully-glazed-curtainwalls-be-green

TechTarget. (2013, March). *independent and dependent variables*. Retrieved May 17, 2016, from http://whatis.techtarget.com/definition/independent-variable

The International Council of Shopping Centers . (1999). *ICSC Shopping Center Definitions* . New York: International Council of Shopping Centers .

Townsville. (2014). *Guide 3 shading out the heat.* townsville. Retrieved from https://www.townsville.qld.gov.au/__data/assets/pdf_file/0007/4120/Sustainable-Housing-Guide-3.pdf

TRIPinfo. (2012). *Types of Shopping Centers*. Retrieved april 27, 2016, from TRIPinfo.com: http://www.tripinfo.com/tips/Shopping001.html -->

Ürge-Vorsatz, D., Eyre, N., Graham, P., Harvey, D., Hertwich, E., Jiang, Y., . . . Novikova, A. (n.d.). *Energy End-Use: Buildings.* (E. Jochem, Ed.) Hungary. Retrieved March 17, 2016

Uyigue, E., Yapp, J., Odele, M., & Lebot, B. (2010). Overview of UNDP GEF Energy Efficiency Project in Nigeria: Promoting Energy Efficiency in Residential and Public Sector in Nigeria. *Regional Workshop on Energy Efficiency*, (p. 2). Ouagadougou, 12-13 April. Retrieved March 4, 2016

Veal, A. (2006). *Research Methods for Leisure and Tourism* (Third Edition ed.). London: Prentice Hall.

Wordtravels. (2016). *Abuja Climate and Weather*. Retrieved July 24, 2016, from wordtravels: http://www.wordtravels.com/Cities/Nigeria/Abuja/Climate

World Nuclear Association. (2016, May). *World Energy Needs and Nuclear Power*. Retrieved May 22, 2016, from World Nuclear Association: http://www.world-

nuclear.org/information-library/current-and-future-generation/world-energy-needs-and-nuclear-power.aspx

Yilmaz. (1988). *Evaluation of Built Environment from the Thermal Comfort Viewpoint.* TÜBITAK mag 716.

Yin, R. K. (2014). *Case study research: Design and methods.* Los Angeles, CA: Sage.

Young, D., & Buck, J. (2006). *Energy Use in Malls and Shopping Centres: Evidence from Canada.* Canada: CBEEDAC. Retrieved April 28, 2016

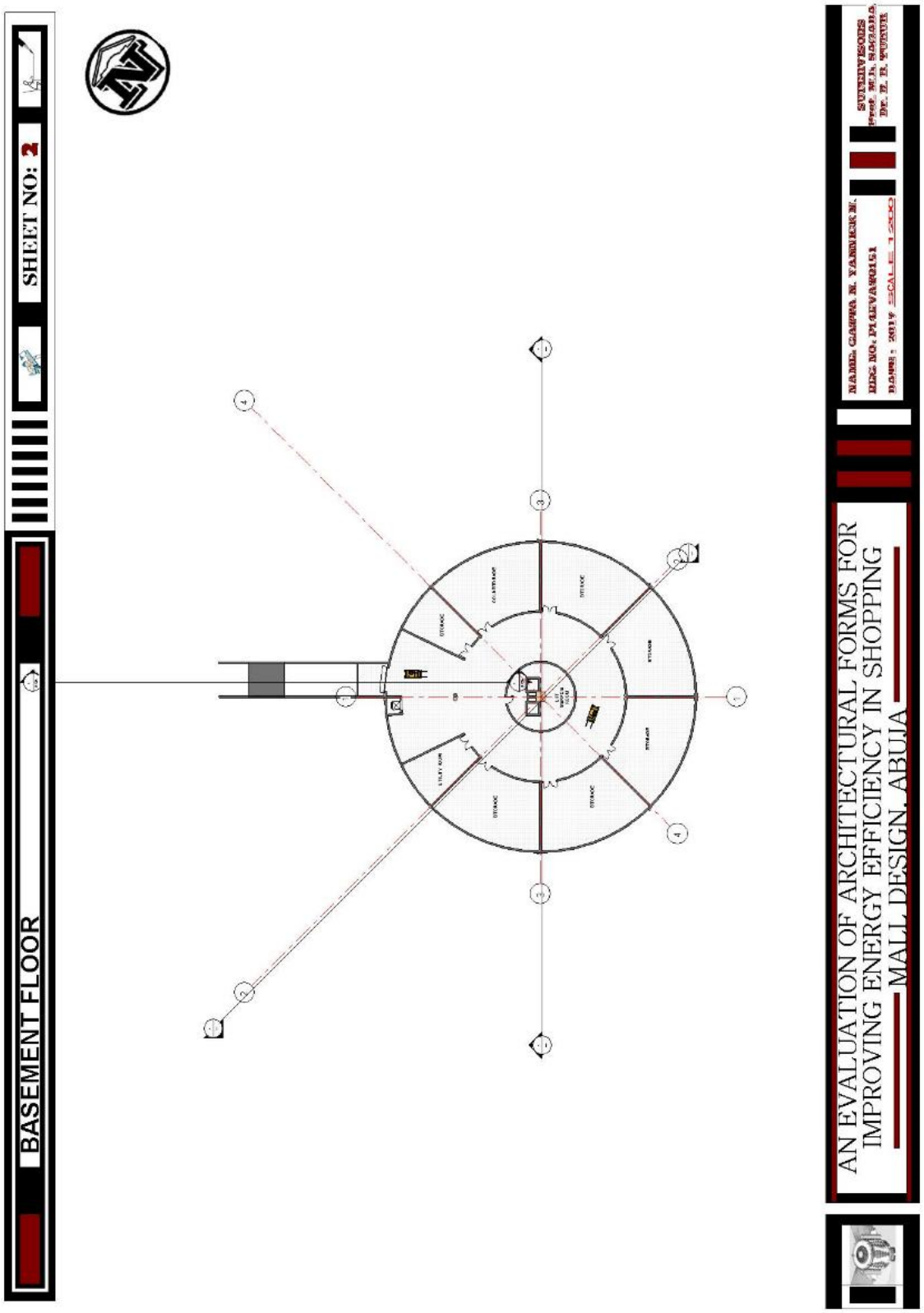
Zhang, L., Zhang, L., & Wang, Y. (2016, March). Shape optimization of free-form buildings based on solar radiation gain and space efficiency using a multi-objective genetic algorithm in the severe cold zones of China. (Jean-LouisScartezzini, Ed.) *SolarEnergy*, 38-50. doi:http://dx.doi.org/10.1016/j.solener.2016.02.053

APPENDICES

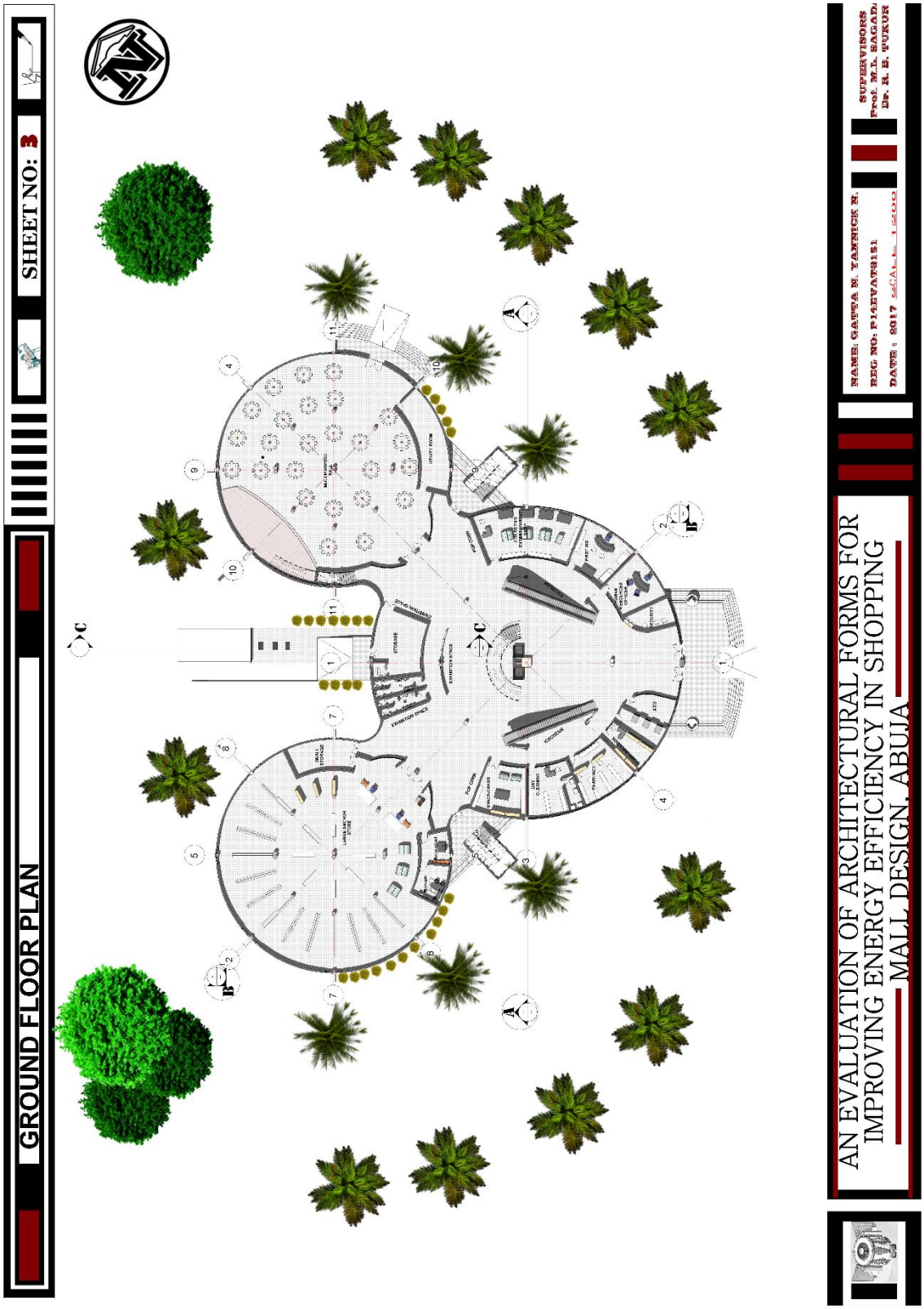
Appendix I: Proposed site plan



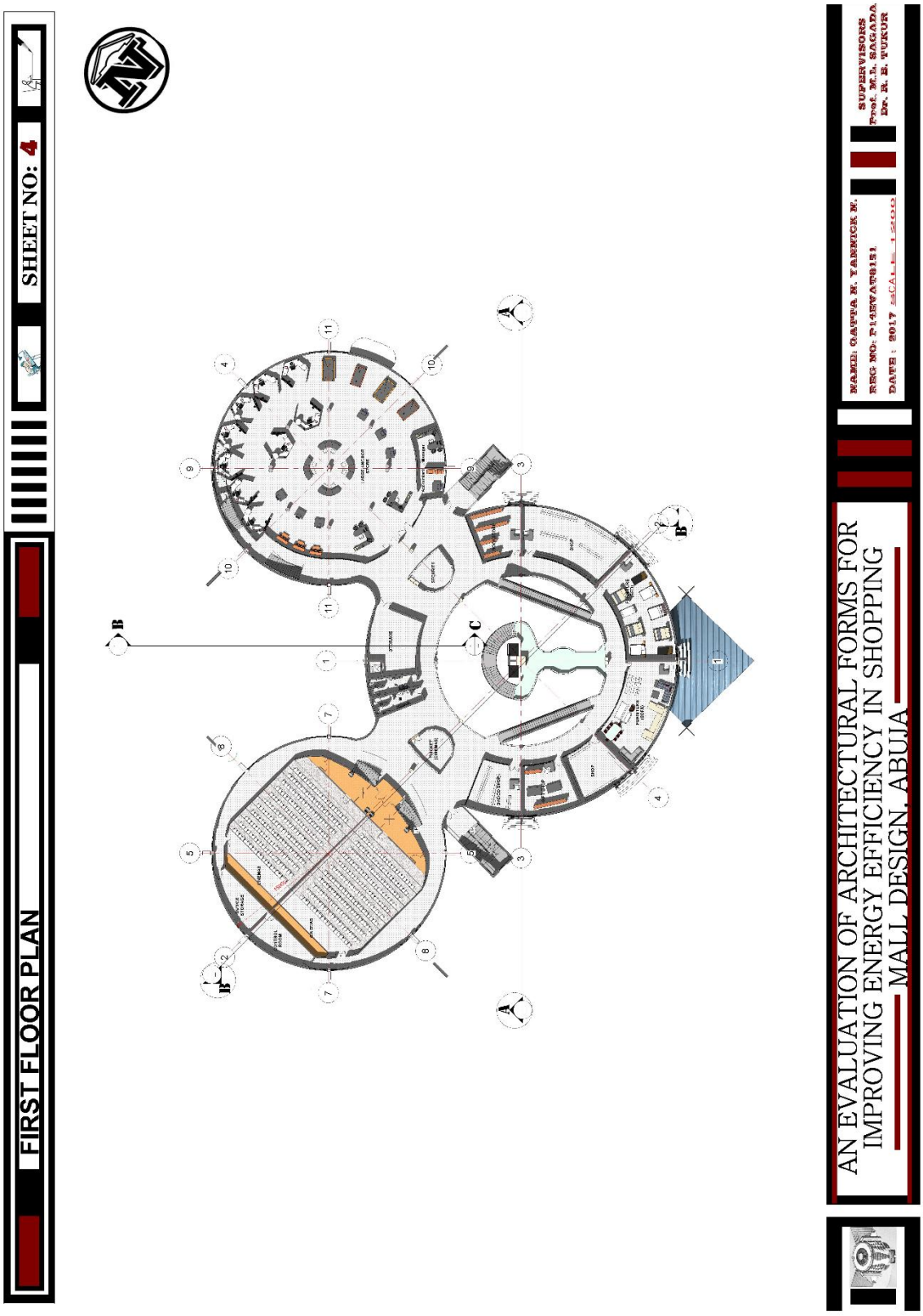
Appendix II: Proposed basement floor plan



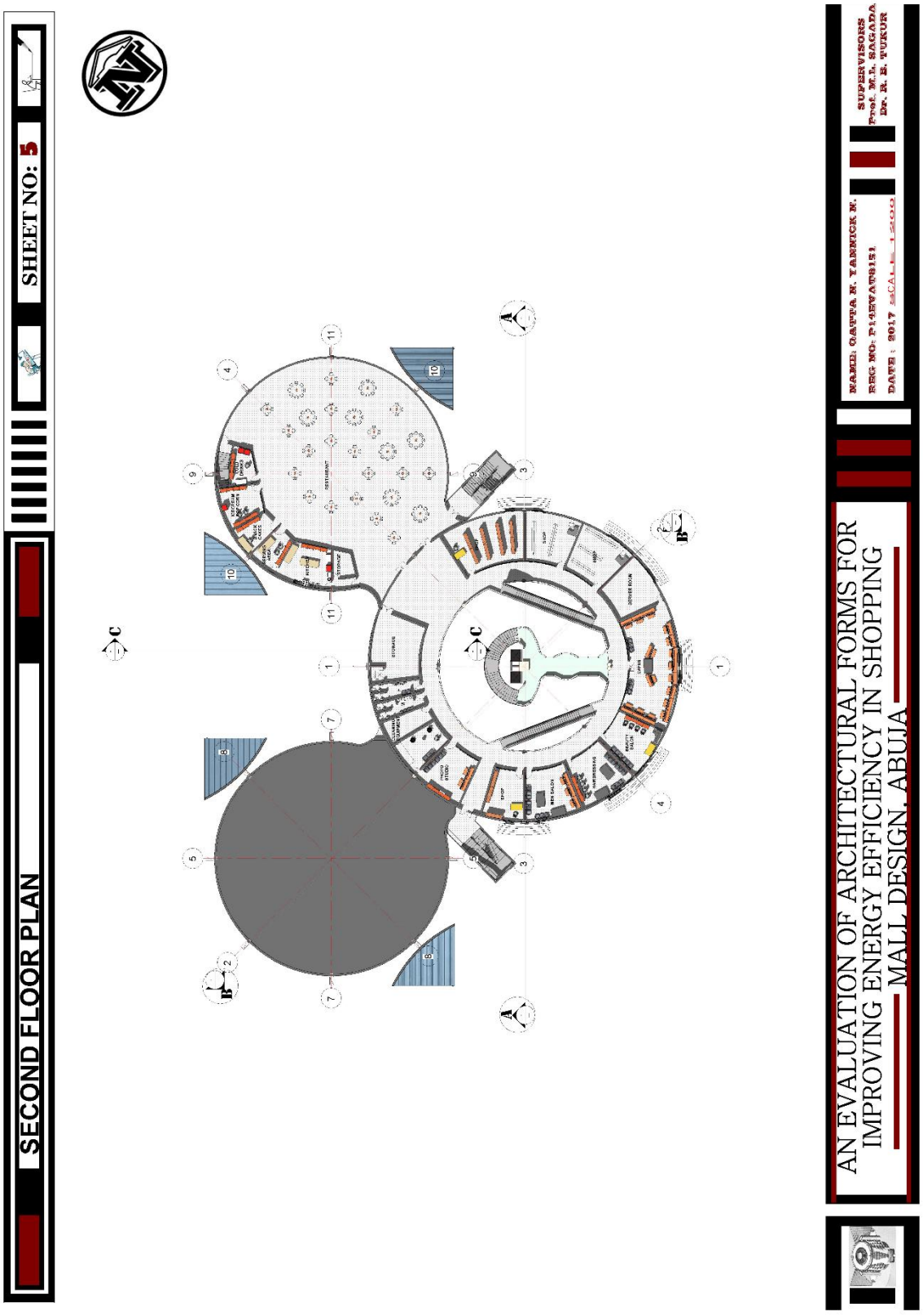
Appendix III: Proposed ground floor plan



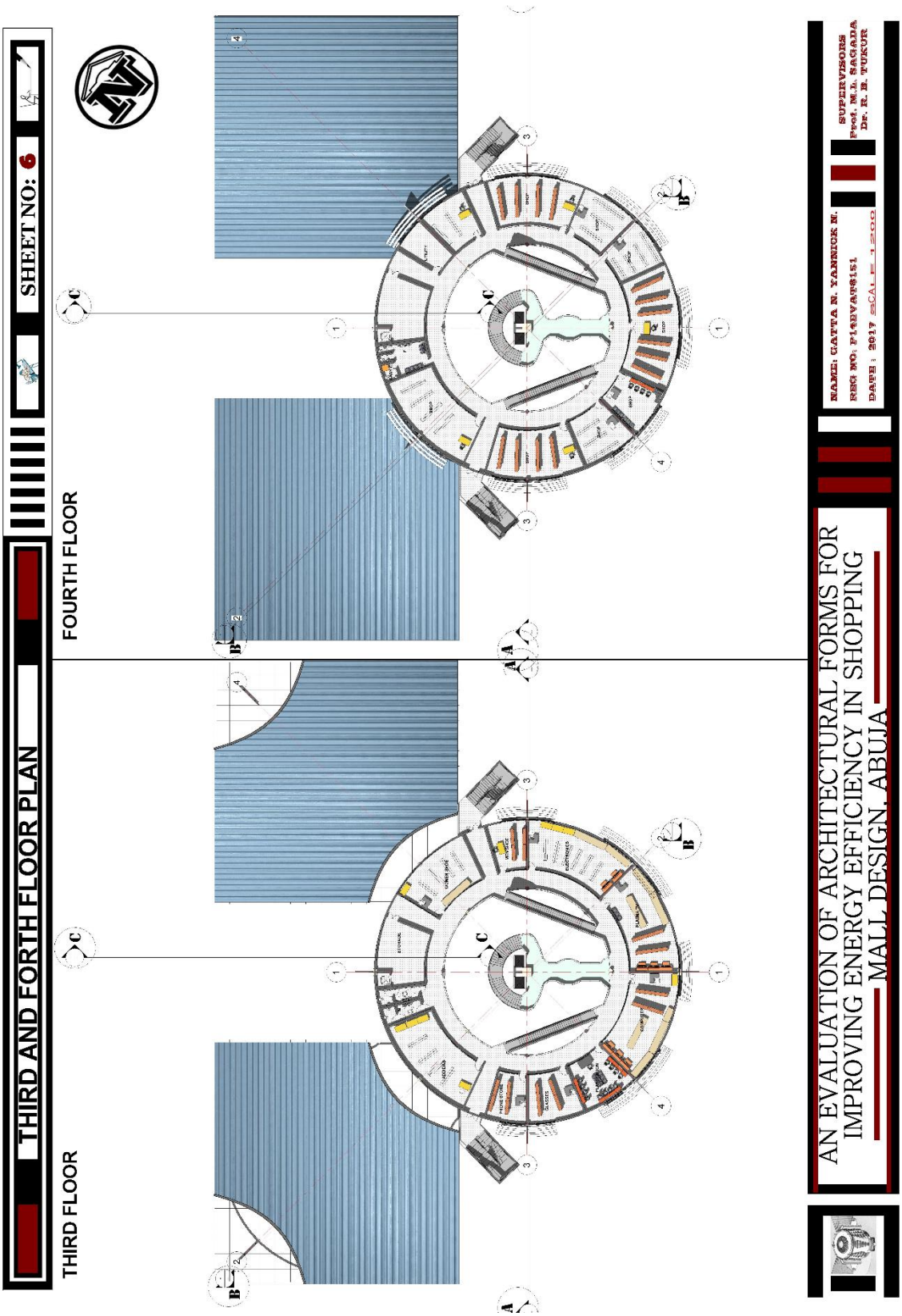
Appendix IV: Proposed first floor plan



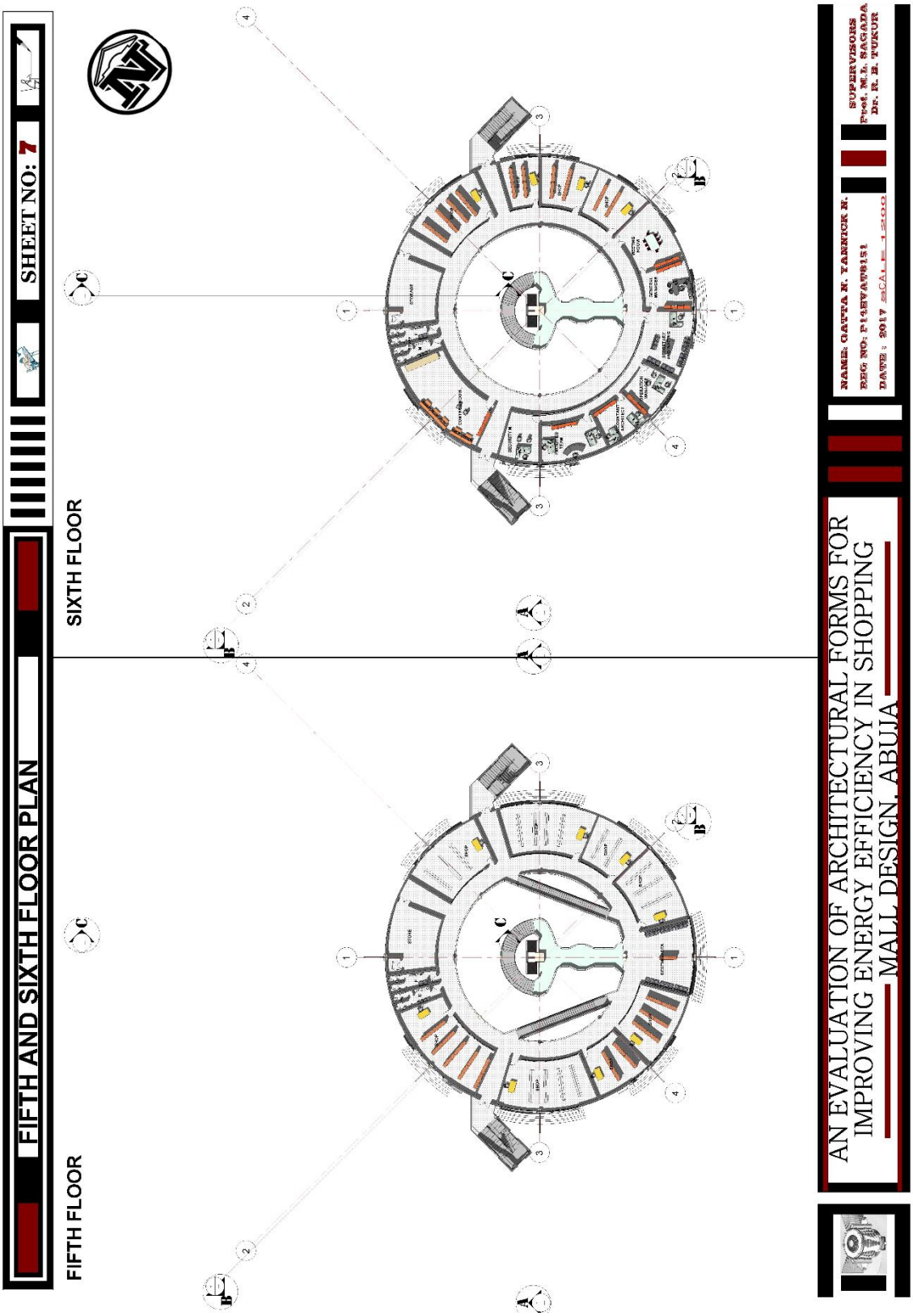
Appendix V: Proposed second floor plan



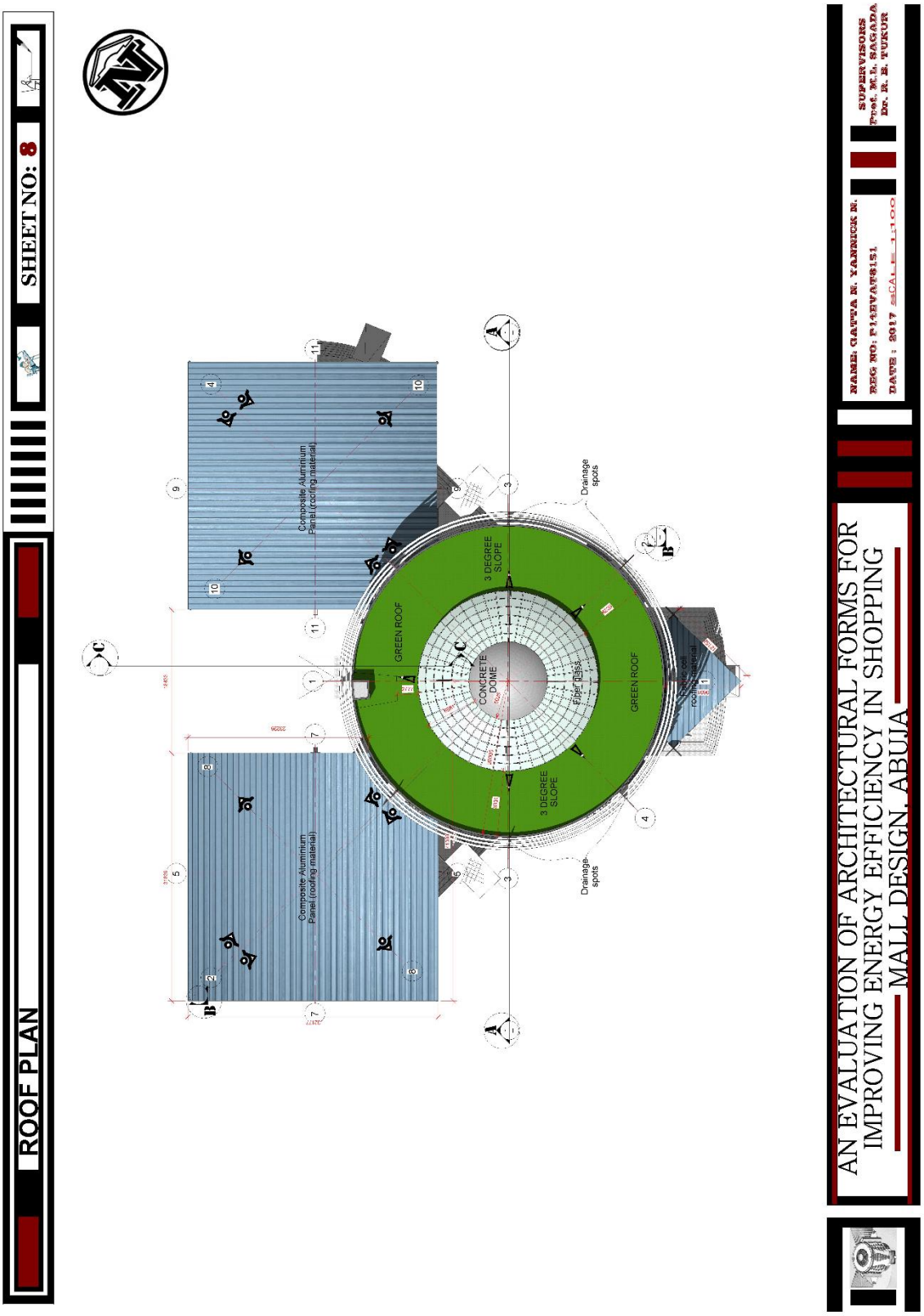
Appendix VI: Proposed third and fourth floor plans



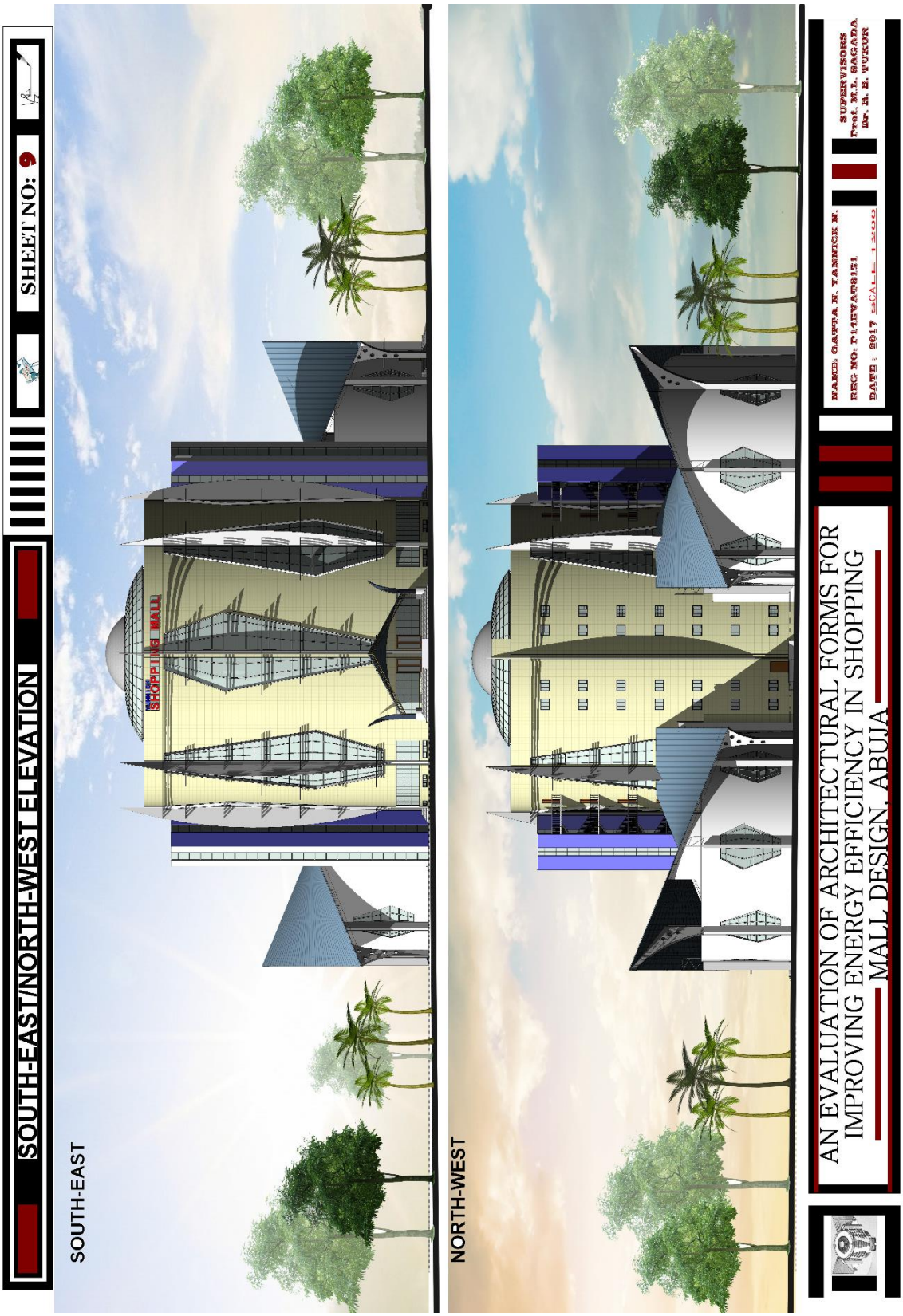
Appendix VII: Proposed fifth and sixth floor plan



Appendix VIII: Proposed roof plan



Appendix IX: Proposed South-East and North-West elevation

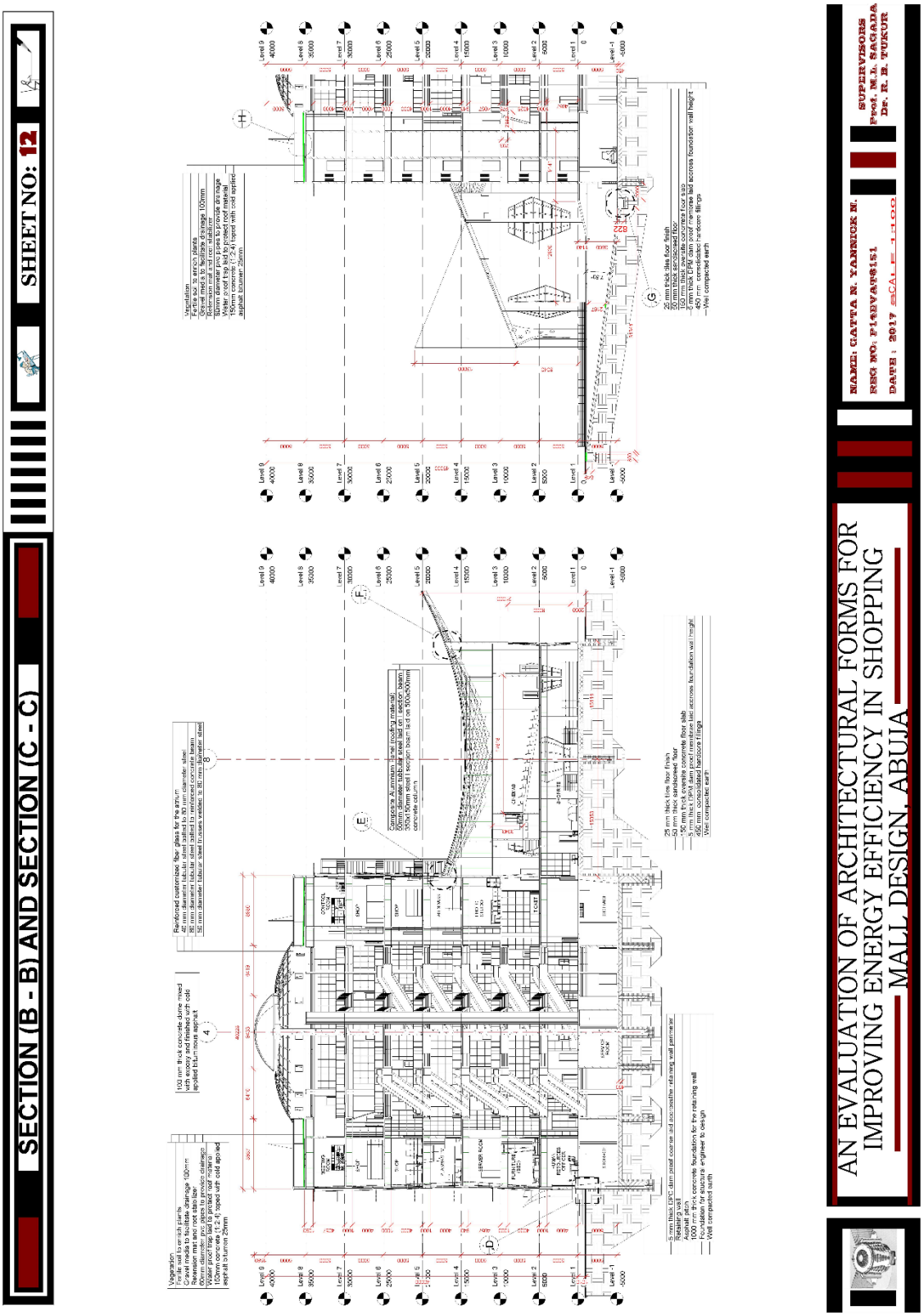


Appendix X: Proposed North-East and South-West elevation

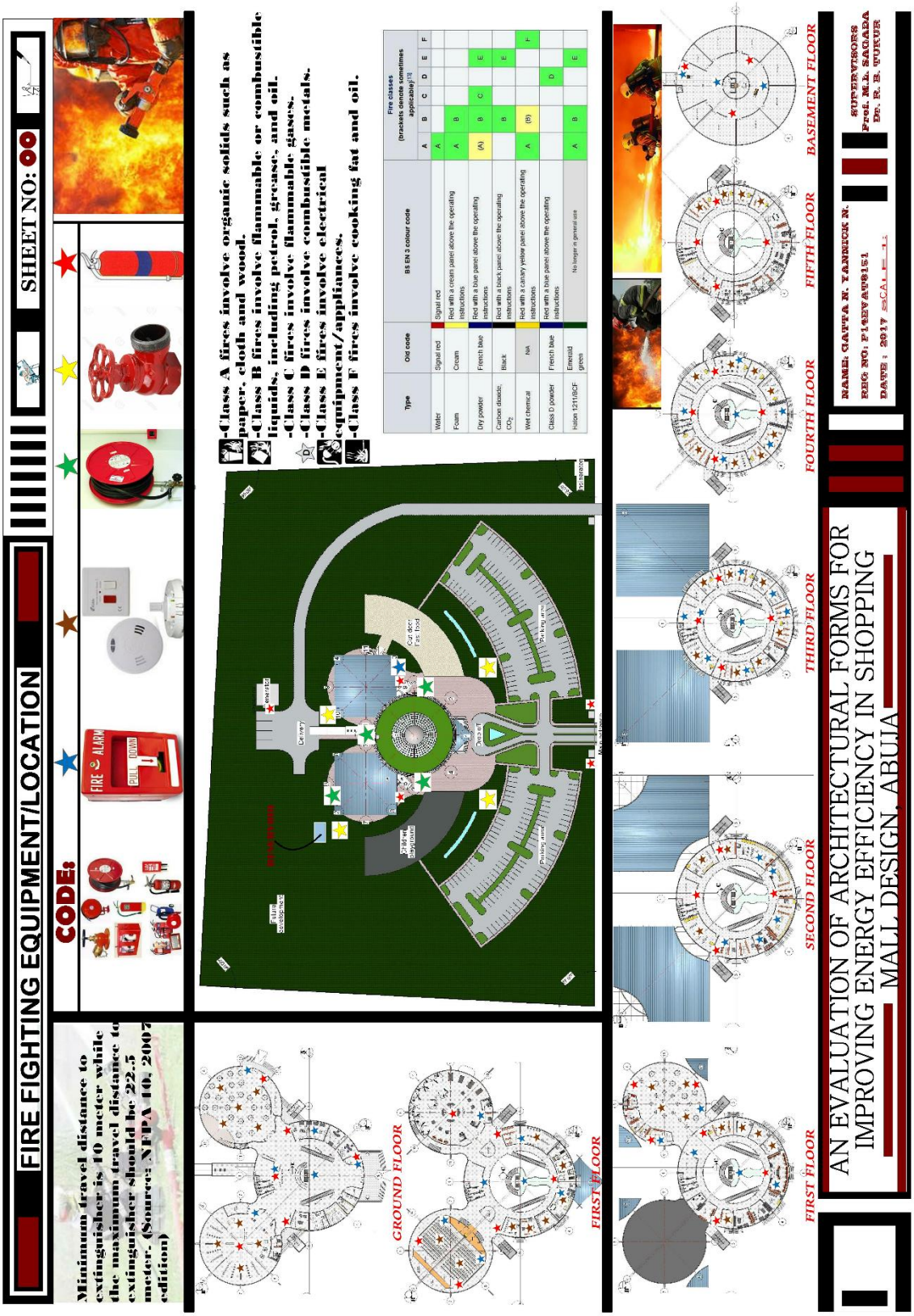


Appendix XI: Proposed Section (A-A')

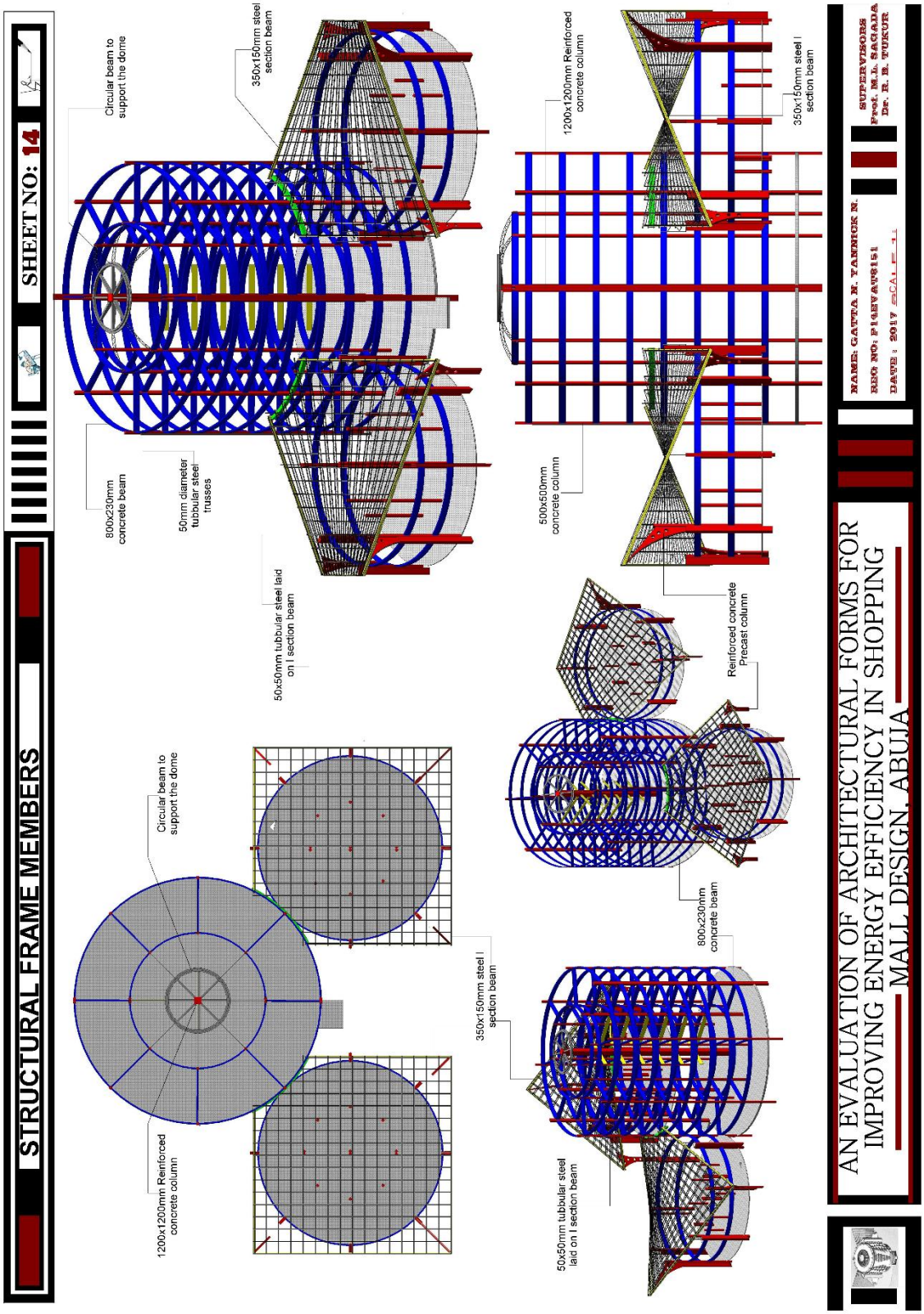
Appendix XII: Proposed Section (B-B') and (C-C')



Appendix XIII: Fire fighting equipment/location



Appendix XIV: Structural frame system



Appendix XV: Arial 3D view



Appendix XVI: 3D view from the south parking area:



Appendix XVII: 3D view from the entrance



Appendix XVIII: 3D view from the east parking area



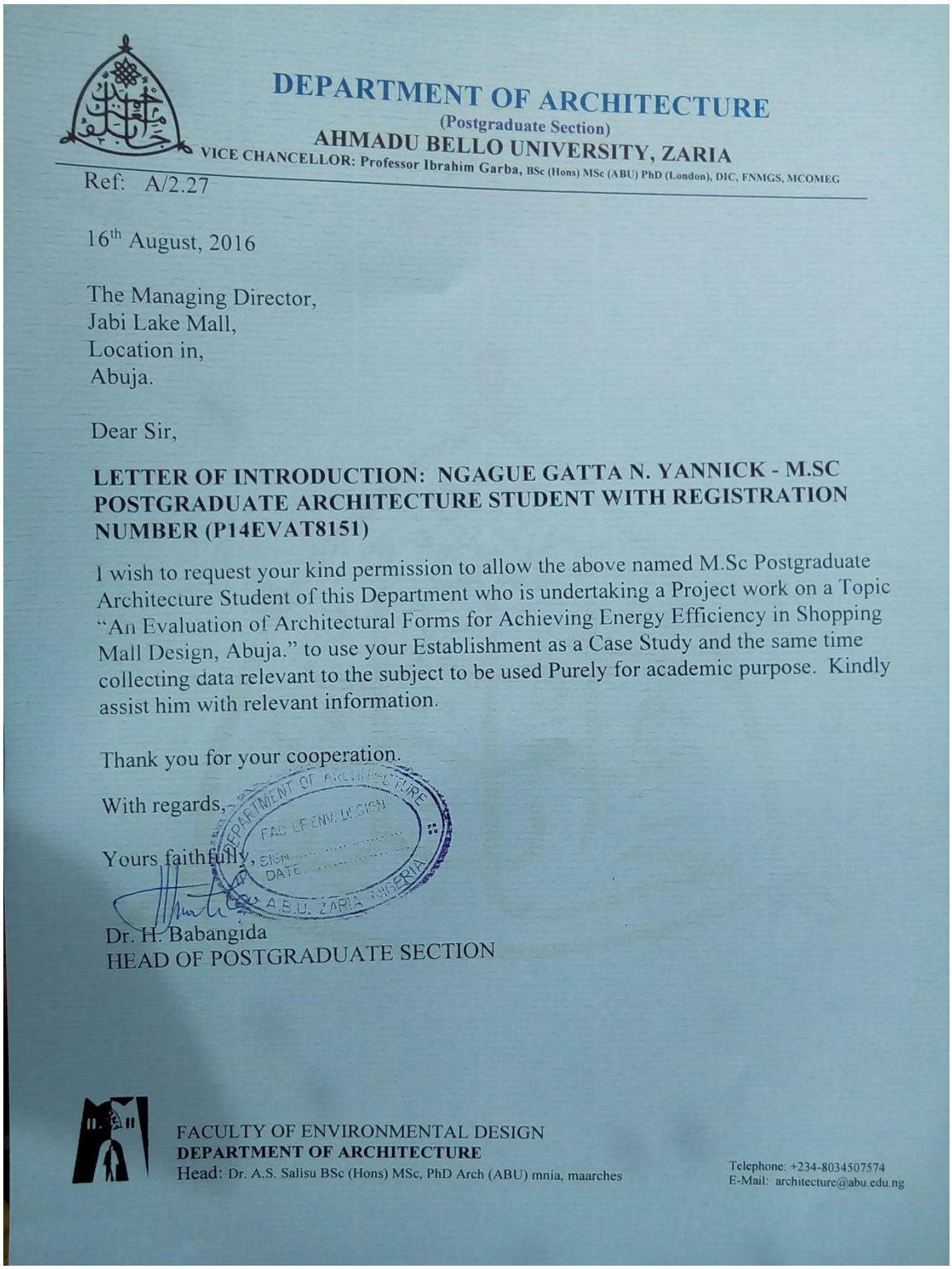
Appendix XX: 3D view showing the entrance to the basement floor



Appendix XIX: 3D view showing the outdoor restaurant



Appendix XXI: Letter of introduction for Jabi Lake Mall



DEPARTMENT OF ARCHITECTURE
(Postgraduate Section)
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: Professor Ibrahim Garba, BSc (Hons) MSc (ABU) PhD (London), DIC, FNMGS, MCOMEG

Ref: A/2.27

16th August, 2016

The Managing Director,
Jabi Lake Mall,
Location in,
Abuja.

Dear Sir,

LETTER OF INTRODUCTION: NGAGUE GATTA N. YANNICK - M.SC POSTGRADUATE ARCHITECTURE STUDENT WITH REGISTRATION NUMBER (P14EVAT8151)

I wish to request your kind permission to allow the above named M.Sc Postgraduate Architecture Student of this Department who is undertaking a Project work on a Topic "An Evaluation of Architectural Forms for Achieving Energy Efficiency in Shopping Mall Design, Abuja." to use your Establishment as a Case Study and the same time collecting data relevant to the subject to be used Purely for academic purpose. Kindly assist him with relevant information.

Thank you for your cooperation.

With regards,

Yours faithfully,

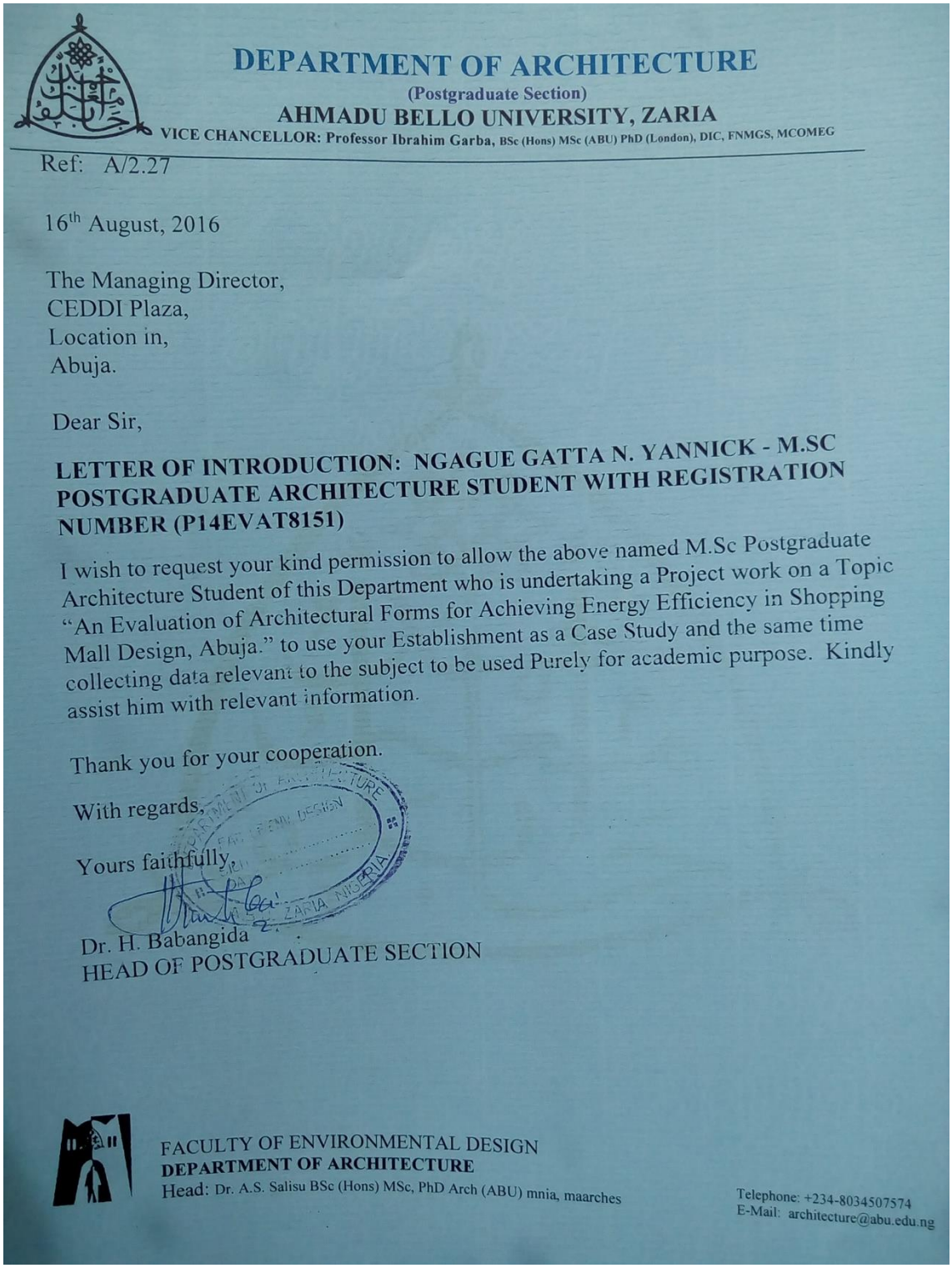
DEPARTMENT OF ARCHITECTURE
FAC. OF ENV. DESIGN
SIGN .....
DATE .....
A.B.U. ZARIA NIGERIA

Dr. H. Babangida
HEAD OF POSTGRADUATE SECTION

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. A.S. Salisu BSc (Hons) MSc, PhD Arch (ABU) mnia, maarches

Telephone: +234-8034507574
E-Mail: architecture@abu.edu.ng

Appendix XXII: Letter of introduction for Ceddi plaza



DEPARTMENT OF ARCHITECTURE
(Postgraduate Section)
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: Professor Ibrahim Garba, BSc (Hons) MSc (ABU) PhD (London), DIC, FNMGS, MCOMEG

Ref: A/2.27

16th August, 2016

The Managing Director,
CEDDI Plaza,
Location in,
Abuja.

Dear Sir,

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Thank you for your cooperation.

With regards,

Yours faithfully,

Dr. H. Babangida
HEAD OF POSTGRADUATE SECTION

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
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Telephone: +234-8034507574
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Appendix XXIII: Letter of introduction for Silverbird

DEPARTMENT OF ARCHITECTURE
(Postgraduate Section)
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: Professor Ibrahim Garba, BSc (Hons) MSc (ABU) PhD (London), DIC, FNMGS, MCOMEG

Ref: A/2.27

16th August, 2016

The Managing Director,
Silver Bird Mall,
Abuja.

Dear Sir,

LETTER OF INTRODUCTION: NGAGUE GATTA N. YANNICK - M.SC POSTGRADUATE ARCHITECTURE STUDENT WITH REGISTRATION NUMBER (P14EVAT8151)

I wish to request your kind permission to allow the above named M.Sc Postgraduate Architecture Student of this Department who is undertaking a Project work on a Topic "An Evaluation of Architectural Forms for Achieving Energy Efficiency in Shopping Mall Design, Abuja." to use your Establishment as a Case Study and the same time collecting data relevant to the subject to be used Purely for academic purpose. Kindly assist him with relevant information.

Thank you for your cooperation.

With regards,

Yours faithfully,

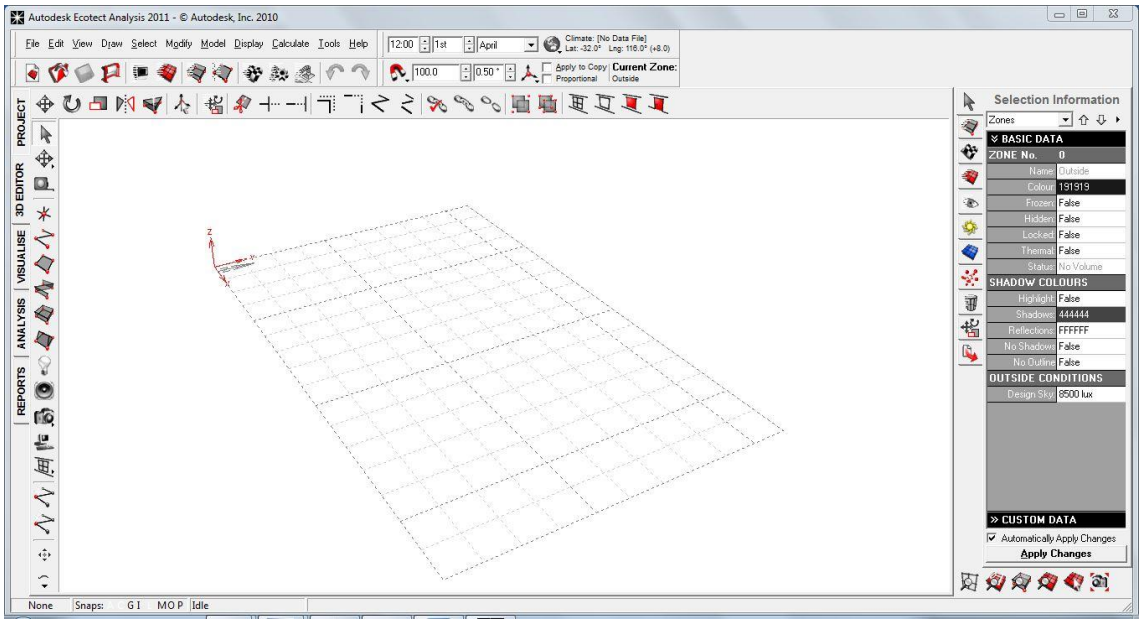
DEPARTMENT OF ARCHITECTURE
FAC. OF ENV. DESIGN
SIGN .....
DATE .....
A.B.U. ZARIA NIGERIA

Dr. H. Babangida
HEAD OF POSTGRADUATE SECTION

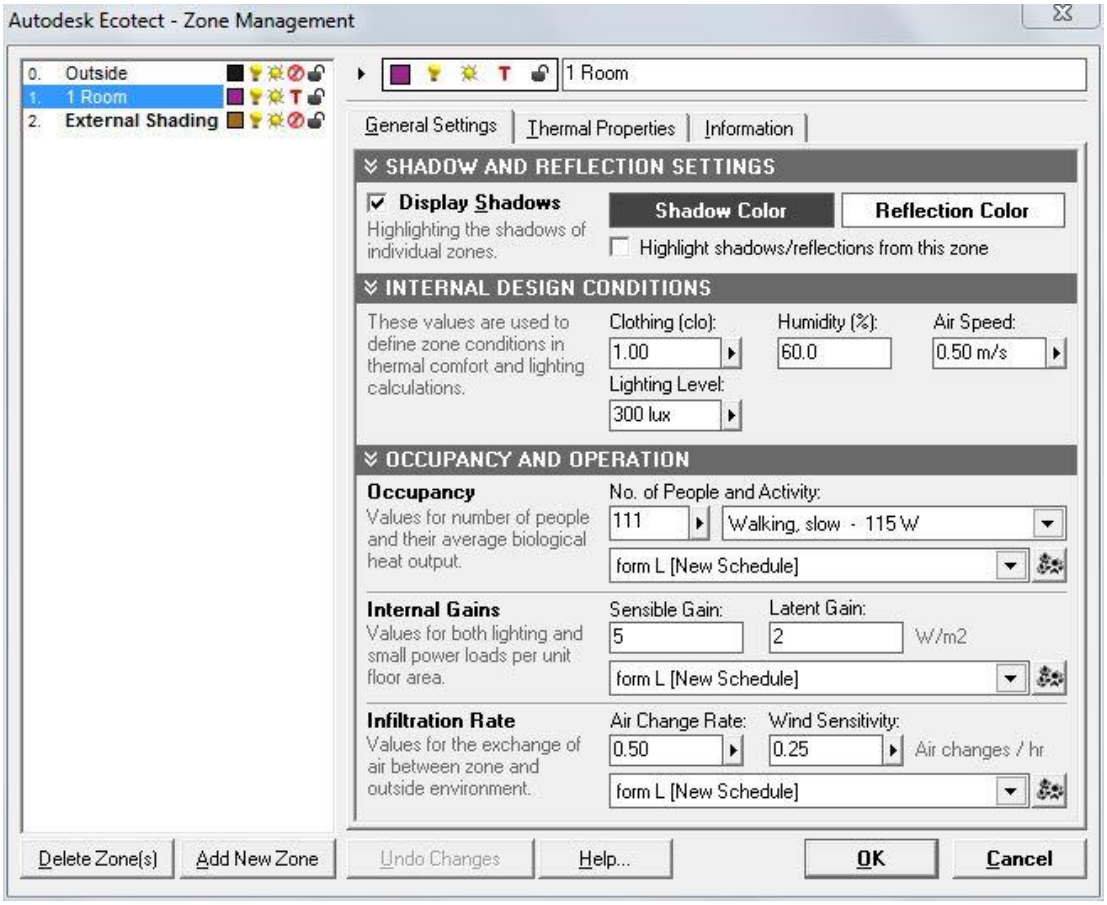
FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. A.S. Salisu BSc (Hons) MSc, PhD Arch (ABU) mnia, maarches

Telephone: +234-8034507574
E-Mail: architecture@abu.edu.ng

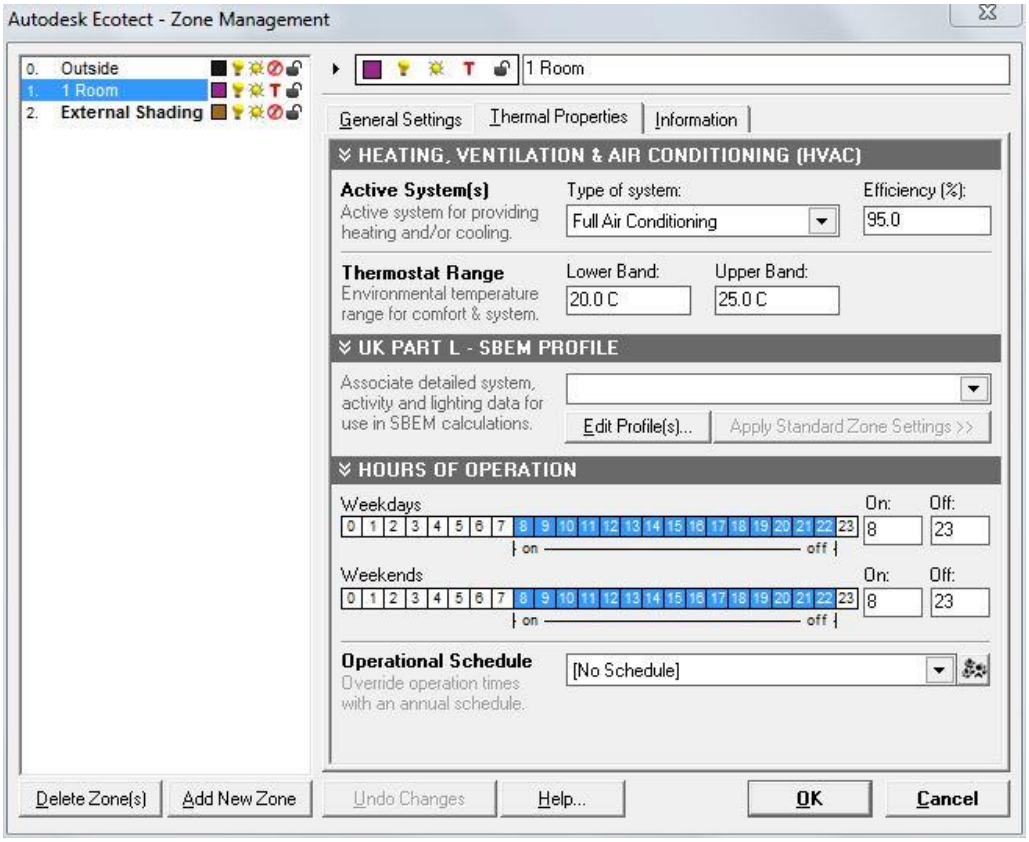
Appendix XXIV: Typical Ecotect Analysis 2011 interface



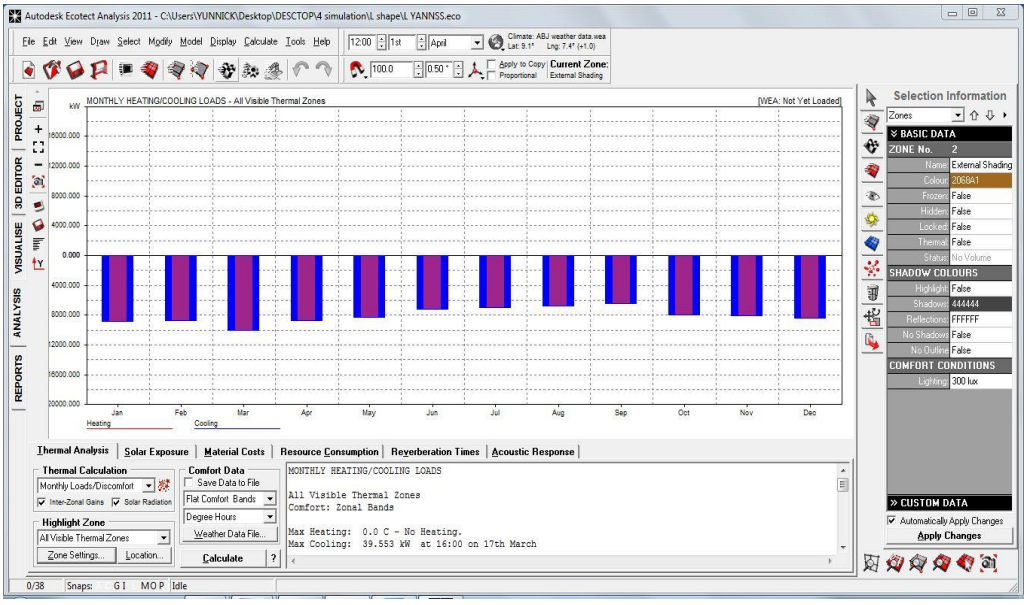
Appendix XXV: Typical general settings for all the building forms



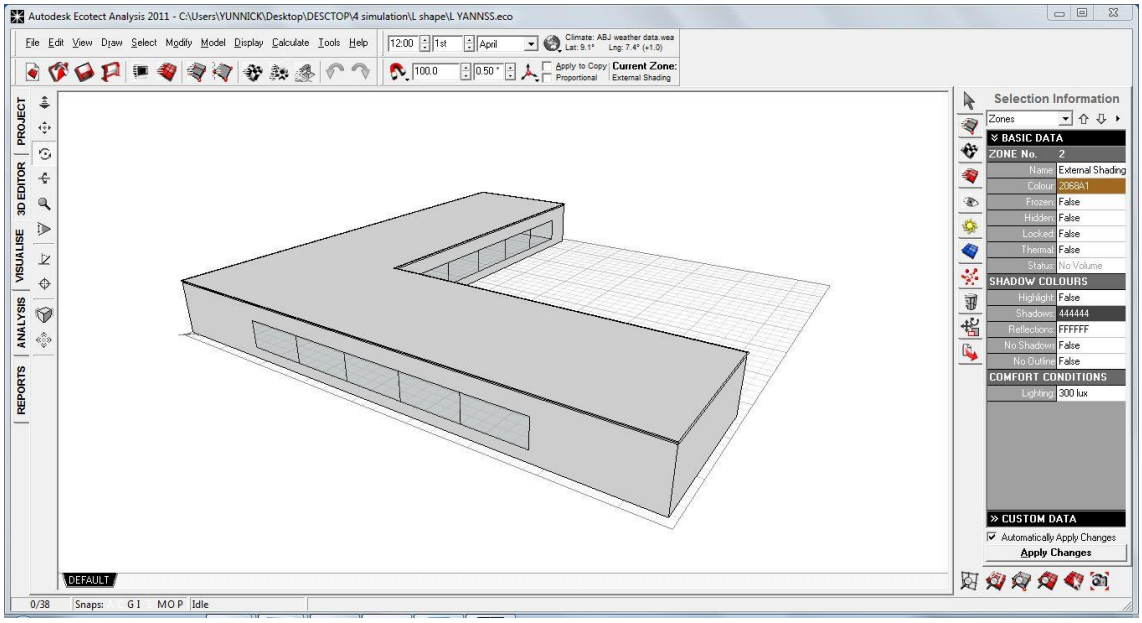
Appendix XXVI: Typical thermal properties for all the building forms



Appendix XXVII: Typical display Monthly heating/cooling loads -all visible thermal zones



Appendix XXIX: Typical Ecotect Analysis 2011 interface with a model imported from Revit 2014



Appendix XXVIII: Base case model of Silverbird as it is

