ENHANCING ENERGY EFFICIENCY THROUGH PASSIVE DESIGN PRINCIPLES IN A HOT- HUMID CLIMATE FOR SHOPPING PLAZA, LOKOJA

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By

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DECLARATION

I hereby declare that the work in this thesis entitled **"ENHANCING ENERGY EFFICIENCY THROUGH PASSIVE DESIGN PRINCIPLES IN A HOT-HUMID CLIMATE FOR SHOPPING PLAZA, LOKOJA"** is based on the original research work carried out by me in the Department of Architecture under the supervision of Arc.S.S.Tulpule and Dr. Amina Batagarawa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Eneye Ege, SERIKI ---------- ----------

(M.Sc/ Env.-Des./ 2362 / 2011-2012) Signature Date

CERTIFICATION

This thesis entitled "Enhancing Energy Efficiency through Passive Design Principles in a Hot- Humid Climate for Shopping Plaza, Lokoja" by Eneye Ege, SERIKI meets the regulations governing the award of the degree of Masters of Science in Architecture of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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(Dean, School of Postgraduate Studies) Date ……..

DEDICATION

To the Lord Jesus Christ who by his mercy saved me and made this work possible when things seem to be appearing impossible.

To my lovely parents Mr. Daniel Seriki and Mrs. Mary Seriki who have seen much in me to have given everything that is worth more than gold to me.

To all who work towards making the environment sustainable.

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ABSTRACT

Shopping plazas are major developmental facilities of urban landscape and they provide leisure, entertainment and shopping for users. The amount of energy to run such equipments are excessively high coupled with the inconsistent nature of power supply from the central electricity supply. Buildings that promote good shopping activities can be achieved through passive design. In achieving this, the architectural profession has a leading role to play in adopting passive design principles which are environmentally friendly and cost effective. This research explores passive design principles in enhancing energy efficiency in a hot-humid climate of Lokoja. This was achieved by carrying out an evaluative case study research. Cases were purposively selected from Nigeria. Instruments of data collection used are: interview, visual survey and application of energy efficient architectural checklist. The research results obtained shows that more passive design principles such as: use of atrium, use of cavity walls and use of soft landscape need to be employed and properly maximized in design of shopping plazas in Nigeria. The following are some recommendations: The Nigeria Institute of Architect (NIA) and Architect Registration Council of Nigeria (ARCON) should organize more symposiums where issues on energy efficiency and passive design will be discussed with the focus of educating practicing architects on recent researches and innovations on these issues.

TABLE OF CONTENTS

COVER PAGE ..... **Error! Bookmark not defined.**

TITLE PAGE ..... **Error! Bookmark not defined.**

DECLARATION iv

DEDICATION vi

ACKNOWLEDGEMENT vii

ABSTRACT ix

CHAPTER ONE 1

INTRODUCTION 1

1.1 BACKGROUND OF STUDY 1

1.2 STATEMENT OF RESEARCH PROBLEM 2

1.3 AIM AND OBJECTIVES 3

1.4 RESEARCH QUESTIONS 3

1.5 SCOPE OF STUDY 4

1.6 JUSTIFICATION 4

CHAPTER TWO 5

LITERATURE REVIEW 5

2.1 INTRODUCTION 5

2.2 THE CONCEPT OF ENERGY EFFICIENCY 5

2.2.1ENERGY EFFICIENT BUILDINGS 5

2.3 THERMAL COMFORT AND ENERGY EFFICIENCY 6

2.4 PASSIVE DESIGN 8

2.4.1 ADVANTAGES OF PASSIVE DESIGN 9

2.5 PASSIVE DESIGN PRINCIPLES FOR ENHANCING ENERGY EFFICIENCY ..11

2.5.1 PLANNING ASPECTS……...11
2.5.1.1 BUILDING FORM…….11
2.5.1.2 BUILDING ORIENTATION…….12
2.5.1.3 SPATIAL ORGANISATION…….13
2.5.1.4 LANDSCAPE…….14
2.5.2 BUILDING ENVELOPE……..15
2.5.2.1 BUILDING MATERIALS……15
2.5.2.2 NATURAL VENTILATION…….17
2.5.2.3 DAY- LIGHTING…….19
2.6 CLIMATE 22
2.6.1 DESIGNING WITH CLIMATE……...22
2.6.2 NIGERIAN CLIMATIC ZONES 24
2.6.2.1 HOT – DRY CLIMATE…….....24
2.6.2.2 TEMPERATE – DRY CLIMATE…….25
2.6.2.3 WARM –HUMID CLIMATE……...25
2.6.2.4 HOT – HUMID CLIMATE……...25
2.7 SHOPPING PLAZAS 25
2.7.1 CLASSIFICATION OF SHOPPING PLAZAS. 26
2.7.1 NEIGHBORHOOD SHOPPING CENTRES……...26
2.7.2 COMMUNITY SHOPPING CENTRES……..27
2.7.3 REGIONAL SHOPPING CENTRES……...27
2.7.4 SUPER-REGIONAL SHOPPING CENTRE……...27
2.8 ARCHITECTURAL DESIGN REQUIREMENTS FOR SHOPPING PLAZA.....27
2.9 INFERENCE FROM LITERATURE REVIEW. 29

CHAPTER THREE 30

RESEARCH METHODOLOGY 30

3.1 INTRODUCTION 30

3.2 RESEARCH APPROACH 30

3.3 POPULATION OF STUDY 30

3.4 SAMPLE AND SAMPLING TECHNIQUES 31

3.5 INSTRUMENTS OF DATA COLLECTION 31

3.5.1 INTERVIEW 31

3.5.2 VISUAL SURVEY 32

3.5.3 APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST 32

3.6 VARIABLES OF STUDY 32

CHAPTER FOUR 33

CASE STUDY AND DATA PRESENTATION 33

4.1 INTRODUCTION 33

4.2 CASE STUDY ONE: PALMS SHOPPING MALL, LAGOS 33

4.2.1 BACKGROUND INFORMATION 33

4.2.2 SPATIAL ORGANISATION 35

4.2.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST 37

4.3 CASE STUDY TWO: CEDDI PLAZA, ABUJA 40

4.3.1 BACKGROUND INFORMATION 40

4.3.2 SPATIAL ORGANISATION 43

4.3.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST 46

4.4 CASE STUDY THREE: IKEJA CITY MALL, ALAUSA, LAGOS STATE. 49

4.4.1 BACKGROUND INFORMATION……49

4.4.2 SPATIAL ORGANISATION.....50

4.3.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST, (SHOPRITE, ALAUSA, LAGOS STATE).....53

CHAPTER FIVE……...56

DESIGN REPORT 56

5.1 INTRODUCTION 56

5.2 GEOGRAPHICAL LOCATION OF LOKOJA, NIGERIA 56

5.3 SITE SELECTION CRITERIA 60

5.4 CLIMATIC ANALYSIS OF THE SITE. 61

5.4.1 TEMPERATURE.....61

5.4.2 RAINFALL..... 62

5.4.3 SUNSHINE.....63

5.4.4 RELATIVE HUMIDITY.....64

5.4.5 WIND……65

5.5 PHYSICAL ANALYSIS OF SITE.....66

5.5.1 LOCATION AND DESCRIPTION.....66

5.5.2 ACCESSCIBILITY.....67

5.5.3 GEOLOGY……...68

5.5.4 TOPOGRAPHY……69

5.5.5 VEGETATION.....70

5.5.6 UTILITIES.....70

5.5.7 SUNRISE AND SUNSET.....71

5.6 DESIGN BRIEF AND DEVELOPMENT 71
5.7 DESIGN PHILOSOPHY 72
5.7.1 CONCEPT OF DESIGN…… 72
5.7.2 SITE ZONING CONCEPT..... 73
5.7.3 SITE PLAN..... 74
5.7.4 PLAN CONCEPT..... 75
5.7.4.1 GROUND FLOOR PLAN..... 76
5.7.4.2 FIRST FLOOR PLAN..... 77
5.7.4.3 SECOND FLOOR PLAN..... 78
5.7.4.4 THIRD FLOOR PLAN..... 79
5.7.5 CIRCULATIONS..... 80
5.7.6 PLAZA AMENITIES..... 81
5.7.7 LANDSCAPE FEATURES..... 82
5.7.8 BUILDING FAÇADES..... 83
5.8 THE CONSTRUCTION TECHNOLOGY..... 85
5.8.1 CONSTRUCTION METHOD..... 85
5.8.2 FLOORS..... 86
5.8.3 SKIRTING..... 86
5.8.4 WALL..... 86
5.8.5 CEILING……..88
5.8.6 FOUNDATIONS REQUIREMENTS..... 88
5.8.7 FOUNDATION CHOICE..... 88
5.9 MATERIALS, FINISHES AND SERVICES 88
5.9.1 FIRE..... 90

5.9.2 SECURITY....90
5.9.3 DISPOSAL SYSTEM....91
5.9.4 PLUMBING/ WATER DISTRIBUTION SYSTEM....91
5.9.5 STORM WATER DRAINAGE....91
5.9.6 POWER SUPPLY....91
CHAPTER SIX....92
CONCLUSION AND RECOMMENDATION....92
6.1 INTRODUCTION....92
6.2 CONCLUSION....92
6.3 CONTRIBUTION TO KNOWLEDGE....93
6.4 RECOMMENDATION....93
REFERENCES....94

LIST OF FIGURES

Figure 2.1: Window overhangs…….....08

Figure 2.2: Effect of building form on energy efficiency…….....12

Figure 2.3: Building orientation……13

Figure 2.4: Insulated brick cavity walls absorb heat thereby cooling the interior…….....16

Figure 2.5: Solar reflective glass reflects heat thereby enhancing the cooling of the building interior…….....17

Figure 2.6: Details of a sunlight tube…….....20

Figure 2.7: Sunlight tube captures day-lighting from both the roof top and the exterior walls of a building…….....20

Figure 2.8: Reflection process through a sunlight tube.……21

Figure 2.9: Worldwide climate classifications. ……23

Figure 4.1: Ground floor plan of Palms shopping mall, Lagos…….....36

Figure 4.2: Spatial organization of basement plan, Ceddi plaza, Abuja…….....43

Figure 4.3: Spatial organization of ground floor plan, Ceddi plaza Abuja…….....44

Figure 4.4: Spatial organization of first floor plan, Ceddi plaza Abuja……..44

Figure 4.5: Spatial organisation of second floor plan, Ceddi plaza Abuja……45

Figure 4.6: Ground floor plan with the spatial organisation of Ikeja city mall, Alausa, Lagos…….....51

Figure 5.10: Map of Nigeria with location of Kogi State…….....57

Figure 5.11: Map of Kogi State with the Location of Lokoja Local Government Area…...58

Figure 5.12: Map of Lokoja Urban Area …….....59

Figure 5.13: Rating scale of site selected …….....60

Figure5.14: Average Annual Temperature…….....62

Figure 5.15: Mean Annual Sunshine of Lokoja……....64

Figure 5.16: Location drawing of Proposed Site……...66

Figure 5.17: Site Analysis of Proposed Site……..67

Figure 5.18: Design concept of the proposed Lokoja shopping plaza……..73

Figure 5.19: Site zoning concept of the proposed Lokoja shopping plaza……...74

Figure 5.20: Site plan of the proposed Lokoja shopping plaza…….75

Figure 5.21: Ground floor plan of the proposed Lokoja shopping plaza…….76

Figure 5.22: First floor plan of the proposed Lokoja shopping plaza…….....77

Figure 5.23: Second floor plan of the proposed Lokoja shopping plaza…….....78

Figure 5.24: Third floor plan of the proposed Lokoja shopping plaza…….79

Figure 5.25: Details of an escalator used in the proposed Lokoja shopping plaza……..80

Figure 5.26: 3D view of the children outdoor recreation park of the proposed Lokoja shopping plaza ……..81

Figure 5.27: Interior view of the anchor store in the proposed Lokoja shopping plaza.....82

Figure 5.28: 3D view of the car park in the proposed Lokoja shopping plaza…….82

Figure 5.29: Good use of landscape design in the proposed Lokoja shopping plaza…....83

Figure 5.30: Elevation views of the proposed Lokoja shopping plaza ……84

Figure 5.31: 3D view of the proposed Lokoja shopping plaza…….85

Figure 5.32: Sections of the proposed Lokoja shopping plaza ……87

LIST OF PLATES

Plate I: Good use of climbers and trees to reduce penetration of heat into the building…….14

Plate II: Approach view with parking spaces in Palms shopping mall, Lagos…….....34

Plate III: Use of curtain walls as means of natural ventilation and lighting of Palms Shopping mall, Lagos …….34

Plate IV: Natural lighting augmented by use of artificial lighting in Palms shopping mall, Lagos…….35

Plate V: Interior spatial view of Palms shopping mall at a glance……36

Plate VI: Approach view of Ceddi plaza, Abuja with good use of Landscape trees……40

Plate VII: Approach view with car park and use of glass as means of ventilation and lighting of the interior of Ceddi plaza, Abuja…….41

Plate VIII: Use of glass for roofing and it serves as an efficient means of interior lighting of Ceddi plaza, Abuja…….41

Plate IX: Use of curtain wall and it serves as an efficient means of interior lighting of Ceddi plaza Abuja……42

Plate X: Use of atrium as an efficient means of interior lighting of Ceddi plaza, Abuja.....42

Plate XI: Interior view of the eatery and how natural lighting is augmented by use of artificial lighting**,** Ceddi plaza Abuja…….....45

Plate XII: Interior view of a boutique store, Ceddi plaza Abuja……....46

Plate XIII: Approach view with use of glass windows to enhance day-lighting and ventilation of Ikeja city mall, Alausa, Lagos…….....49

Plate XIV: Car park with few trees and hard landscape of Ikeja city mall, Alausa, Lagos. ……50

Plate XV: Interior view of supermarket showing the spatial arrangement of goods and how natural lighting is augmented by use of artificial lighting, Ikeja city mall, Alausa, Lagos State…….51

Plate XVI: Use of Escalator and Artificial Lighting to supplement Natural Lighting, Ikeja city mall, Alausa, Lagos State……...52

Plate XVII: Use of glass for roofing and these serves as an efficient means of interior lighting of Ikeja city mall, Alausa, Lagos State……52

Plate XVIII: Zone eight junction, Lokoja…….68

Plate XIX: Access road to proposed site ……..68

Plate XX: Proposed site is characterized by Lateritic soil type ……...69

Plate XXI: Topography of proposed site …….....69

Plate XXII: Vegetation of proposed site ……..70

LIST OF TABLES

Table 4.1: Assessment of the application of energy efficient architectural features (Palms shopping mall, Lagos)……...39

Table 4.2: Assessment of application of energy efficient architectural features (Ceddi plaza, Abuja)……48

Table 4.3: Assessment of application of energy efficient architectural features (Ikeja city mall, Alausa, Lagos State)……..54

Table 5.1: The monthly mean rainfall (mm) of Lokoja from 1981-2010……..63

Table 5.2: Mean monthly humidity (%) of Lokoja from 1961-1999…….65

LIST OF APPENDIX

Appendix1: Site Location…….……99

Appendix 2: Site Analysis…….……..100

Appendix3: Site Plan…..…….……101

Appendix 4: Ground Floor Plan (Working Drawing) …….……...102

Appendix5: First Floor Plan (Working Drawing) …….…….103

Appendix6: Second Floor Plan (Working Drawing) …….……104

Appendix 7: Third Floor Plan (Working Drawing) …….……..105

Appendix 8: Elevation Plan (Presentation Drawing) …….……106

Appendix 9: Elevation Plan (Presentation Drawing) …….……107

Appendix 10: Sections…..…….…….108

Appendix 11: Finishes Schedules …..…….……...109

Appendix 12: Finishes Schedules …..…….……...110

Appendix 13 : Letter of Introduction for Case Study…..…….……111

Appendix 14 : Interview Questions…..…….…….112

Appendix 15 : Energy Efficient Architectural Features Check-List……113

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

One of the vital functions of buildings is the protection of its occupants from harsh and unpleasant weather. The primary target of environmental building design is the creation of a comfortable and energy efficient internal environment. Observations by Lawal, Akinbami and Akinpade (2012) in a study on environment have shown that most buildings utilize more of active energy for the both thermal and visual comfort, thus showing that these buildings are not passive in nature.

Passive design is a term that describes an age-old concept: designing buildings that takes advantage of the climate, free energy of the sun and that respond to their natural environment. Stewart (2009) assert that passive design maximize the advantage of natural climate for heating and cooling of interior living spaces. Passive design encompasses a wide range of strategies which maximizes the natural climate thereby resulting in energy-efficient building design and decreases energy use per unit of output thereby enhancing energy conservation. This concept emphasizes architectural design approaches that minimize building energy consumption by integrating conservative energy-efficient architectural features, such as appropriate amounts of fenestration, an efficient building envelope, thermal mass and increased day lighting design (Sanford and Stamas, 2008). Shopping plazas are vital because they are paraphernalia to fill the lacuna created by a need for suitable distribution of goods to a fast increasing population. Shopping plazas are built to replicate the retail offer in established city centres, providing comparison shopping in a

‘continuous’ selling space on goods such as clothing, foot-wear, furnishing, and services such as restaurants and cinemas, all under one roof. Shopping plazas attempts to replicate the commercial ‘live centre’ of cities, artificially devised to recreate the same intensity of urban buzz (if not more) removed from city streets (Fong, 2003).

Heating and cooling of buildings account today for high energy consumption in most shopping plazas, malls, offices, hotels, and other public buildings (Adamson & Aberg, 1993). Life cycle analyses have demonstrated that the majority of energy in a building is consumed in operational energy or during the post occupancy phase of a building's life (Cement and Concrete Association of Australia, 1994). The International Hotel and Restaurant Association (2005), also establishes that in many countries, especially in the industrialized world, buildings account directly for over 50% of total energy consumption, and even more when one includes what it costs to manufacture the materials required for construction.

1.2 STATEMENT OF RESEARCH PROBLEM

In developing countries like Nigeria especially in urban settings, passive design principles though desirable are in deficit. As living standards rise people install cooling equipments to improve thermal comfort (Adamson & Aberg, 1993). For buildings such as plazas, the amount of energy to run such equipments are excessively high coupled with the inconsistent nature of power supply from the central electricity supply but a building interior that is thermally comfortable and promote a good shopping activities can be achieved through passive design.

Therefore there is an urgent necessity to employ cost saving measures which are environmentally friendly such as passive design principles in shopping plaza designs in order to enhance energy efficiency and conserve energy.

1.3 AIM AND OBJECTIVES

1.3.1 Aim

To explore passive design principles in enhancing energy efficiency in a hot-humid climate of Lokoja in a shopping plaza.

1.3.2 Objectives

a. To study the concept of passive design principles that can enhance energy efficiency;
b. To identify the passive design principles applicable to a hot-humid climate that can enhance energy savings;
c. To propose energy efficient design that would incorporate passive design principles in a shopping plaza in Lokoja.

1.4 RESEARCH QUESTIONS

This research seeks to answer the following questions:

a. What passive design principles can be employed to enhance energy efficiency in a hot-humid climate?
b. What is the possible percentage of energy savings achieved by adopting passive design principles?

c. What are the passive design principles and the architectural design requirements applicable in shopping plaza design?

1.5 SCOPE OF STUDY

The research focuses on passive design principles applicable in a tropical hot-humid climate of Nigeria which enhances energy efficiency in a shopping plaza thereby boosting the comfort of shoppers and conserving energy. This research will also explore the concepts behind various outstanding plazas in Nigeria and the connection of these concepts to passive design principles. Passive design solutions will be applied to the design problems realized and used in the proposal of Lokoja plaza.

1.6 JUSTIFICATION

Shopping plazas are very necessary because they are tools to fill the gap created by a need for convenient distribution of goods to a fast growing population. This enables residents to acquire their needed goods and services. With the rapid geometric increase and influx of people into Lokoja (Alabi, 2009), there is need to meet the shopping needs of it residents. The concept of enhancing energy efficiency through passive design principles has also become very vital in an area like Lokoja which has a climate that is hot throughout the year i.e an average daily temperature range between 31.4°c and 33.2°c for a greater part of the year. Furthermore, the inconsistent nature of power supply and the high cost of cooling equipments in addition to the green house gas emissions from such equipments have prompted the need on how to enhance energy efficiency and achieve a thermally comfortable shopping area for shoppers in a tropical hot-humid climate of Lokoja.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter gives a detail review of the concepts, theories and models of; energy efficiency, energy efficient buildings, thermal comfort and passive design. In-addition, Nigerian climatic zones, types of shopping plazas, the architectural design requirements of shopping plazas and are discussed.

2.2 THE CONCEPT OF ENERGY EFFICIENCY

Encarta dictionary defines efficiency as achieving effectiveness without any wasted energy. Energy efficiency is a cost effective means of achieving an environmental friendly design that saves money and combats green house gas emissions. Community Research and Development Centre CREDC (2009) emphasize that energy efficiency has become a vital and an urgent aspect of sustainable design which is presently a global demand. Janssen (2004) asserts that an improvement in energy efficiency is considered as any action undertaken by a producer or user of energy products, which decreases energy use per unit of output, without affecting the level of service provided.

2.2.1ENERGY EFFICIENT BUILDINGS

United Nations (1991) defines energy efficient buildings as buildings that have minimum levels of energy inputs. Well-designed energy efficient buildings maintain the best environment for human comfort while minimizing the cost of energy. According to the Development and Land Use Policy Manual for Australia (DLUPM) (2000), the objectives

of energy efficient buildings are to improve the comfort levels of the occupants and reduce energy use (electricity, natural gas, etc) for heating, cooling and lighting. Chowdhury (2006) assert that increased energy efficiency in buildings can provide financial benefits through reduced electricity bills and have a role in reducing total societal energy use.

2.3 THERMAL COMFORT AND ENERGY EFFICIENCY

Thermal comfort is a subjective sensation. It is that state of mind that expresses satisfaction with the thermal environment. Alternatively, it is that state of mind that does not express dissatisfaction with the thermal environment (Ogunsote,1991). It is equivalent to conditions in which human beings can sleep soundly and work comfortably and when there is a minimum demand on the thermo-regulatory mechanisms of the body. The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE), (2009) defines thermal comfort as the state of mind that expresses satisfaction with the surrounding environment. Factors such as temperature, ventilation, humidity and radiant energy affect thermal comfort, and for humans the comfort zone is within a very narrow range of conditions. Exterior climate conditions alter the acceptable interior conditions. Energy efficiency is achieved when occupant comfort is maintained through limited reliance on mechanical space conditioning.

The following parameters are factors that enhance energy efficiency and promote thermal comfort of occupants in a building:

a) Window size

b) Window orientation

c) Shading device

(a) Window Size

Size of window openings are important design elements for admitting daylight, air flow, providing cross-ventilation and thermal comfort. Gut and Ackerknecht (1993) recommend that windows should be large and fully openable, with inlets of a similar size on opposite walls for proper cross-ventilation in hot-humid climates.

(b) Window Orientation

Gut and Ackerknecht (1993) note that "openings in hot and humid regions should be placed according to the prevailing breeze so that air can flow through the internal space thereby enhancing thermal comfort". Ahmed (1987) in her study on the effects of climate on the design and location of windows for buildings in Bangladesh states that windows should be avoided on western walls as it is almost impossible to shade it in all seasons. Liping (2007) also emphasize on avoiding east or west facing rooms for the purpose of thermal comfort and energy use.

(c) Shading Devices

Shading is the first line of defense to reduce the ingress of solar gain, and it can also reduce the effective temperature experienced by an occupant by up to $8^{o}C$ (Nick and Koen, 2005). Windows can be shaded with overhangs to prevent direct solar radiation from penetrating the building and this is illustrated in Fig. 2.1. Watson and Labs (1983) categorized shading devices into three categories namely solar transmittance of glazing materials, interior shading and exterior window shades. Solar transmittance is defined as the heat admitting or rejecting characteristic of the glazing materials. Watson and Labs (1983) and Gut and Ackerknecht (1993) advice against heat absorbing, heat reflecting and tinted glazing. According to Watson and Labs (1983) heat absorbing clear and tinted glazing reduces solar

transmission by absorbing heat within the material itself. They state that the absorbed heat can be uncomfortable to occupants because it adds heat to the interior by conduction and thermal radiation.

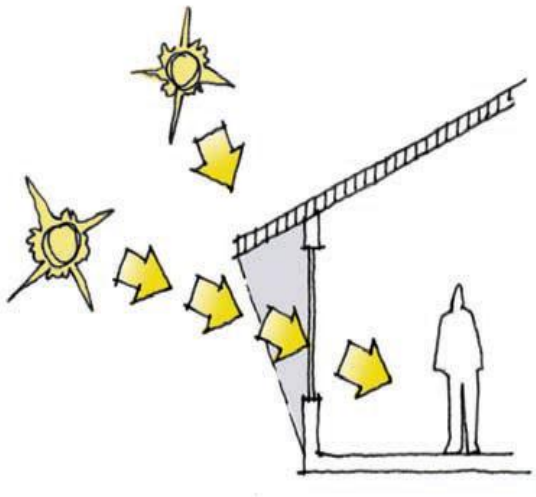


Fig. 2.1: Window overhangs (Source: Passive design toolkit, 2009)

2.4 PASSIVE DESIGN

Passive design is one of the oldest and most effective energy conservation techniques. It literally goes back to the cave man. Cave dwellings in the northern hemisphere often had openings toward the south so that the sun could heat the interior rock during the day, and this heat was then released into the cave at night (Shearer, 2010). The theory remains the same, but modern technology and building materials have made it vastly more efficient. Passive design includes a wide range of strategies which maximizes energy flow from natural climate into the design, construction and management of a building. Passive design strategies in architecture entail the use of non energized elements to achieve an optimum design of a building that is more climatically responsive and energy economical. Passive design doesn't move the solar energy; it uses it right where it's collected (Shearer, 2010).

This means that the collection spots must be strategically placed in the first place so that they perform some needed function inside the building. For example, if a building has a lot of windows that regularly get a lot of sunshine, the interior will be naturally heated by the sun; this is an example of solar energy being collected and passively used. A wide variety of features can help the process, from placement of windows to the orientation of building in addition to the planting of flowers for landscaping. For example, making use of landscape lights that are powered by the sun is one of the most common examples of passive design. The key to designing a passive design building is to best take advantage of the local climate (Shearer, 2010). Elements to be considered include window placement and glazing type, thermal insulation, thermal mass, and shading. A building designed using passive design can save huge amounts of money over the life of the building.

Solar cooling systems are used for cooling and ventilation of buildings. The first concern in solar cooling is how to avoid cooling loads. If excessive heating can be minimized, then the problem of providing sufficient cooling will be half solved. Cooling loads are due to sunshine through windows or on the outside of walls or roofs, hot air entering the building or heat conducted from hot outside air to the inside. Natural cooling systems are a passive cooling system that depends solely on natural means for the cooling of buildings.

2.4.1 ADVANTAGES OF PASSIVE DESIGN

Tahmina(2009) provides the following as the advantages of passive design:

(i) Cost Savings

(ii) Energy Efficiency

(iii) Aesthetics

(iv) Enhance Comfort

(v) Environmentally Friendly

(i) Cost Savings: Passive design is a cost saving way to heat a building. The Light House Sustainable Building Centre (2011) establishes that passive design and optimal building envelope performance can help reduce utility bills and the need for mechanical systems and their associated costs. The United States Department of Energy (2009) estimates that incorporating passive design elements into buildings and homes can reduce heating bills by as much as 50 percent.

(ii) Energy Efficiency: Passive design is a clean energy resource that can decrease the need for fossil fuels. Passive design principles help reduce a building's demand for lighting, heating and cooling. Lower energy bills all year round.

(iii) Aesthetics: The New Mexico Solar Energy Association (2009) believes that one advantage of passive design is the aesthetic appeal of the architecture itself.

(iv) Enhances Comfort: The intent of passive design is to flood the building with natural light. Passive design buildings are more airy and well lighten and with more spacious feeling than a conventional structure. Careful placement of window on the earth sheltered sides ensures that abundant daylight enters all sides of the building. Passive design buildings are warmer in winter, cooler in summer (even during a power failure).

(v) Environmentally Friendly: Passive design is clean, renewable energy which doesn't contribute to global warming, acid rain or air pollution. Passive design reduces greenhouse gases that contribute to global warming because it relies on the natural climate and solar energy, a renewable, nonpolluting resource.

2.5 PASSIVE DESIGN PRINCIPLES FOR ENHANCING ENERGY EFFICIENCY

Passive design principles have proven to be extremely effective and can greatly contribute in decreasing the cooling load of buildings. Tahmina (2009) assert that there are principles classified into planning aspects and building envelope that help to guide the passive design process in order to achieve energy efficiency in a design. These are:

1. Planning Aspects:
    (a) Building form
    (b) Building orientation
    (c) Spatial organization
    (d) Landscape
2. Building Envelope:
    (a) Building material
    (b) Natural ventilation
    (c) Day-lighting

2.5.1 PLANNING ASPECTS

2.5.1.1 BUILDING FORM

Givoni (1998) states that building form largely depends on whether the building is planned to be air-conditioned or if it is intended to rely on natural ventilation. He recommends a compact shape for the building dwelled by people who use air conditioners and open forms for naturally ventilated buildings. Gut and Ackerknecht (1993) have suggested forms with large surfaces rather than compact buildings as large surfaces favour ventilation and heat emission at night-time. The building forms should thus be open, outward oriented and not compact. Effect of building forms on energy efficiency is illustrated in Fig. 2.2.

Compactness of the building minimizes the surface area of the building envelope, resulting in a reduction of the heat gain through the envelope.

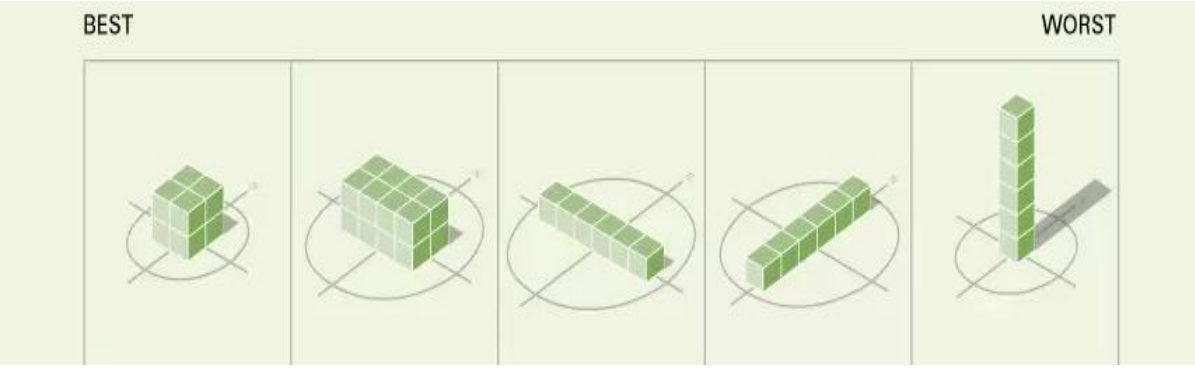


Fig. 2.2: Effect of building form on energy efficiency. (Source: Passive design toolkit, 2009)

2.5.1.2 BUILDING ORIENTATION

Building orientation is the position of the building on site taking into consideration the sunrise and sunset. Proper building orientation plays an important role in reducing cooling loads in tropical hot-humid climates where there is a high level of radiation from the sun. This can be achieved by reducing exposure of buildings to the sun. East and west facing walls receive the highest intensities of radiation, especially during hot periods. These walls should thus normally be kept as small as possible and contain as few and small openings as possible. The application of orientation in enhancing energy efficiency is illustrated in Fig.2.3. In general, north and south facing is the best preferred orientation.

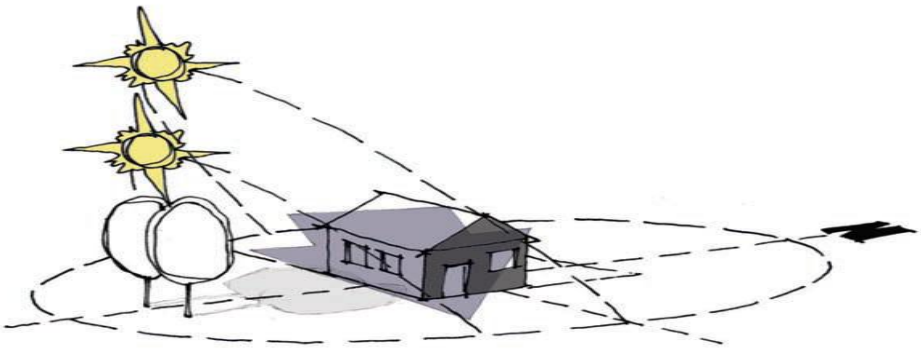


Fig. 2.3: Building orientation. (Source: Passive design toolkit, 2009)

2.5.1.3 SPATIAL ORGANISATION

According to Gut and Ackerknecht (1993) assert that the arrangement of rooms depends on their function and according to the time of the day, they are in use. A study of spatial organization by Mowla (1985) in Dhaka, Bangladesh reveals that eastern facades in Dhaka get morning sun throughout the year amounting to almost 700 W/ m2. He advises that rooms which are used later during the day can be arranged on the east side as they are warm in the morning and cooled down in the afternoon. Mowla (1985) furthermore assert from his studies on spatial organization in Dhaka that western facades get afternoon sun with a radiation of about 700 W/ m2 throughout the year. He suggests placing rooms that are used in the morning on the west side as they are cooler in the morning and heat up in the afternoon. He also stresses that southern facades in summer, do not get any sun throughout the day. However, in summer, northern facade gets low altitude morning and evening sun. He claims that rooms facing north and south remain relatively cool if provided with adequate shading.

2.5.1.4 LANDSCAPE

Landscaping is an effective means of protecting the building from unwanted solar gains and redirecting wind flow to enter the house for natural ventilation. Plants prevent most solar radiation from striking surfaces made of concrete, bricks and asphalt. Modification of the surrounding climate and irradiance reduction achieved by plants is an efficient means of lowering energy usage for space cooling and it has been shown that about 25-80% savings on air conditioning can be achieved with proper landscaping (Nyuk and Yu, 2009). Raeissi and Taheri (1999) acknowledge the beneficial effects of trees. They state that planting of trees can result in energy saving, reduction of noise and pollution, modification of temperatures and relative humidity and psychological benefits on humans. Their study on proper tree planting for energy saving concludes that the cooling loads of a house can be reduced by 10%- 40% by appropriate tree planting. They also note that trees can act complementary to window overhangs, as they are better for blocking low morning and afternoon sun which is illustrated in Plate I.



Plate I: Good use of climbers and trees to reduce penetration of heat into the building, Rockhurst University, Kansas city, U.S.A. (Source: Ogunsote,Prucnal-Ogunsote,Adegbie,2005)

2.5.2 BUILDING ENVELOPE

2.5.2.1 BUILDING MATERIALS

The selection of material for construction is very vital in hot-humid climatic region of Nigeria for achieving optimum comfort. The thermal properties of materials which affect the rate of heat transfer in and around the building and consequently affect the thermal condition and comfort of the occupants include the following:-

(a) Thermal Conductivity: This is the ability of materials to conduct heat.

(b) Thermal Stability: The ability of materials to retain its basic physical and mechanical properties and inner structure when heated.

(c) Thermal Resistance: This is the ability of material to resist heat flow.

(d) Heat Capacity: This is the ability of material to absorb heat when its temperature is raised.

(e) Surface Coefficient: This determines the rate of heat exchange between the surface and the surrounding air.

(f) Surface Characteristics: This determines reflectivity, absorptive and emissive of a material, for example, colour, texture, etc.

Thermal mass is the ability of a material to absorb, hold and gradually release heat. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber has low thermal mass. Appropriate use of thermal mass throughout a building can make a big difference to comfort and cooling bills (Chris, 2008). This is illustrated in Fig. 2.4 using insulated brick cavity walls. For instance, Sustainable Energy Authority, Victoria, Australia assert that the use of construction materials with high thermal

mass such as insulated brick cavity walls can reduce total heating and cooling energy requirements by up to 25-30% compared to a home built with a low thermal mass. Buildings in the tropics using high thermal mass materials should be well shaded to avoid heat gain and insulated internally to reduce heat transfer.

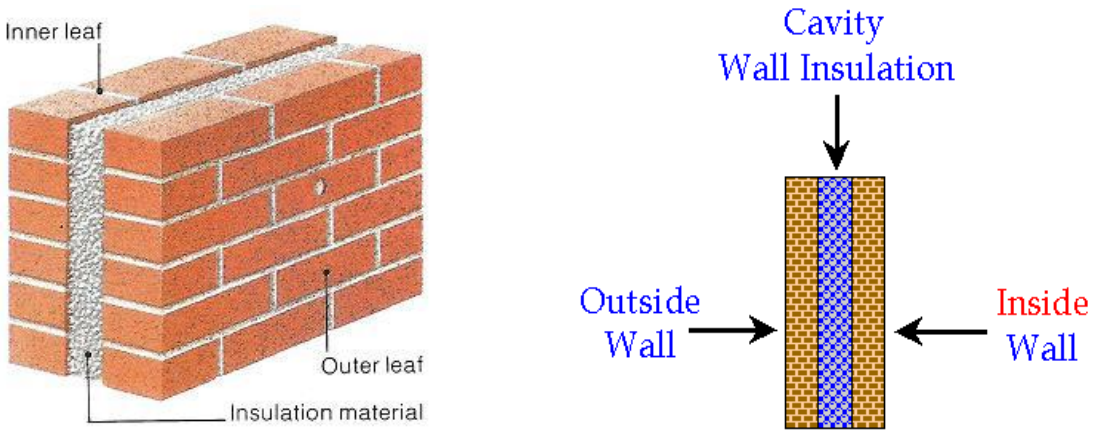


Fig. 2.4: Insulated brick cavity walls absorb heat thereby cooling the interior (Source: www.smarthousingmanual.com, 2002).

Passive design can be achieved and energy efficiency can be enhanced through the use of appropriate construction materials. For instance, the use of solar reflective glass in buildings helps to reflect heat because the glass has been treated with metallic coating in order to reflect heat rather than absorbing it. This type of glass is used in environmentally friendly construction with the goal of reducing heat gain and loss, making structures much cheaper to heat and cool over the course of the year and enhancing energy efficiency. This is illustrated in Fig. 2.5.



Fig. 2.5: Use of solar reflective glass to enhance the cooling of the building interior (Source: www.smarthousingmanual.com, 2002).

2.5.2.2 NATURAL VENTILATION

Ventilation is the movement of fresh air to replace hot air. According to Watson and Labs (1983) ventilation has three useful functions in the building sector. It is used to:

(a) Satisfy the fresh air needs of the occupants

(b) Increase the rate of evaporative and sensible heat loss from the body

(c) Cool the building interior by an exchange of warm indoor air by cooler outdoor air.

Givoni (1998) also points out that cross-ventilation can be used to enable faster cooling and better ventilation. He stresses that building layout which provides good potential for cross-ventilation is more appropriate for developing countries in hot-humid regions where the vast majority of people cannot afford to buy air conditioners. He recommends a spread out building with openable windows to facilitate cross-ventilation. Watson & Labs (1983) explain that "natural ventilation can be generated by the following two forces:

(a) Temperature difference between the outdoors and the indoors

(b) Wind flow against the building

(a) Temperature Difference Between The Outdoors and the Indoors.

When a mass of air inside the room is heated, it expands and becomes less dense and rises. If openings are provided at different heights on the building's envelope, the indoor pressure is higher at the upper opening and lower at the lower opening. This pressure differences generate an inward flow at the lower opening and an outward flow at the upper one. When thermal forces discharge air from a building, the action is termed as stack effect.

(b) Wind Flow Against The Building.

As wind blows against a building, the air in front of the building is compressed and creates a pressure zone. The air next to the leeward wall and above the roof expands and the pressure is reduced, creating a suction zone. These pressure differences between any two points on the building's envelope determine the possibility for ventilation when openings are provided at these points (driving force) and if air can flow inside the building through openings with the higher pressure to openings exposed to a zone with lower pressure. Cross- ventilation is defined as the situation in which outdoor air can flow in through inlet openings, located in the pressure zone, and flow out via outlet openings located in the suction sections of the building.

Other common natural ventilation and thus cooling techniques is the use of courtyards. A study of courtyards by Ali (2007) in Dhaka uses "two typologies of six storied residential apartments, namely, the courtyard type and the non-courtyard type for comparison of thermal data. The results of this comparative analysis reveal that the buildings with courtyards are much more comfortable and thus desirable for the dwellers of Dhaka, which also has a tropical hot-humid climate like Lokoja.

2.5.2.3 DAY- LIGHTING

Day-lighting reduces the need for electric lighting and contributes to bright and productive indoor environments. The selection, size and placement of windows will determine the level of natural day-lighting in a room or building. Things to consider are the path of the sun and seasonal variations, optimal amount of day-light, glare control and the resultant heat gains and losses associated with the choice of windows and frames**.** Krarti (2005) conducted a simplified analysis method to evaluate the potential of day-lighting to save energy associated with electric lighting use in commercial buildings. Performance of day-lighting are investigated for several combinations of building geometry, window opening size, and glazing type for four geographical locations in the United States. Their simulation results indicate that day lighting saves up to 31% of the total annual energy use from the artificial lighting system.

Another method of capturing day-lighting into the building interior is through the use of sunlight tubes. Sunlight tubes utilize the state of the art design and technology to capture sunlight from the rooftop or exterior walls, redirect it down a highly reflective shaft and then diffuse an abundance of pure day-light throughout the interior space. The use of sunlight tubes is illustrated from Fig. 2.6 to Fig. 2.8.

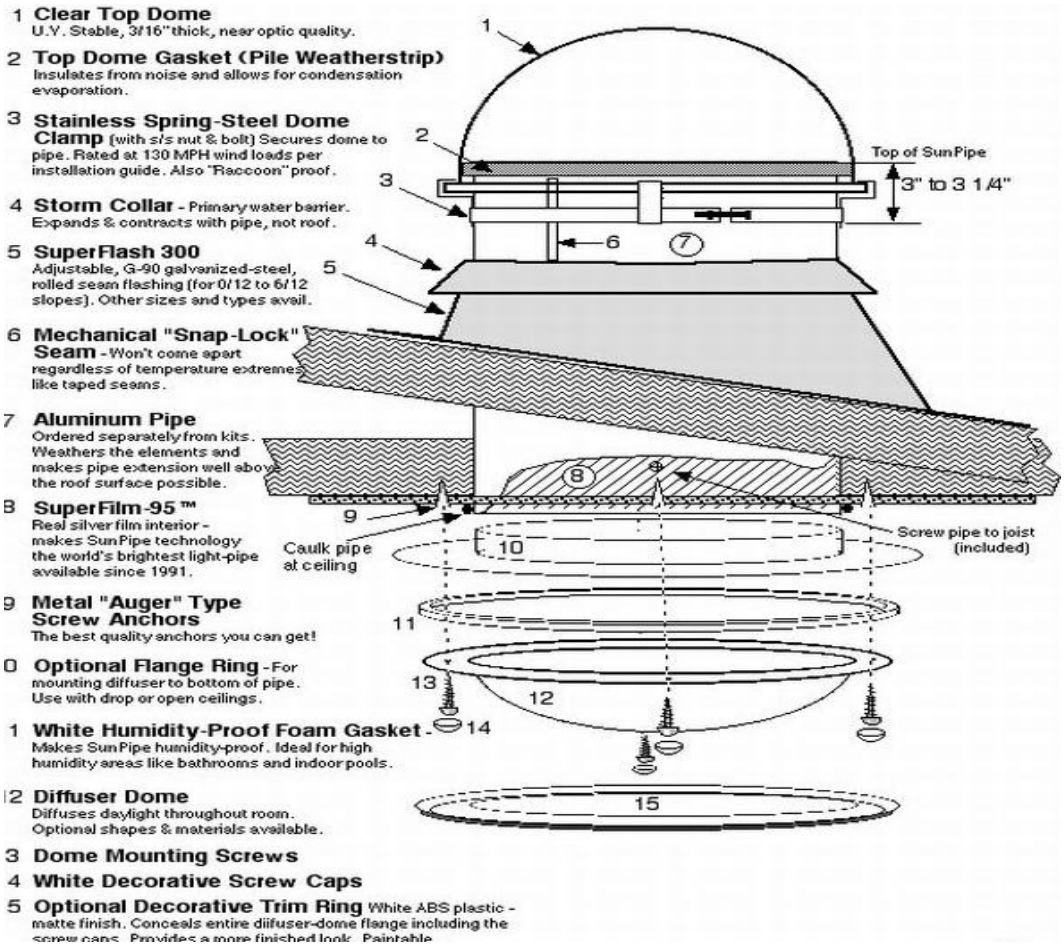


Fig. 2.6: Details of a sunlight tube (Source: www.solatubes.com, 2014).

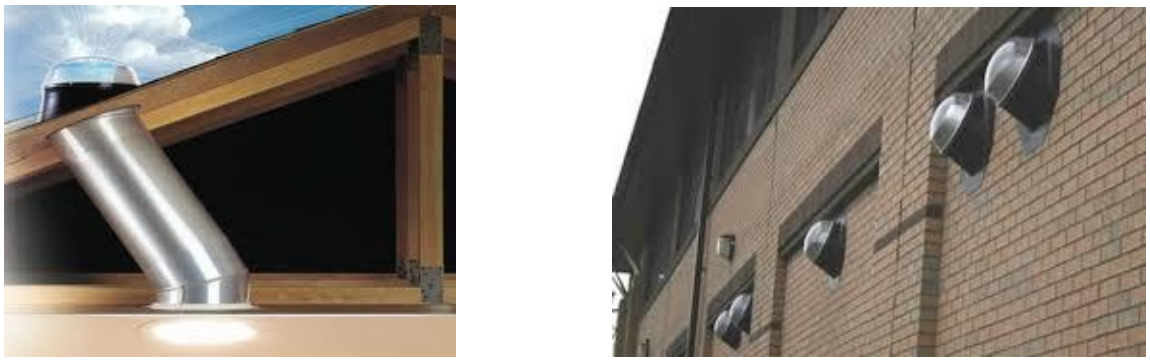


Fig. 2.7: Sunlight tube captures day-lighting from both the roof top and the exterior walls of a building (Source: www.solatubes.com, 2014).



Fig. 2.8: Reflection process through a sunlight tube.
(Source: www.solatubes.com, 2014).

The use of atrium using ethylene tetra-fluoro-ethylene (ETFE) as material for covering the atrium is another method of capturing day-lighting into the building interior. Ethylene tetra-fluoro-ethylene is a polymer, a transparent plastic related to teflon. This material is replacing glass and plastic in some of the most innovative buildings being designed and constructed today. When compared to glass, it's 1% the weight, transmits more light, is a better insulator, and costs less to install. Ethylene tetra-fluoro-ethylene is also resilient (able to bear 400 times its own weight, with an estimated 50 year life-span), and recyclable.

2.6 CLIMATE

Climate is a statistical composite of weather conditions of a particular place viewed over a very long period of time e.g. 30-40 years (Dean, 2004). The word climate comes from a Greek word 'klima', which means the 'slope' of the earth in respect to the sun. The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. The following are the elements of climate: temperature, pressure, cloud, sunshine, rainfall, wind and humidity. Micro-climate is found in a more limited space like a room, a street, town or small landscape while marco-climate is that of a much larger space such as over a country , a continent or on oceans.

2.6.1 DESIGNING WITH CLIMATE

The entire world can be classified into five main climatic zones as illustrated in Fig.2.9 according to Koppens climatic classification (2009) as:

(a.) Tropical Zone

(b.) Dry Zone,

(c.) Moderate Zone

(d.) Continental

(e) Polar Zone.

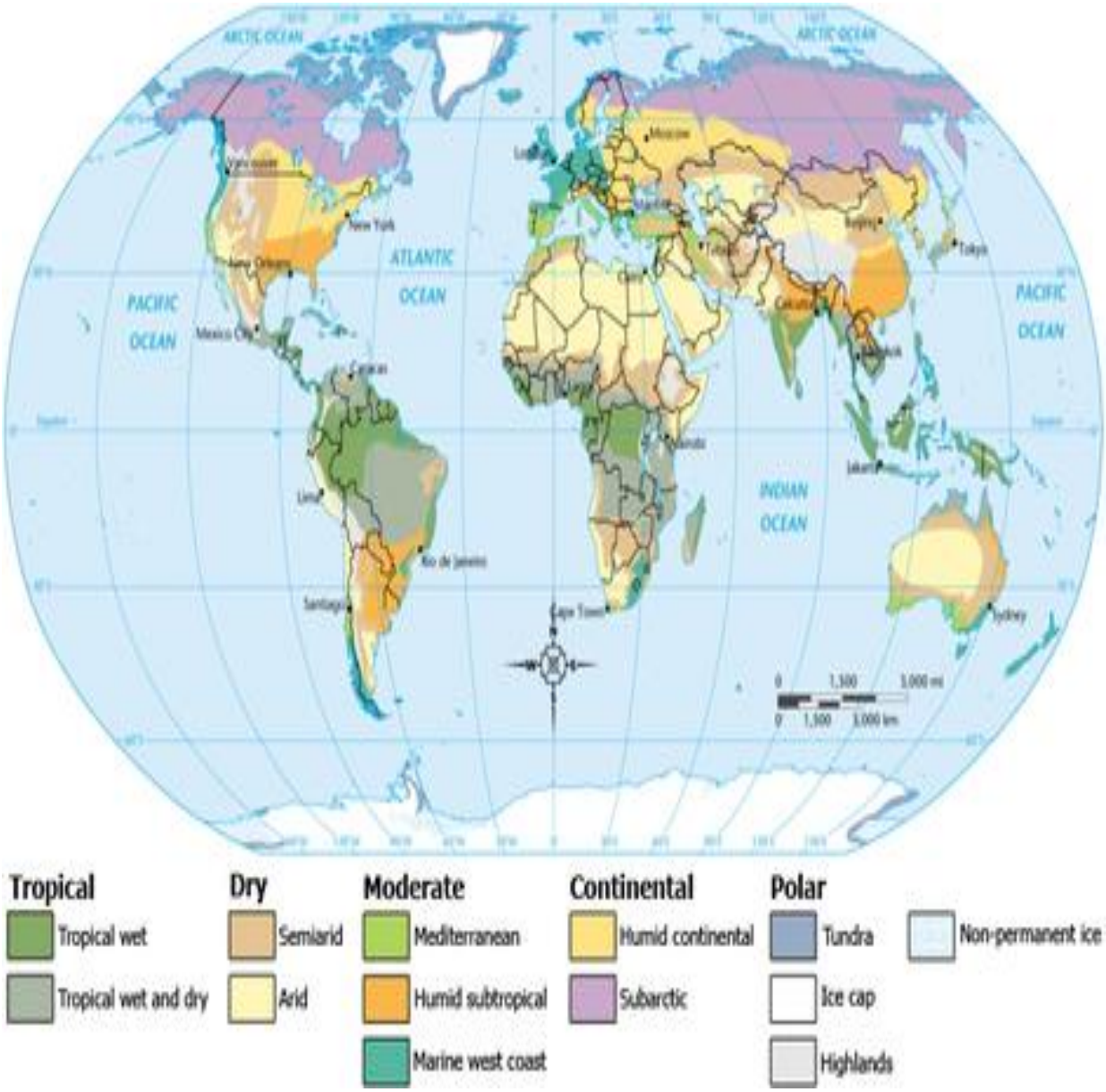


Fig. 2.9: Worldwide Climate Classifications.
(Source: Koppens Climatic Classification, 2009)

Through the ages, climate has always been a vital determinant of architecture and building. The art of building and the quality of the architecture of a place have always reflected the people's adaptation to local materials and methods of their economic, social and cultural needs, which are affordable to their economic capacity. Hence, the need to design with climate has always been a major consideration in architecture. Vitruvius (1960) in his ten

books on Architecture drew attention to the importance of climate in architecture and town planning. It is therefore important to analyze the climatic scenario of an area in order to understand the typical thermal behavior of buildings in such an environment. Knowledge on the thermal behavior of the building envelope is crucial to control the amount of heat movement in a building space. According to Zain (2007), factors that influence thermal comfort in humans include outdoor air temperature, relative humidity and airflow. Various strategies also need to be adopted to facilitate air flow because it has been observed by Zain (2007) that if there is no air flow, occurrence of thermal comfort is only 44% occurrences in temperatures below 28.69 °c but an air flow of 0.7 m/s can improve the occurrence of thermal comfort to 100%.

2.6.2 NIGERIAN CLIMATIC ZONES

Climatic zones are defined for a better understanding of the workings of the global climatic system Markus and Morris (2008). The Nigerian macro-climate is classified into four zones according to Komolafe (1988) namely:

a) Hot – Dry
b) Temperate – Dry
(c.) Warm - Humid
(d.) Hot – Humid

2.6.2.1 HOT – DRY CLIMATE

The climate of this zone is characterized by a long dry season and consequently a short rainy season. This zone is associated with cold and dry harmattan wind, high temperature range (owing to hot afternoons and cold nights) and intense sunlight. This zone covers some of the savannah regions, highland regions and semi-desert regions and it includes towns like Zaria, Yola, Maiduguri, Kano, Sokoto, Kaduna, Katsina. These areas are

associated with cold nights, dusty and sandy storms and humidity percentage of 10-40 % and characterized with low rainfall.

2.6.2.2 TEMPERATE – DRY CLIMATE

This zone is characterized with cool climate found at high altitudes around Jos Plateau, Manbilla Plateau and other few mountainous regions. These areas are associated with cool and comfortable weather.

2.6.2.3 WARM –HUMID CLIMATE

The climate of this zone is characterized with warm and humid climate. This zone is associated with cool and warm winds, cool temperature and low sunlight during the day. This zone covers the rain-forest regions and it includes towns like Lagos, Port-Harcourt and are characterized with humidity percentage of 60-95 % and with high rainfall.

2.6.2.4 HOT – HUMID CLIMATE

This zone is characterized with warm and hot winds, high temperature and intense sunlight during the day. This zone covers most of the savannah regions which includes towns like Abuja, Lokoja, Markurdi, Ilorin, Minna. These areas are associated with warm nights and hot afternoons and characterized by humidity percentage of 50-60%.When the climate of this region is properly utilized, energy efficiency can be enhanced and thermal comfort achieved.

2.7 SHOPPING PLAZAS

The definition of shopping plazas differs from places and circumstances. The general idea behind a shopping plaza is a compilation of diverse profit-making activities taking place in one entity. Plaza comes from a Spanish word describing an open urban space. The Encyclopedia Britannica (2009) defines a shopping plaza as a collection of independent

retail stores, services, and a parking area conceived, constructed, and maintained by a management firm as a unit. Shopping plazas may also contain restaurants, theatres, professional offices, service stations, and other establishments. The Microsoft Encarta (2008) defines shopping plaza as collection of retail businesses in a building or set of buildings under one management. Cyril (2006) defines a shopping plaza as a shopping centre enclosed within a large structure; often two or three stories high, usually designed around a central atrium; may have numerous stores, as well as entertainment facilities such as movie theatres, fast-food outlets, restaurants, and public areas.

2.7.1 CLASSIFICATION OF SHOPPING PLAZAS.

There are four general classes of shopping centres. The distinction between each is not very absolute, but individuals should be able to recognize each one (Fong, 2003). The following are a list of them:

(i) Neighborhood Shopping Centres

(ii) Community Shopping Centres

(iii) Regional Shopping Centres

(iv) Super-Regional Shopping Centres

2.7.1 NEIGHBORHOOD SHOPPING CENTRES.

This class sells daily needs such as foods, drugs, sundries, and personal services. It has from 10 to 15 stores and will be supported by approximately 5,000 to 30,000 residents. It will be developed on 3 to 5 acres of land, and the most prominent store will be the grocery market.

2.7.2 COMMUNITY SHOPPING CENTRES

This class will sell apparel, hardware, and equipment in addition to the everyday needs of the shoppers. It will include 20 to 40 stores, will be supported by 30,000 to 130,000 people, and will require 10 to 30 acres of land. The most prominent store will be a junior department store.

2.7.3 REGIONAL SHOPPING CENTRES

This class of shopping center provides almost the complete spectrum of consumer goods and services. It usually is designed in strip (mall) fashion with one or both ends anchored by a major department store and smaller shops located along the plaza. A more recent design calls for a large major department store that serves as a central core with smaller shops clustered about it. The average regional center contains from 300,000 to over 1,000,000 square feet of gross leasable area. It requires between 35 and 100 acres of land and is supported by about 300,000 people. This class of shopping center offers the same goods and services as many commercial core areas in major cities.

2.7.4 SUPER-REGIONAL SHOPPING CENTRES

A super-regional center is one containing over 1,000,000 square feet of leasable area, and over 6,000 parking spaces. It offers the complete spectrum of goods and services. This type of center is relatively new and few are presently in existence around the world.

2.8 ARCHITECTURAL DESIGN REQUIREMENTS FOR SHOPPING PLAZA.

Shopping Centre Council of Australia, 2002 provided the following design issues, processes and framework for consideration for shopping centre designs. They are:

a) Shopping centre designs must have a good link with the local community by studying the demography of the geo-graphical area and the income level of residents of the area.

b) The need for big rectangular or square forms should be incorporated into the design in order to contain large format retailing.

c) Convenient parking spaces should be provided in order to meet the needs of customers.

d) Provision of easily accessible and available loading docks.

e) Shopping centre should be designed to allow direct and convenient access by walking, cycling and public transport. Access by all means of road transport mode should be encouraged.

f) Security is a vital issue in shopping centre designs and as such should be designed to minimize the potential for criminal activities with measures such as providing good sight lines, avoiding spaces that can be used for hiding and shortening dead spaces. The chief security means used are surveillance cameras positioned in strategic location and security personnel.

g) Shopping centre design must incorporate leisure, entertainment, recreational and outdoor facilities into design thereby providing focus for social activities.

h) Good and easy circulation movement of customers and visitors should be taken into consideration in the design. This implies incorporating escalators, lift system (passengers and service lift) and staircases in shopping centre design.

2.9 INFERENCE FROM LITERATURE REVIEW.

Various researches had been carried out as regards passive design and energy efficiency. From the literatures reviewed one notices that passive design principles such as landscape design, building form, natural ventilation, day-lighting, building orientation and building envelope are extremely effective in decreasing cooling loads of building thereby enhancing energy efficiency. Hence, it is very paramount to employ the above mentioned passive design principles as variables of study thereby helping in achieve the aim of the research.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter outlines how the research on enhancing energy efficiency through passive design principles in a hot – humid climate of Lokoja is carried out. Issues such as the research approach, population of study, sample and sampling techniques, instruments of data collection and data analysis are discussed.

3.2 RESEARCH APPROACH

Case study research is defined as an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not evident (Yin, 1994). In this research, case study approach is adopted and cases are purposively selected and properly examined, analyzed, and tabulated. Oluigbo (2011) assert various case studies applications that are relevant to architectural research as; exploratory, explanatory, evaluative, illustrative and critical instance but further claims that cases are identified for study due to their inherent qualities which are in consonance with the phenomenon under investigation. The evaluative case study type is most relevant for this research as this application establishes that evaluative case studies are used in testing the effectiveness of programs in order to suggest modifications and alternatives (Veal, 2006).

3.3 POPULATION OF STUDY

The population of study will entail shopping plazas located within Nigeria in order to investigate how passive design principles are applied in their design to enhance energy efficiency.

3.4 SAMPLE AND SAMPLING TECHNIQUES

This research entails a purposive selection of cases from Nigeria. The selection of the case studies was based on the following criteria:

a. They were relative to the area of research and they proffer solutions to the research questions outlined from the outset of the study.

b. They are representative of typical modern multi-shopping centres design within Nigeria and cases were accessible and the architectural drawings of these cases were also available. This helped in achieving the third objective.

3.5 INSTRUMENTS OF DATA COLLECTION

The instruments of data collection used are:

a) Interview

b) Visual Survey

c) Application of Energy Efficient Architectural Features Check-list.

3.5.1INTERVIEW

This is a situation whereby experts who are very knowledgeable in a particular field are questioned with the primary aim of learning from their wealth of experience. In this research, interview was conducted with expects in the field of sustainable architecture and climatic designs thereby achieving the first objective. Interviews was also conducted with senior personnel's and managers of various cases selected in order to inquire about various appliances and equipments that consume most of the energy so as to propose alternative passive design approach that will be energy efficient thereby achieving the third objective.

3.5.2 VISUAL SURVEY

This is a method of data collection in which the researcher uses his or her eyes to see data, make record and take notes. In this research visual survey was employed because it also helps to achieve the third objective by noting shopping plaza activities, spatial organization of shopping plazas and this reflect in various formats such as photographs, sketches and notes relevant to passive design and energy efficiency.

3.5.3 APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST.

Check-list serves as a visual lens to focus the study on set objectives. Energy efficient architectural features check-list was applied to purposively selected cases and this was obtained from in-depth study of literature and was developed based on the objectives of the study.

3.6 VARIABLES OF STUDY

Variables that apply to energy efficient design as they relate to the Nigerian tropical climate and how they enhance energy efficiency in shopping plazas are analyzed. The following are such variables:

a) Building envelope

b) Landscape design

c) Building form

d) Natural Ventilation

e) Day-Lighting

f) Building orientation

CHAPTER FOUR

CASE STUDY AND DATA PRESENTATION

4.1 INTRODUCTION

This chapter focuses on case studies relevant to passive design and how such cases have enhanced energy efficiency. Cases were properly documented and data obtained from cases were assessed and analyzed using energy efficient architectural features.

4.2 CASE STUDY ONE: PALMS SHOPPING MALL, LAGOS

4.2.1 BACKGROUND INFORMATION

The Palms Shopping Mall is located on a 45,000-square-metre plot of land in Lekki Peninsula, Lagos, Nigeria. It has 21,000 square metres of lettable retail space. The mall is built on swampland that was reclaimed by the Lagos State Government. The project was first conceived in 1999 by the Chairman and Managing Director of Persianas Properties Limited, Mr. Adetayo Amusan but was officially commissioned in February, 2005 by two former Nigerian Heads of State - General Olusegun Obasanjo and General Ibrahim Babangida, as well as the Oba of Lagos, His Royal Highness, Oba Rilwan Babatunde Osuolale Aremu Akiolu I. Johannesburg based Bentel Associates International (BAI) internationally recognized retail design experts, were retained by the developers to design the mall. The mall has 69 stores and a six modern screen cinema with a parking space for 1000 cars as illustrated from plate II - IV.



Plate II: Approach view with parking spaces in palms shopping mall, Lagos. (Source: Researcher's Field Survey, September, 2013).



Plate III: Use of curtain walls as means of natural ventilation and lighting in Palms shopping mall, Lagos. (Source: Researcher's Field Survey, September, 2013).



Plate IV: Natural lighting augmented by use of artificial lighting in Palms shopping mall, Lagos (Source: Researcher's Field Survey, September, 2013)

4.2.2 SPATIAL ORGANISATION

The Palms offers the exciting concept of "one-stop shopping"- an idea that is still relatively new to the country. It presents the convenience and unique experience of retail, leisure, entertainment, movies, games and health. There are 69 shops of varying size and design which include electronics shops, boutiques, cosmetics shops, hair-dressing salons, restaurants and gifts shops as illustrated in plate V and fig. 4.1. The spatial organization of the site is such that the car park is situated at the entrance to the mall. The shopping mall is accessed via two entrances directly and has a simple linear plan with corridors double banked by stores. The palms have a gross leasable space of 20,000m^2 with two anchor stores, namely: Shoprite and Game. The whole of the mall is housed on two levels only; the ground floor houses most of the stores leaving the first floor with 6 cinemas, ticket collection space and a book store.

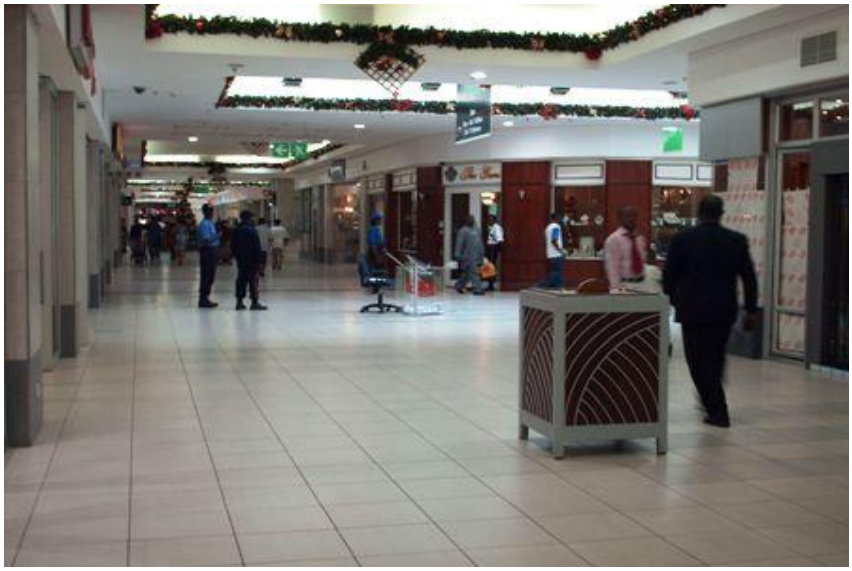


Plate V: Interior spatial view of palms shopping mall at a glance
(Source: Researcher's Field Survey, September, 2013).



Fig 4.1: Ground floor plan of Palms Shopping Mall, Lagos
(Source: Researcher's Field Survey, September, 2013).

4.2.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST.

The following energy efficient architectural features check-list is used in the assessment of Palms Shopping Mall, Lagos and the full assessment is shown in Table 4.1:

(i) Building envelope

(ii) Natural lighting

(iii) Natural ventilation

(iv) Landscape design

(v) Building orientation

(vi) Building form

Table 4.1: Assessment of the Application of Energy Efficient Architectural Features (Palms Shopping Mall, Lagos).

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
1.	Building Envelope	Suitability of the materials to the climate			✓	
		Use of external insulation		✓		
		Use of light colours				✓
2.	Natural Lighting	Wall to window ration (40%)			✓	
		Use of specially transparent glass			✓	
3.	Natural Ventilation	Use of operable windows			✓	

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
4.	Landscape Design	Use of soft landscape		✓		
		Use of hard landscape.				✓
5.	Building Orientation	Sun Orientation (East -West)			✓	
		Wind Orientation (South-West – North-East)			✓	
6.	Building Form	Large building surface area.			✓	

(Source: Researcher's Field Survey, September, 2013).

4.3 CASE STUDY TWO: CEDDI PLAZA, ABUJA

4.3.1 BACKGROUND INFORMATION

Ceddi Plaza is owned by Ceddi Corporation and is managed by Broll Property Services Nigeria. The plaza is located at 264 Tafawa Balewa Way in the Central Business Area of Abuja, directly opposite the Nigeria National Petroleum Corporation headquarters complex and adjacent to the Federal Mortgage Bank of Nigeria. The plaza consists of 10,000 square meters of retail and office space. Ceddi plaza is a mixed-use facility and was officially opened in November, 2005. The attraction for the shopping centre include the first multi-screen cinema in Abuja, a multi media store, the restaurants, specialist retailers, bank cash office, airline ticket office, exclusive men and women's fashion stores, a health spa, beauty salon, pharmacy, wine bar, cigar shop and the café. This is illustrated in plate VI to plate X.



Plate VI: Approach View of Ceddi Plaza, Abuja showing good use of Landscape trees (Source: Researcher's Field Survey, September, 2013).



. Plate VII: Approach view with use of glass as means of ventilation and lighting of the interior of Ceddi Plaza, Abuja (Source: Researcher's Field Survey, September, 2013)



Plate VIII: Use of glass for roofing and it serves as an efficient means of interior lighting of Ceddi Plaza, Abuja (Source: Researcher's Field Survey, January, 2014).



Plate IX: Use of curtain wall and it serves as an efficient means of interior lighting of Ceddi Plaza, Abuja (Source: Researcher's Field Survey, January, 2014).



Plate X: Use of atrium as an efficient means of interior lighting of Ceddi Plaza, Abuja (Source: Researcher's Field Survey, January, 2014).

4.3.2 SPATIAL ORGANISATION

The plaza is made up of three floors of retail (eateries, boutiques, entertainment and services) with corporate office spaces .The main entrance foyer opens into the giant circular atrium, traversing the entire six floors with two panoramic lifts framing the grand staircase. This main atrium is connected to the other atrium on the three shopping levels through the mall. The second and third floors are open plan offices with provision for voice and data outlets. This will ensure that the offices can offer tenants the latest technology. The penthouse on the fourth floor is designed for maximum visibility. Ceddi Plaza is made up of 55 specialty shops, offices and service providers consisting of movie theaters, a bookstore, champagne lounge, the atrium, restaurants, cafes, boutiques, shoes, accessories, home interior design stores, furnishings, health & beauty salons, gift shops, telephones, banking and ATMs, dry cleaning services, a dental office, pharmacy, photo studio and children's entertainment. This is illustrated in fig. 4.2 to fig. 4.5 and from plate XI to XII.



Fig 4.2: Spatial Organisation of basement plan, Ceddi Plaza, Abuja (Source: www.ceddicorporation, September, 2013).

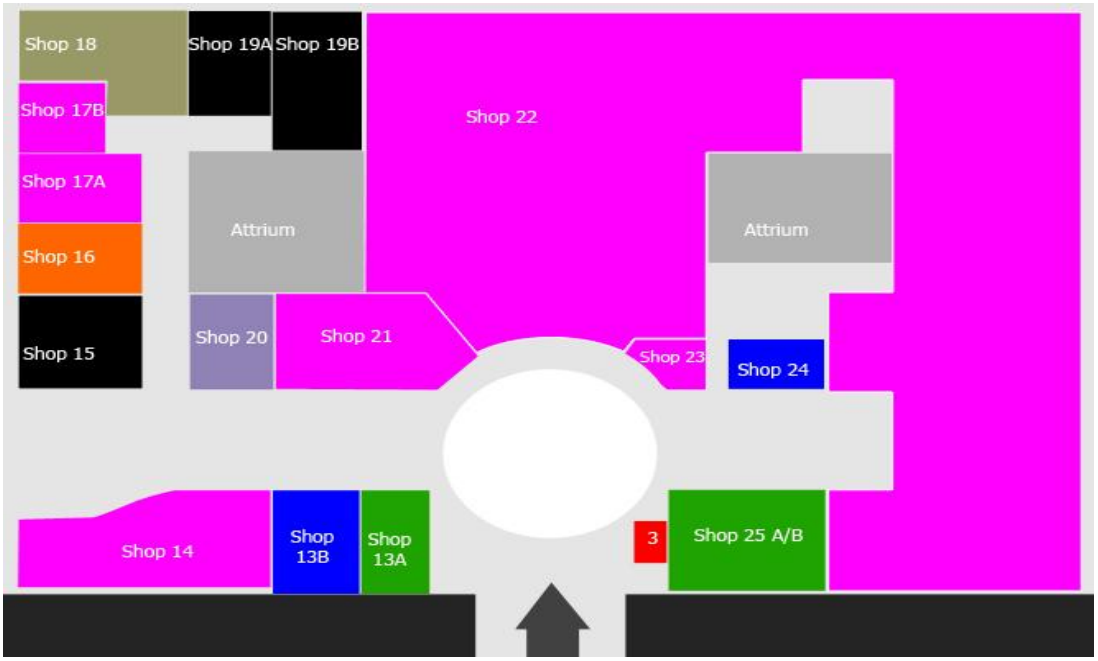


Fig 4.3: Spatial organisation of ground floor plan, Ceddi Plaza Abuja (Source: www.ceddicorporation, September, 2013).

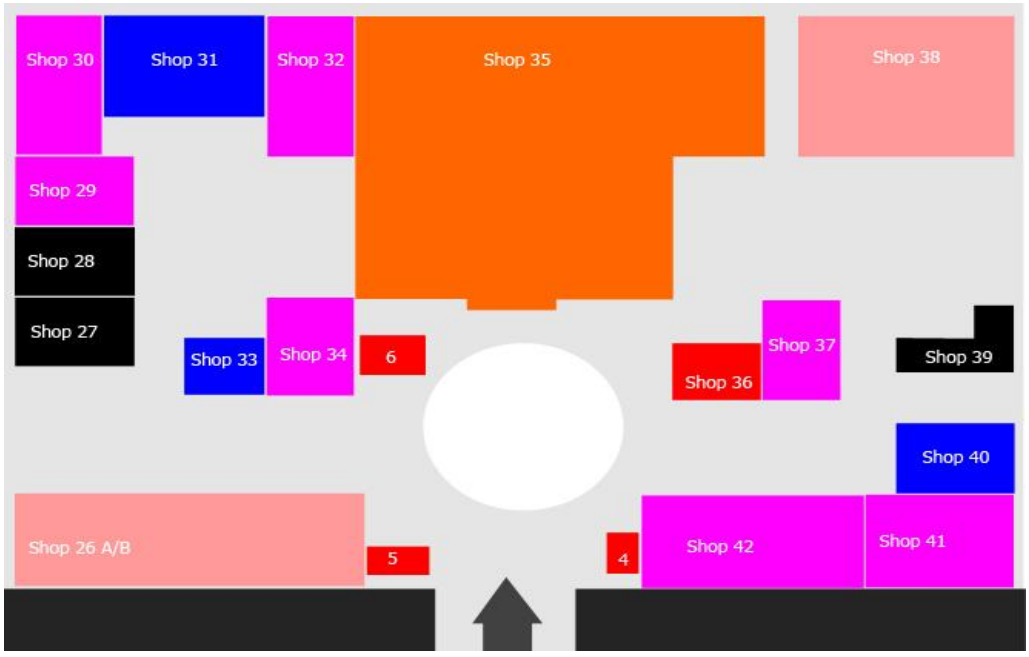


Fig 4.4: Spatial organisation of first floor plan, Ceddi Plaza Abuja (Source: www.ceddicorporation, September, 2013).

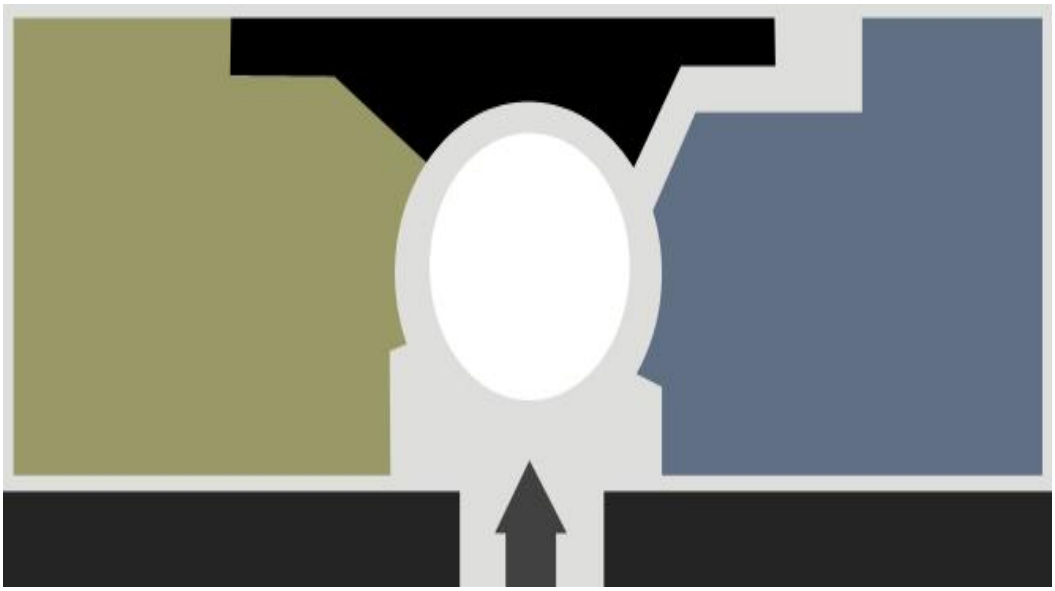


Fig 4.5: Spatial organisation of second floor plan, Ceddi Plaza Abuja (Source: www.ceddicorporation, September, 2013).



Plate XI: Interior view of the eatery and how natural lighting is augmented by use of artificial lighting, Ceddi Plaza Abuja (Source: Researcher's Field Survey, September, 2013).



Plate XII: Interior view of the boutique store, Ceddi Plaza Abuja
(Source: Researcher's Field Survey, September, 2013).

4.3.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST.

The following energy efficient architectural features check-list are used in the assessment of Ceddi Plaza, Abuja and the full assessment is shown in Table 4.2:

(i) Building envelope

(ii) Natural lighting

(iii) Natural ventilation

(iv) Landscape design

(v) Building orientation

(vi) Building form

Table 4.2: Assessment of Application of Energy Efficient Architectural Features Check-list, (Ceddi Plaza, Abuja)

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
1.	Building Envelope	Suitability of the materials to the climate			✓	
		Use of external insulation		✓		
		Use of light colours				✓
2.	Natural Lighting	Wall to window ration (40%)				✓
		Use of specially transparent glass				✓
3.	Natural Ventilation	Use of operable windows				✓

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
4.	Landscape Design	Use of soft landscape				✓
		Use of hard landscape.			✓	
5.	Building Orientation	Sun Orientation (East -West)			✓	
		Wind Orientation (South-West – North-East)			✓	
6.	Building Form	Large building surface area.				✓

(Source: Researcher's Field Survey, September, 2013).

4.4 CASE STUDY THREE: IKEJA CITY MALL, ALAUSA, LAGOS STATE.

4.4.1 BACKGROUND INFORMATION

Ikeja city mall is owned by three firms namely Actis which owns 60 percent equity in the mall, Paragon Holdings and RMB Investments & Advisory which owns 20 percent each. The mall is located at Alausa, near the seat of the Lagos State government secretariat. The mall was built by Gruppo Nigeria Investment Ltd and was built on a land covering 28,500meters square. The mall is made up of a 5-screen silverbird cinema, shoprite supermarket, specialist facilities for department stores, banks, cafés, bars, restaurants, hair-dressing / beauty salon, etc. Shoprite is a mixed use facility and was officially opened on Wednesday, 14th December, 2011 by the Lagos State governor, Mr. Babatunde Fashola. This is illustrated from plate XIII to XVII and in fig. 4.6.



Plate XIII: Approach View and use of glass windows to enhance day-lighting and ventilation of Ikeja city mall, Alausa, Lagos.(Source: Researcher's Field Survey, November, 2013).



Plate XIV: Car park with few trees and hard landscape of Ikeja city mall, Alausa, Lagos. (Source: Researcher's Field Survey, November, 2013).

4.4.2 SPATIAL ORGANISATION

Consumers or visitors pack their cars at the carport by the main entrance. There is a double escalator from the ground floor to the upper floor. The main entrance foyer opens into the colossal spherical lighting, traversing the entire building. Shoprite is made up of 100 specialty shops, offices and service providers consisting of a bookstore, champagne lounge, restaurants, cafes, fashion boutiques, telecom accessories store, home interior design stores, furnishings, health and beauty salons, gift shops, cinemas centre, dry cleaning services, a pharmaceutical store, photo studio and children's entertainment centre.

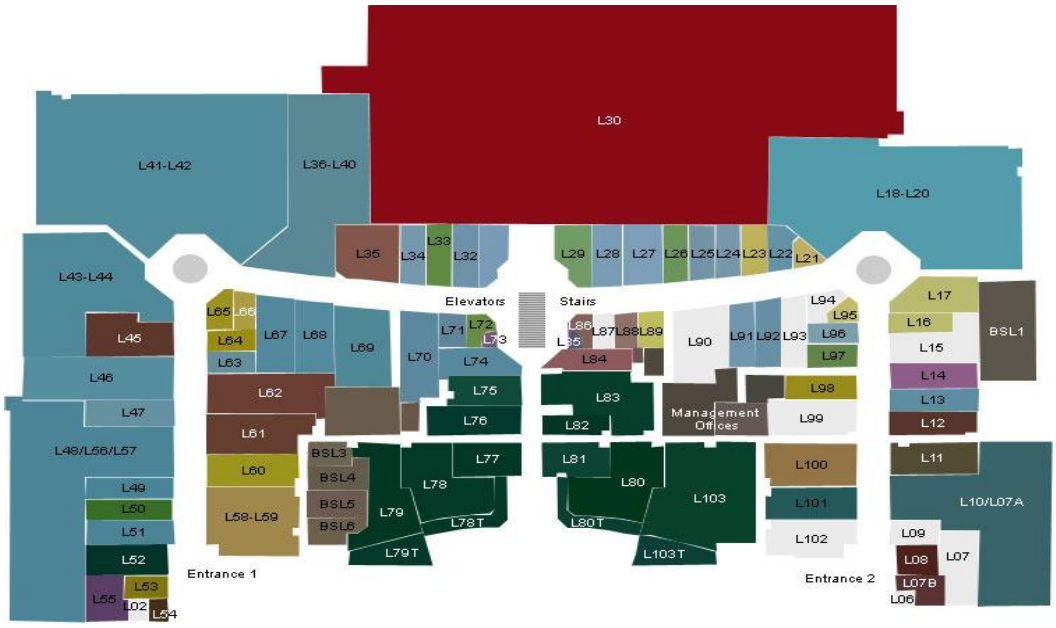


Fig. 4.6: Ground floor plan with the spatial organization of Ikeja city mall, Alausa, Lagos (Source: Researcher's Field Survey, November, 2013).



Plate XV: Interior view of supermarket and the spatial arrangement of goods and how natural lighting is augmented by use of artificial lighting, Ikeja city mall, Alausa, Lagos State.(Source: Researcher's Field Survey, November, 2013).



Plate XVI: Use of escalator and artificial lighting to supplement natural lighting, Ikeja city mall, Alausa, Lagos State. (Source: Researcher's Field Survey, November, 2013).



Plate XVII: Use of glass for roofing and these serves as an efficient means of interior lighting of Ikeja city mall, Alausa, Lagos State (Source: Researcher's Field Survey, November, 2013).

4.3.3 ASSESSMENT OF APPLICATION OF ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST, (SHOPRITE, ALAUSA, LAGOS STATE).

The following energy efficient architectural features check-list are used in the assessment of Ikeja city mall, Alausa, Lagos State and the full assessment is shown in Table 4.3:

(i) Building envelope

(ii) Natural lighting

(iii) Natural ventilation

(iv) Landscape design

(v) Building orientation

(vi) Building form

Table 4.3: Assessment of Application of Energy Efficient Architectural Features Check-list, (Ikeja city mall, Alausa, Lagos State).

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
1.	Building Envelope	Suitability of the materials to the climate			✓	
		Use of external insulation			✓	
		Use of light colours				✓
2.	Natural Lighting	Wall to window ration (40%)			✓	
		Use of specially transparent glass				✓
3.	Natural Ventilation	Use of operable windows			✓	

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
4.	Landscape Design	Use of soft landscape		✓		
		Use of hard landscape.				✓
5.	Building Orientation	Sun Orientation (East -West)				✓
		Wind Orientation (South West – North-East)				✓
6.	Building Form	Large building surface area.				✓

(Source: Researcher's Field Survey, November, 2013).

CHAPTER FIVE

DESIGN REPORT

5.1 INTRODUCTION

In this chapter, an attempt is made to initiate the readers of this thesis to the site. The site selection criteria are discussed and the geography of the site is analyzed in terms of both climatic and physical analysis. This chapter further gives a detail report of the proposed shopping plaza design and the following were properly analyzed: design brief, design development, circulation movement, design philosophy, construction technology, services, materials and finishes.

5.2 GEOGRAPHICAL LOCATION OF LOKOJA, NIGERIA

Lokoja is the capital city of Kogi State and it lies on latitude 7.48 degree north and longitude 6.44 degree east. Fig 5.10 is a diagram of Nigeria map showing location of Kogi State. Lokoja became the administrative capital of Kogi State on 27th of August, 1991 as a result of the state creation exercise during General Ibrahim Babangida's military regime. Lokoja is bordered to the north by Abuja, to the east by Ayangba, to the west by Kabba and to the south by Ajaokuta which are all in Kogi State. Lokoja is at the confluence of rivers Niger and Benue, and is close to the Federal Capital of Nigeria – Abuja and it is popularly known as the confluence city. Lokoja has a square area of 3180 km² and a population of 195,261 based on the 2006 census. It is situated within the guinea savannah region with a hot-humid climate.

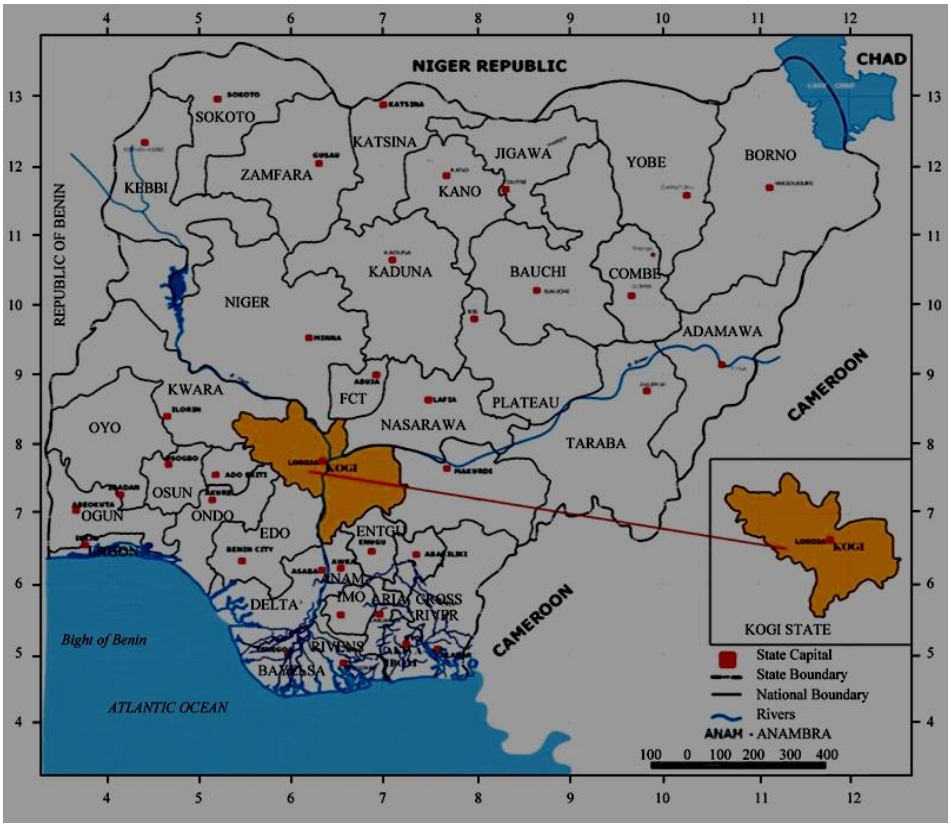


Fig 5.10: Map of Nigeria with location of Kogi State.
(Source: Kogi State Ministry of Land and Environment, 2008)

Lokoja is divided into six (6) phases listed below:

(i) Phase 1 is divided into four (4) districts – Adankolo, Government house, Kabawa and Federal Medical Centre.

(ii) Phase 2 is divided into five (5) districts – Lokongoma Phase 1, Lokongoma Phase 2, Commissioner's quarters, Confluence beach hotel and Ganaja.

(iii) Phase 3 of the city is divided into four (4) districts – International Market, Kogi State Polytechnic, Felele, Permanent Site of Federal University, Lokoja.

(iv) Phase 4 of the city is divided into six (6) districts – Salau Atima Housing Esate, 4th Republic Esate, Lokoja International Confluence Stadium, Zone eight, Kogi State House of Assembly and Crusher village.

(v) Phase 5 of the city is divided into five (5) districts – Mechanic Village Park, Zango-Daji, Otokiti Housing Estate, Chari-Magumeri Barracks and Industrial Layout.

(vi) Phase 6 of the city is divided into five (5) districts – NNPC park, Kungbani, Banda, Naval base and Okumi. Fig 5.11 below is a diagram of Kogi State map showing the location of Lokoja Local Government Area while Fig. 5.12 show map of Lokoja urban area.

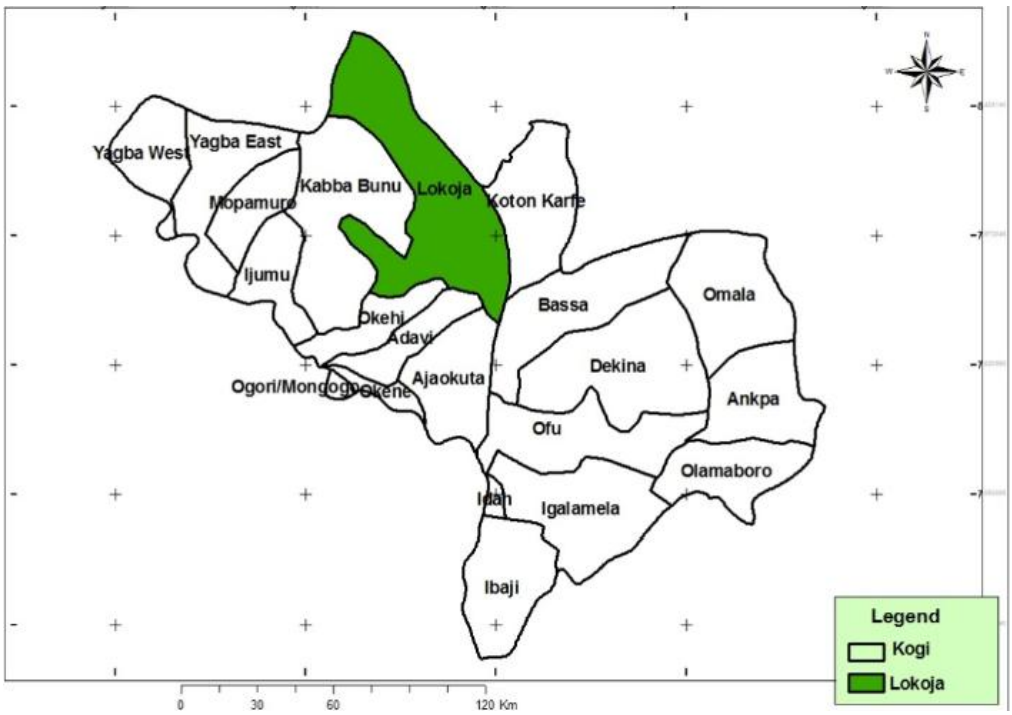


Fig 5.11: Map of Kogi State with the Location of Lokoja Local Government Area.
(Source: Journal of Geography and Geology, 2012)

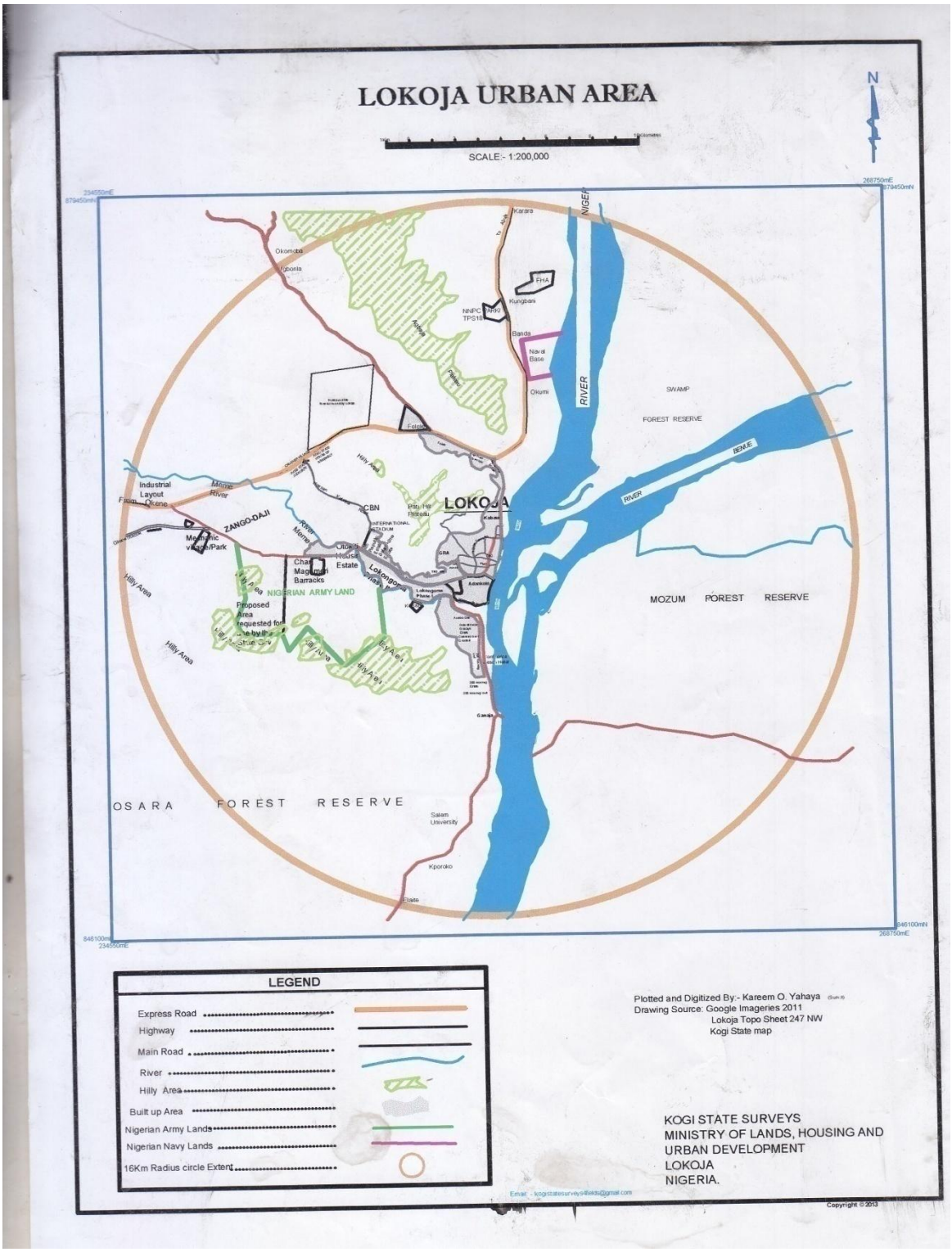


Fig. 5.12: Map of Lokoja Urban Area. (Source: Kogi State Ministry of Lands, Housing and Urban Development Lokoja, March, 2014).

5.3 SITE SELECTION CRITERIA

Certain criteria in conjunction with the Lokoja master plan produced by the Kogi State Ministry of Land and Environment were considered as standard used in deciding the site location in order to provide the residents with a shopping plaza which will meet their shopping needs. The following are a list of such criteria with a rating scale as illustrated in fig: 5.13

(i) Land use compliance

(ii) Quick accessibility from the main road

(iii) Good visual and aesthetic potential

(iv) Demographics of the area

(v) Level of income of residents around the area

(vi) Availability of good infrastructure

(vii) Proximity to both commercial and residential areas.

RATING OF SITE SELECTION.

NOs	CRITERIA	RATING
1.	LANDUSE COMPLIANCE	5
2.	QUICK ACCESSIBILITY FROM THE ROAD	5
3.	GOOD VISUAL AND AESTHETIC POTENTIAL	5
4.	DEMOGRAPHICS OF THE AREA	4
5.	LEVEL OF INCOME OF RESIDENTS ARROUND THE AREA	4
6.	AVALIABILITY OF GOOD INFRASTRUCTURE	4
7.	PROXIMITY OF BOTH COMMERCIAL AND RESIDENTIAL AREAS	5
(35)	TOTAL	32

KEY	
EXCELLENT	5
VERY GOOD	4
GOOD	3
FAIR	2
POOR	1

Fig. 5.13: Rating scale of site selected (Source: Researcher's Field Survey, March 2014).

5.4 CLIMATIC ANALYSIS OF THE SITE.

The site experiences two major weather conditions annually. These are rainy season and dry season. Between these two seasons, there is a brief interlude of harmattan occasioned by the north-east trade wind, characterized with dust, haze, intensified coldness and dryness. It is vital to analyze the climatic scenario of Lokoja in order to be able to design an environmental friendly building which is energy efficient. Lokoja in North-central Nigeria has a hot-humid climate and it lies on latitude 7°30′N and longitude 6°42′E. According to Komolafe (1988) on classification of Nigerian macro-climate, Lokoja is categorized under hot-humid climate. Lokoja has an average maximum temperature of 33.2 °c and an average minimum temperature of 22.8 °c (Royal Meteorological Society, 2013). The climate is characterized as hot throughout the year with intense solar radiation. Lokoja has two distinct weather seasons namely, the dry season, which lasts from November to February and rainy season that lasts from March to October. Annual rainfall ranges from 1016mm to 1524mm (Royal Meteorological Society, 2013).

5.4.1 TEMPERATURE

Daytime temperatures of the site reaches 28 °C to 30 °C and night time lows to around 22 °C to 23 °C. In the dry season, daytime temperatures can soar as high as 40 °C and night time temperatures can drop to 12 °C. Even the chilliest nights can be followed by daytime temperatures well above 30 °C. Fig. 5.14 shows the average annual temperature of Lokoja.

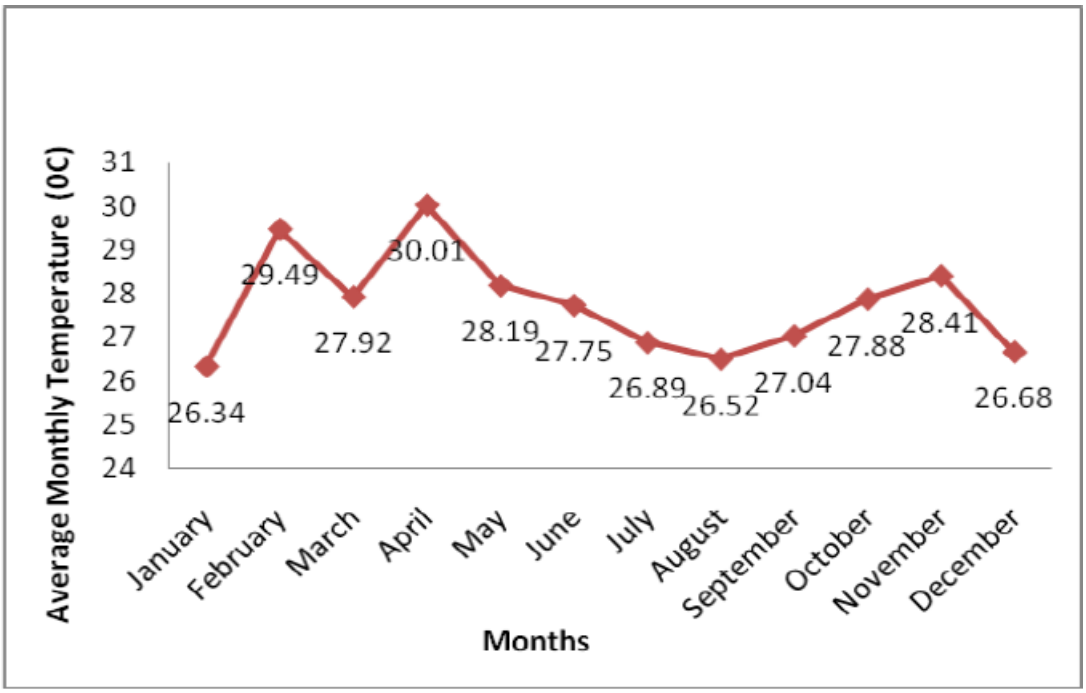


Fig. 5.14: Average Annual Temperature (January-December, 2010)

(Source: American International Journal of Contemporary Research, 2012)

5.4.2 RAINFALL

The rainy season begins from March and ends in October. The annual total rainfall is in the range of 1100 mm to 1600 mm. Table 5.10 shows the annual rainfall data of Lokoja.

Month	Rainfall	Mean
January	33.1	1.1
February	241.2	8.0
March	661.3	22.0
April	3128.7	104.3
May	4698.3	156.6
June	5081.9	169.4
July	5988.5	199.6
August	6120.1	204.0
September	6443.7	214.8
October	4003.7	133.5
November	87.1	2.9
December	17.1	0.6

Table 5.10: The monthly and mean monthly rainfall (mm) of Lokoja from 1981-2010 (Source: International Journal of Science and Technology, 2012)

5.4.3 SUNSHINE

The total sunshine hours in Nigeria increases from the south to the north. The sunshine in Lokoja is highest in March and declines during the rainy season. The maximum diurnal sunshine hours occur in March with nine to ten hours and minimum diurnal sunshine hours occurs in August with six to seven hours. Fig.5.15 shows the mean annual visibility of Lokoja.

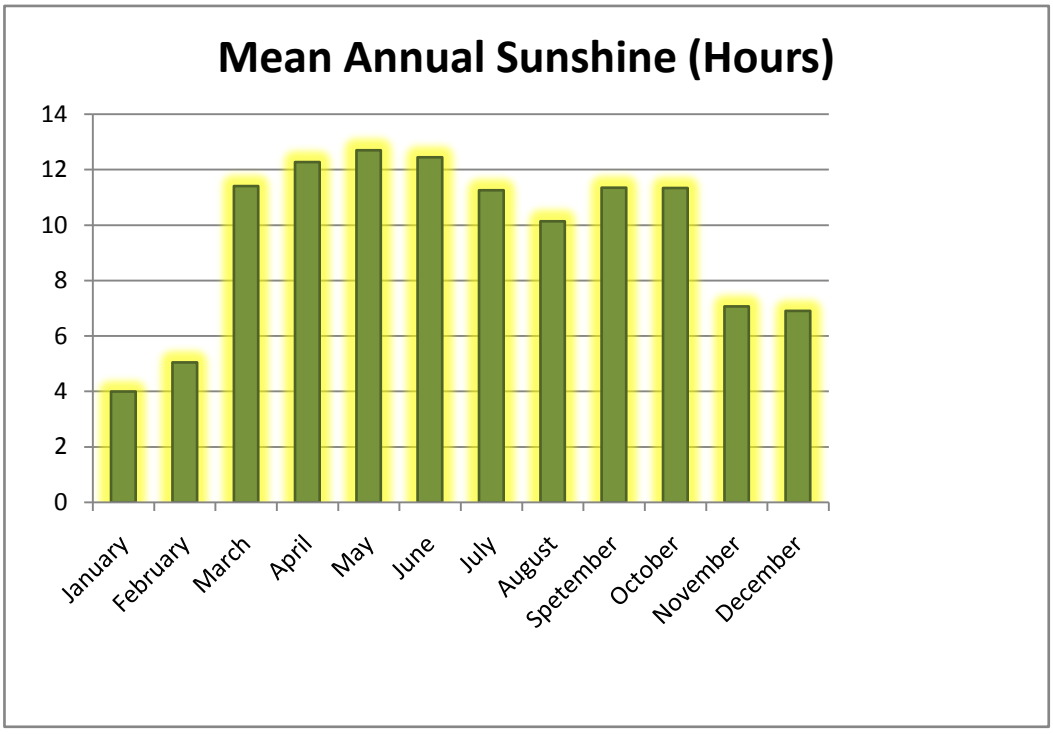


Fig. 5.15: Mean Annual Sunshine of Lokoja (2004-2008) (Source: British Ministry of Overseas Development, Land Resources Division).

5.4.4 RELATIVE HUMIDITY

The Relative Humidity is highest during the rainy season at 82% and lowest during the dry season at 57% in the afternoon. Table 5.11 shows the mean humidity of Lokoja.

Month	Mean Mont Relative H
	Lokoja
January	64
February	57
March	65
April	72
May	78
June	78
July	77
August	74
September	82
October	77
November	75
December	69

Table 5.11: Mean Monthly Humidity (%) of Lokoja from 1961-1999 (Source: Federal Department of Meteorological Services, Oshodi)

5.4.5 WIND

Two major air masses dominate the confluence city of Lokoja: the Tropical Maritime air mass and the Tropical Continental Air mass. The Tropical Maritime air mass is formed over the Atlantic ocean of the south of the country and is therefore warm and moist. It blows from south-west to north-east. The Tropical Continental is developed over the Sahara desert and thus is warm and dry and blows from north-east to south-west. The Tropical Continental air mass comes with the dry season while the Tropical Maritime air mass, comes with the wet season. Lokoja also experiences land and sea breezes.

5.5 PHYSICAL ANALYSIS OF SITE

5.5.1 LOCATION AND DESCRIPTION

The proposed site for the shopping plaza is 135,000 square meters and is located within zone eight in Phase 4 of Lokoja metropolis. The location is along Hassan Usman Kastina road in Zone eight within the proximity of Lokoja International Confluence Stadium and Kogi State House of Assembly; this provides an exclusive development opening both socially and economically, and also enhances a good economic connectivity to both Crusher village and Salau Atima Housing Estate. Fig. 5.16 shows location drawing of proposed site at Lokoja while Fig 5.17 shows the site analysis of proposed site.

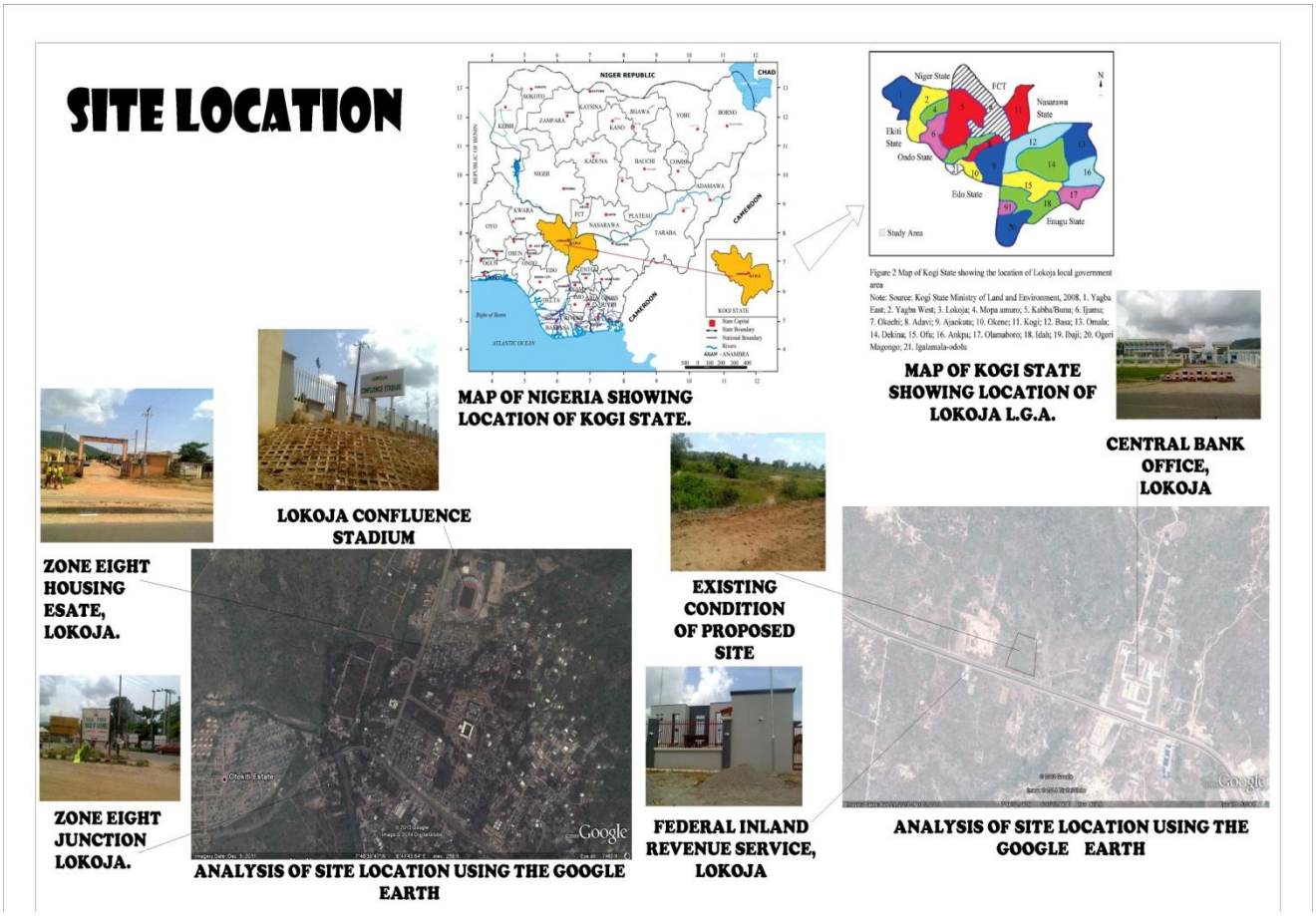


Fig.5.16: Location drawing of Proposed Site (Source: Researcher's Field Survey, March 2014).

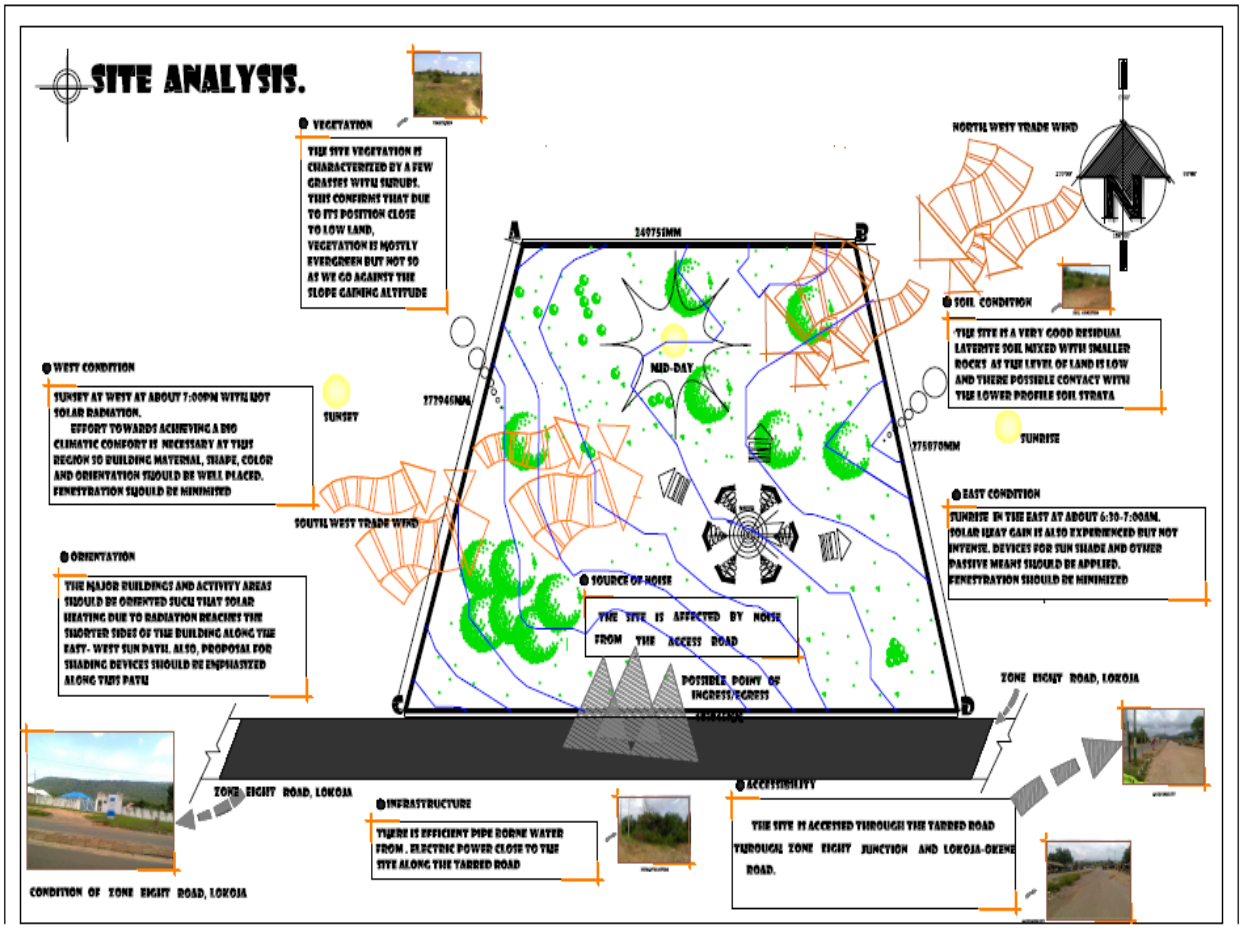


Fig.5.17: Site analysis of proposed site (Source: Researcher's Field Survey, March 2014).

5.5.2 ACCESSCIBILITY

The site can be accessed from both Zone eight junction and Crusher village junction. The site has basic infrastructural facilities such as good roads network and electricity. Plate XVIII shows Zone Eight Junction, Lokoja while Plate XIX shows access road to proposed site from Zone Eight Junction.



Plate XVIII: Zone eight junction, Lokoja (Source: Researcher's Field Survey, March 2014)



Plate XIX: Access road to proposed site (Source: Researcher's Field Survey, March 2014).

5.5.3 GEOLOGY

The site has no rock outcrops. The soil type is lateritic and does not present any critical considerations for design or construction. Plate XX shows the Lateritic soil type of proposed site.



Plate XX: Proposed site is characterized by lateritic soil type (Source: Researcher's Field Survey, March 2014).

5.5.4 TOPOGRAPHY

The site is relatively flat but has a gentle slope towards the North-East in terms of topography. This makes for easy construction, and minimal use of changes in level. Plate XXI shows the topography of proposed site.



Plate XXI: Topography of Proposed Site (Source: Researcher's Field Survey, March 2014).

5.5.5 VEGETATION

The site being located in the guinea savannah region and is characterized by grass and shrubs. Trees should be planted on the site especially along the north-eastern, axis to reduce the effects of the solar heat and wind. Plate XXII below shows the vegetation of proposed site.



Plate XXII: Vegetation of Proposed Site (Source: Researcher's Field Survey, March 2014).

5.5.6 UTILITIES

Existing electricity, sewage, water and telecommunications network are all available on site.

5.5.7 SUNRISE AND SUNSET

Sunrises from the east and set in the west. With the principle of orientation, longer side of the building shall face north or south direction to reduce heat discomfort. While the shorter sides shall face east or west direction. Much openings will be on the north or south directions but less openings will be on the east or west directions.

5.6 DESIGN BRIEF AND DEVELOPMENT

The aim of this work is to design an energy efficient shopping plaza through passive design approach. Major international trends have currently revealed new avenues for accelerated growth development and all-round socio-economic advancement through shopping. It is in the light of this that the Kogi State government intends to develop a city plaza in Lokoja to incorporate passive design principles in order to enhance energy efficiency. The client requires a shopping plaza which is energy efficient and should have: - good aesthetics that would give an attractive impression. The Shopping plaza must contain supermarkets, lettable office spaces; out-door children play-ground, lettable shopping spaces and a food court. A good landscaping with parking spaces and nature's aesthetics features (e.g. water body and vegetation) which enhance patronage from passersby. This brief is a culmination of the studies in all previous chapters; literature review, case studies and the Kogi State Ministry of Land and Environment brief for city plaza in Lokoja metropolis.

The brief is classified into the following:-

a. Commercial
b. Administrative
c. Communal
d. Auxiliary/Services.

Each can be sub-divided into:

a. The commercial aspect includes:-

   i. Lettable shopping spaces.

   ii. Lettable office spaces.

   iii. ATM gallery

   iv. Super-market

   v. Anchor store

b. The administrative aspect includes:-

   i. Manager's office.

   ii. Security post.

   iii. Maintenance unit.

c. The communal aspect includes:-

   i. Food court

   ii. Snooker games

   iii. Table tennis games

   iv Gymnasium

   v. Arcade games

   vi. Cyber-café

   vii. Computer Training Centre

d. The auxiliary/services aspect includes:-

   i. Conveniences.

   ii. Escape stairs.

   iii. Lobby/Circulation spaces

5.7 DESIGN PHILOSOPHY

5.7.1 Concept of Design

The concept for this design is the medium of exchange between a buyer and a seller which is the Nigerian coins and naira notes. When this is properly juxtaposed with

passive design principles a good form that enhances energy efficiency is obtained. Fig 5.18 shows the design concept of the proposed Lokoja shopping plaza.

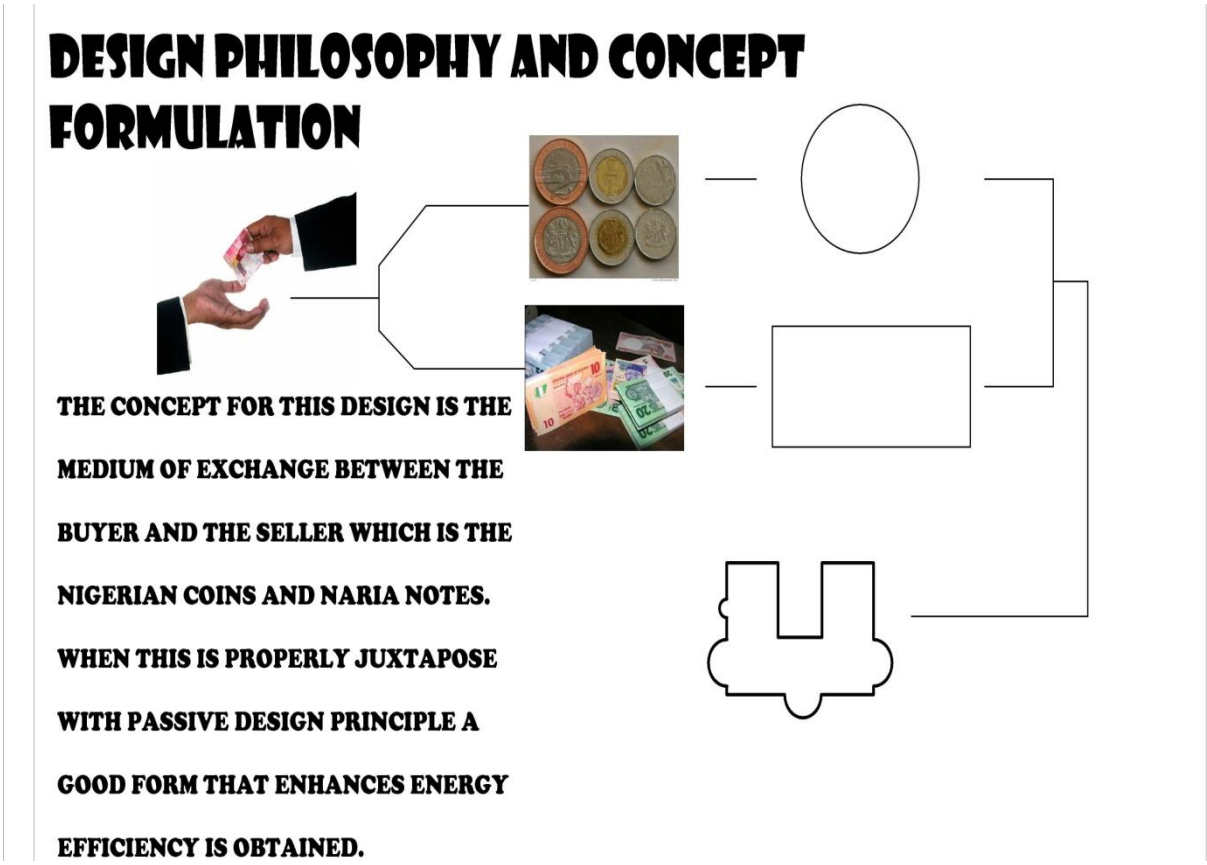


Fig 5.18: Design concept of the proposed Lokoja shopping plaza

5.7.2 Site Zoning Concept

The site zoning system is conceptually divided into four levels: shopping area, green area, outdoor recreation area and parking area. Fig 5.19 shows the site zoning concept of the proposed Lokoja shopping plaza.

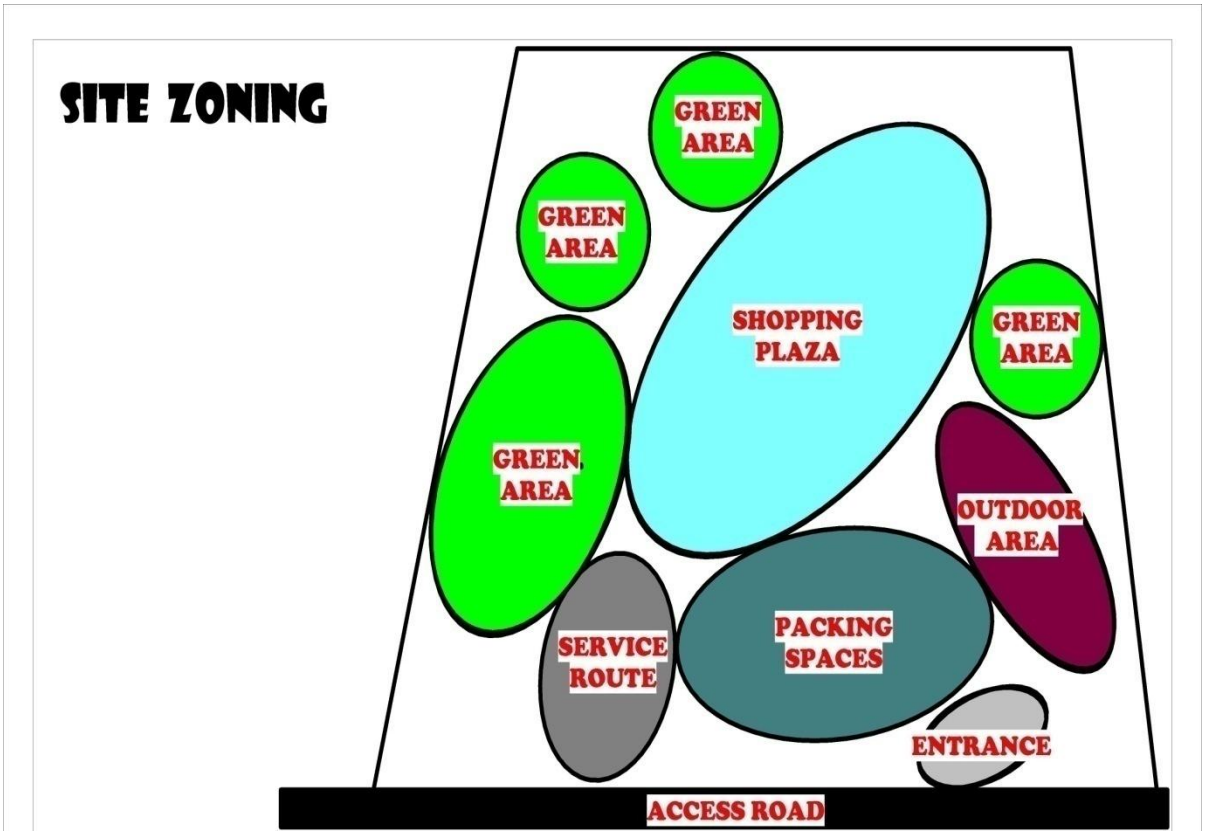


Fig 5.19: Site zoning concept of the proposed Lokoja shopping plaza.

5.7.3 Site Plan

The site zoning concept is what is eventually translated in generating the site plan. Site plan shows how the plaza and other features such as children outdoor park, outdoor seating area, outdoor games area and the ware-house are positioned on site with respect to their relationship with one another.

Fig 5.20 shows the site plan of the proposed Lokoja shopping plaza.

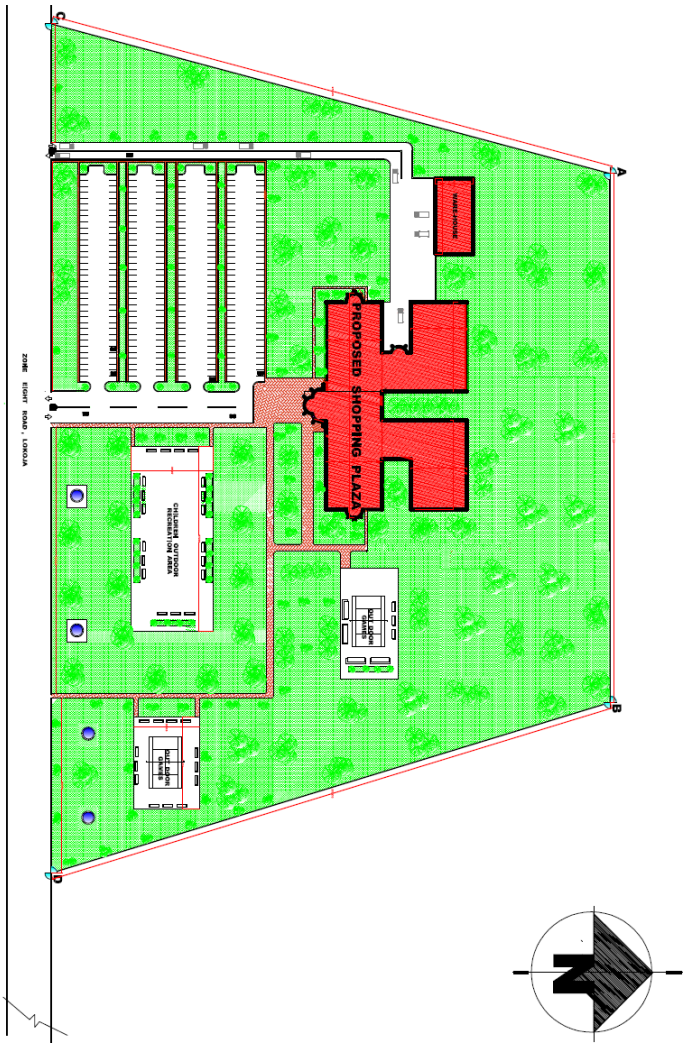


Fig 5.20: The site plan of the proposed Lokoja shopping plaza.

5.7.4 Plan Concept

The plan concept of the design is of loosely connected functional zones organized into four wings. The plan of the building consists of four functional sections, which are connected by a central atrium. The atrium contributes to the day-lighting effect of the plaza thereby enhancing shopping activities.

5.7.4.1 Ground Floor Plan

The ground floor plan consists of a large anchor store, a supermarket, food court, kitchen, conveniences, gymnasium, two ATM galleries, snack court, table tennis games, snooker games, an off-loading bay with a service lift and a security office. The three atria help to enhance day-lighting and shopping activities. At the entrance lobby of the shopping plaza are two escalators and two passenger lifts. These will serve the following functions: to move people from one floor to another and also give them a visual appreciation of the plaza as they move up and down the plaza. Four different staircases are provided at different locations to enhance adequate movement of people. Escape routes from the plaza to walk-ways are provided. Fig 5.21 shows the ground floor plan of the proposed Lokoja shopping plaza.

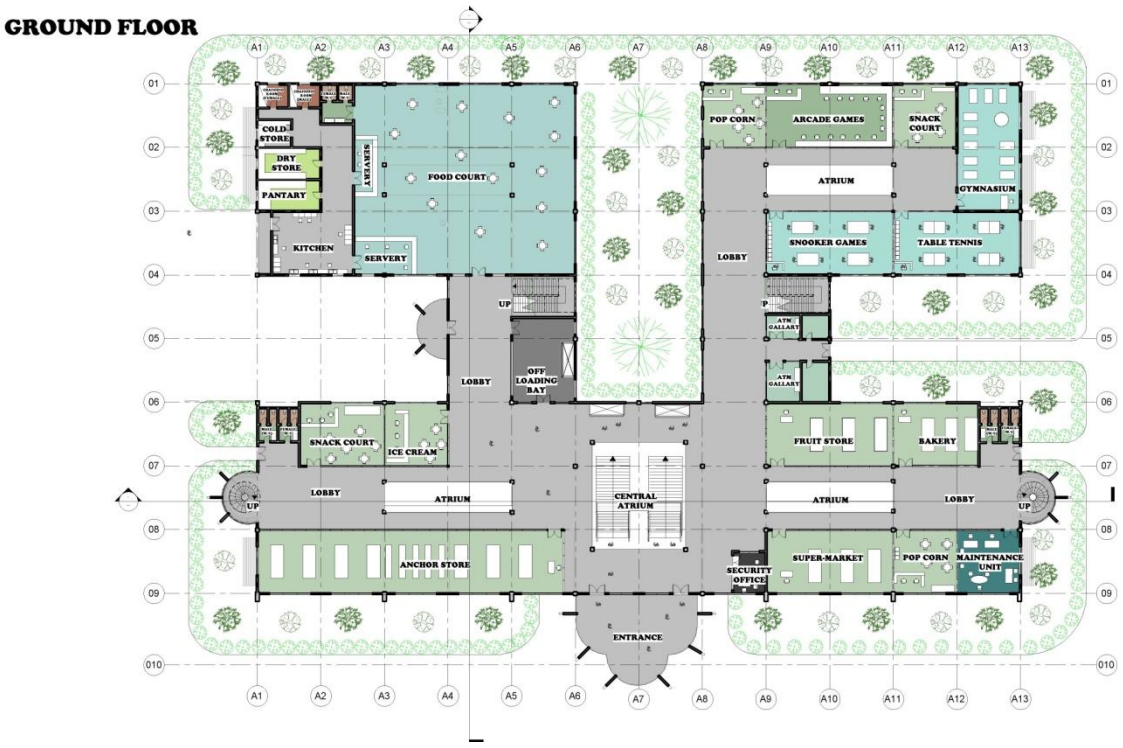


Fig 5.21: The ground floor plan of the proposed Lokoja shopping plaza.

5.7.4.2 First Floor Plan

The first floor plan consists of a cyber-cafe, a computer training centre, floor manager's office, a store, conveniences, eighteen lettiable shopping spaces where various products such as computer accessories, interior decorations, jewelry, art-works and boutique are sold and an off-loading bay with a service lift. The four atria help to enhance day-lighting and shopping activities. At the main lobby of the shopping plaza are two escalators and two passenger's lifts. Fig 5.22 shows the first floor plan of the proposed Lokoja shopping plaza.

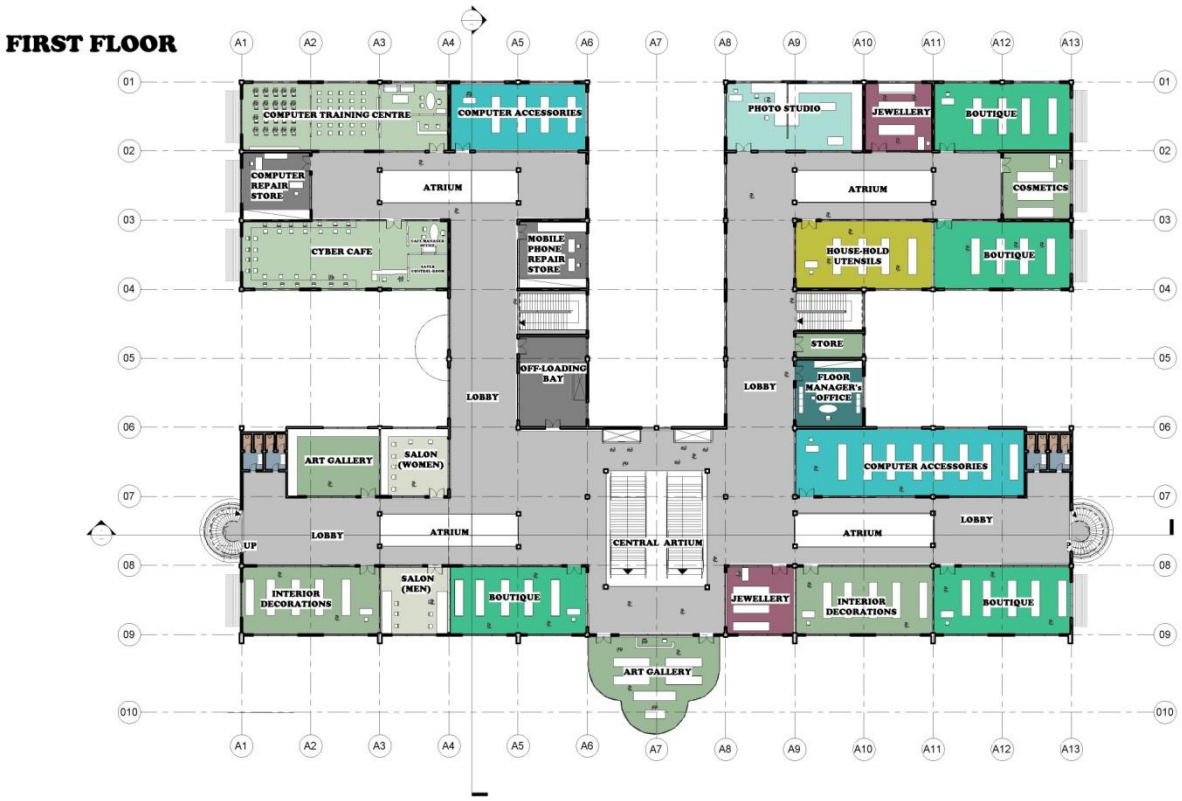


Fig 5.22: First floor plan of the proposed Lokoja shopping plaza.

5.7.4.3 Second Floor Plan

The second floor plan consists of an exhibition gallery, conveniences, off-loading bay with a service lift and twenty four lettiable shopping spaces where various products such as computer accessories, interior decorations, jewelry, art-works and clothes are sold. The four atria help to enhance day-lighting and shopping activities. At the main lobby of the shopping plaza are two escalators and two passenger's lifts. Fig 5.23 shows the second floor plan of the proposed Lokoja shopping plaza.



Fig 5.23: Second floor plan of the proposed Lokoja shopping plaza.

5.7.4.4 Third Floor Plan

The third floor plan consists of the general manager's office, a store, a conference room, conveniences and twenty four lettiable office spaces where various organizations and business outfit such as mtn, glo, and travel agencies can rent. The four atria help to enhance day-lighting. At the main lobby of the shopping plaza are two escalators and two passenger's lifts. Escape staircases are provided. Fig 5.24 shows the third floor plan of the proposed Lokoja shopping plaza.

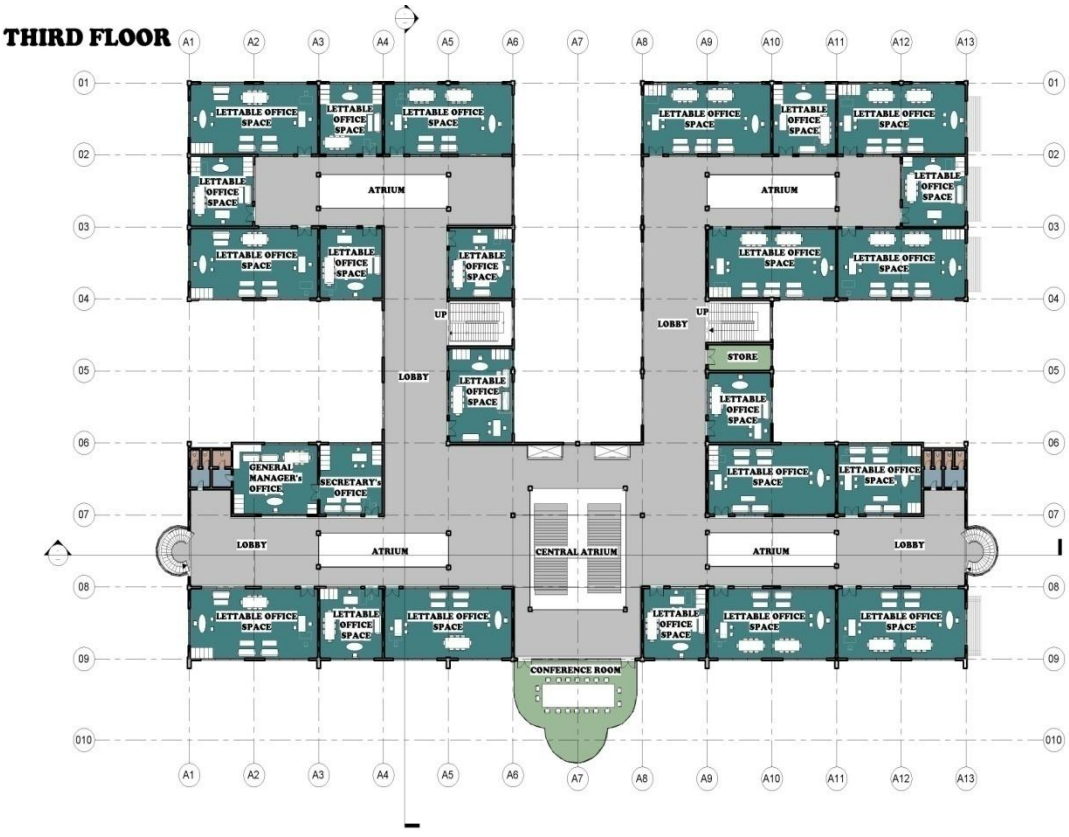


Fig 5.24: Third floor plan of the proposed Lokoja shopping plaza.

5.7.5 Circulations

Considering that the shopping plaza is going to be used by diverse classes of people shopping different products, to achieve a harmonious relationship there must be good interconnectivity and unity of spaces. The service route leads directly to the ware house and off-loading bay while the customers and visitors route leads directly to the parking spaces. Escalators, lifts and stairs are incorporated into the design in order to enhance vertical circulation of customers and visitors among the floors and to stimulate their interest. The escalators and lifts are located in a spacious central atrium, while the staircases are located at the corners of the building. Fig 5.25 shows the details of an escalator used in the proposed Lokoja shopping plaza.

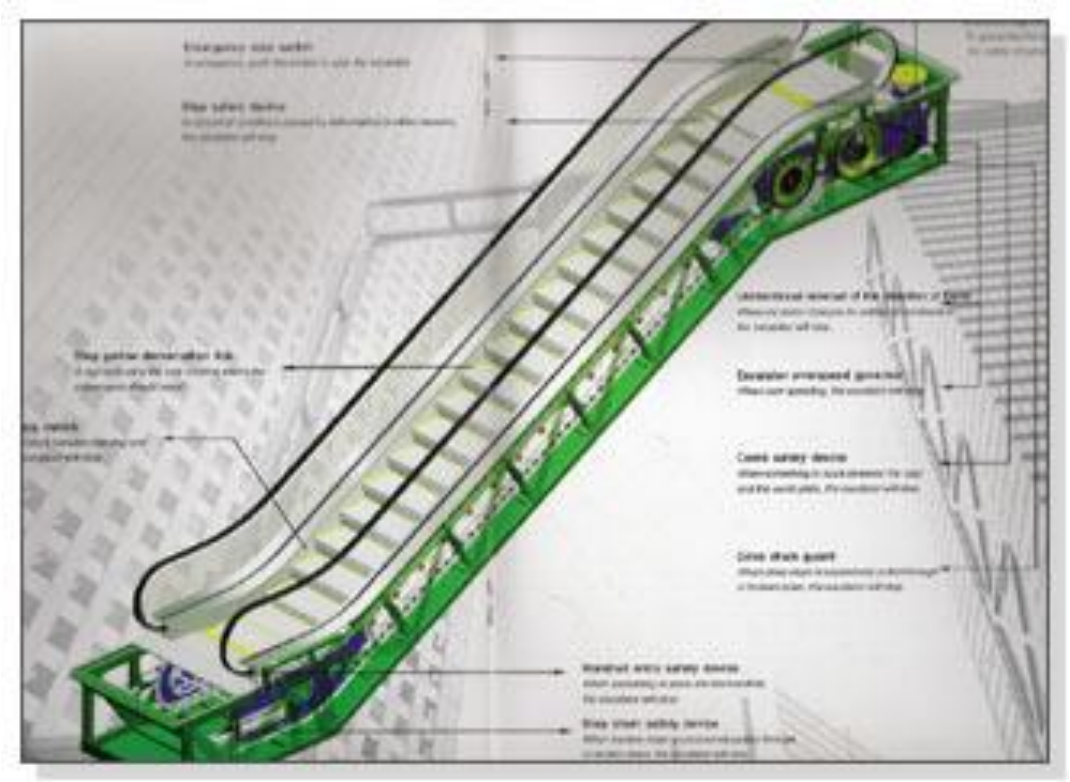


Fig 5.25: Details of an escalator used in the proposed Lokoja shopping plaza.

5.7.6 Plaza Amenities

i. Outdoor seating inform of concrete seats are provided for outdoor relaxation.

ii. Fountains were systematically incorporated into the design since water has a way of enhancing cooling.

iii. Children play ground which enhances out-door recreation is provided with sculpture and other art forms are also provided as major design features. Fig 5.26 shows the 3D view of the children outdoor recreation park of the proposed Lokoja shopping plaza.



Fig 5.26: 3D view of the children outdoor recreation park of the proposed Lokoja shopping plaza.

iv. A large anchor store and a super-market with curtain walls are magnet that attracts visitors, as such are logically placed to influence shoppers flow. Fig 5.27 shows the interior view of the supermarket in the proposed Lokoja shopping plaza.



Fig 5.27: Interior view of the anchor store in the proposed Lokoja shopping plaza.

v. The need for parking is very essential. A ratio of between 5 and 6 car spaces per 1,000 square feet of leased store area is applied in the proposed Lokoja shopping Plaza. Fig 5.28 shows the 3D view of the car park in the proposed Lokoja shopping plaza.



Fig 5.28: 3D view of the car park in the proposed Lokoja shopping plaza.

5.7.7 Landscape Features

Good landscape design helps to create an attractive environment. The proposed Lokoja shopping plaza has an aesthetically pleasing view with good landscape, water body (fountain), trees (for shade and to reduce glare effects, absorb sun

radiation, reduce noise), flowers (to create a colourful and lively atmosphere), well organized pedestrian walkways which are separated from vehicular areas. The outdoor features give a relaxed atmosphere with good natural attractions. Fig 5.29 shows good use of landscape design in the proposed Lokoja shopping plaza.



Fig 5.29: Good use of landscape design in the proposed Lokoja shopping plaza

5.7.8 Building façades

The architectural composition of the building façade is highly attractive. The uniqueness of this design is the provision of visual awareness to the public. Fig 5.30 shows the four elevation views of the proposed Lokoja shopping plaza.

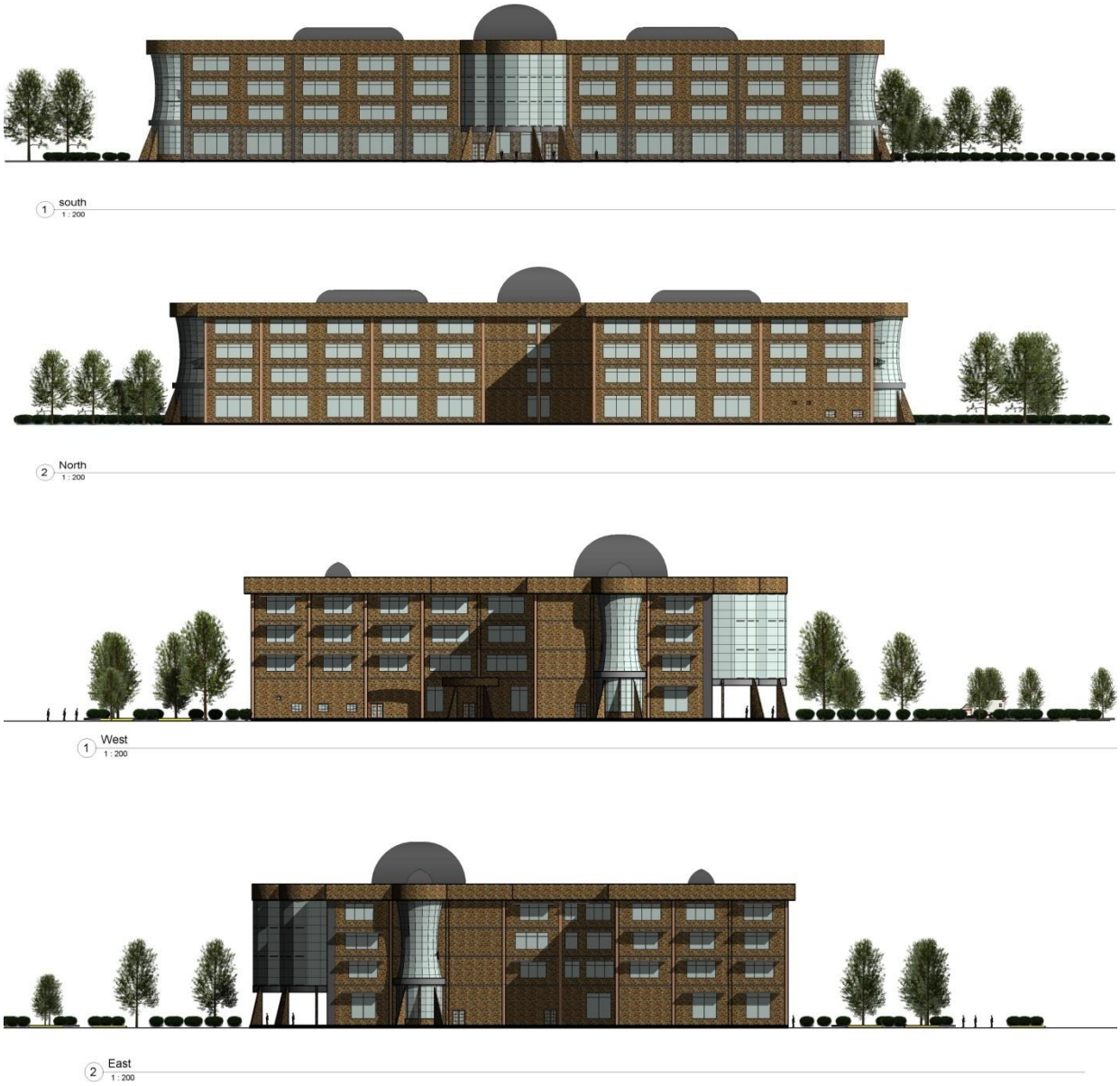


Fig 5.30: Elevation views of the proposed Lokoja shopping plaza.

In essence large windows are place in strategic places whereby goods are displaced close to the windows. The formal is aided by the facts that attraction of any form usually comes

with visibility. Thus the external envelope is designed partly with a see through solar reflective glass with high properties. Fig 5.31 below shows the 3D view of the proposed Lokoja shopping plaza.

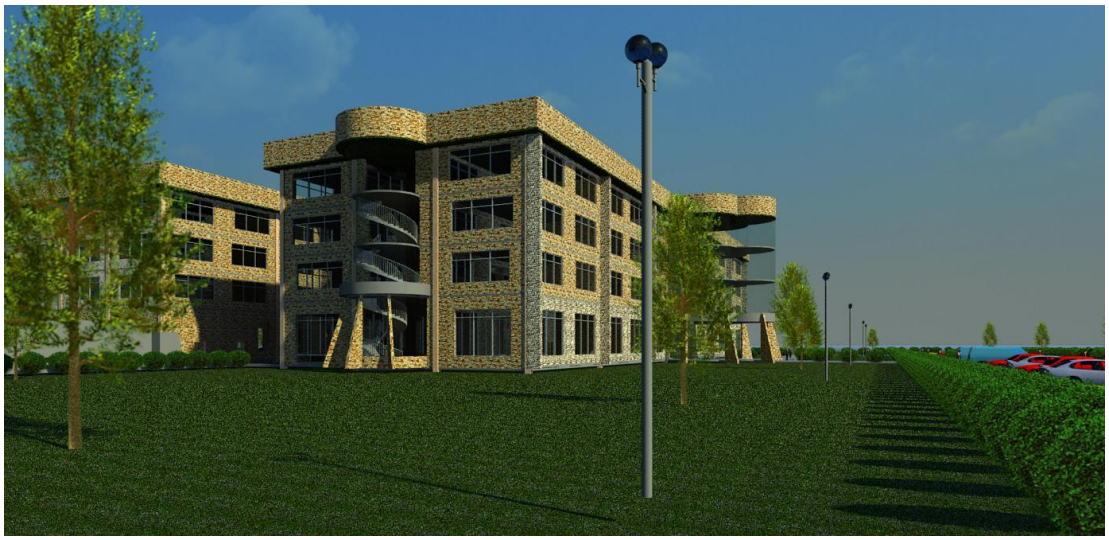


Fig 5.31: 3D view of the proposed Lokoja shopping plaza

5.8 THE CONSTRUCTION TECHNOLOGY

5.8.1 Construction Method

Framing system should be used during the construction of the plaza. The basic structural elements in framing system construction are the columns and beam. The columns are the structural elements designed to carry vertical loads and transfer them through foundations to the ground while the beams are the structural elements transferring onto the columns all the bending forces acting perpendicularly. The entire building component should be produced insitu except for some materials like blocks, steel channels, roofing sheets and other components which production

practicality on site will be difficult should be produce in factory. Earthwork support should be used at the foundation trench. All wiring and piping should be by conduit.

5.8.2 Floors

The activities that will add much live loads and dynamic loads to the floors are located on the ground floor level. Hence there is decrease in loading bearing of the floor with increase in floor levels. The major materials used as floor finishes is granite floor tiles (non-slippery when wet and with high stain resistant) on 50mm screed laid to fall on 25mm cement sand screed. This material was used for the entire flooring. While the conveniences were made of vitrified ceramics tiles of light brown colour, 300 x 600mm sloped to drain.

5.8.3 Skirting

The major material for skirting construction is granite floor tiles of 100 x 600 x 12mm to match approved floor sample. This material was used at the entrance lounge and reception, offices and lobbies. The exhibition hall skirting was made of polished hardwood finished with 100 x 300 x 8mm thick. The restaurant was made of granite floor tiles with 100 x 300 x 8mm thick to matched approved floor sample.

5.8.4 Wall

The exterior walls of the building are cavity walls while the internal partition walls are majorly curtain walls and little of sandcrete blocks which were finished with 2 coats of CAPL lilac brown over 12mm thick cement plaster. The walls of the changing room and conveniences were finished with vitrified ceramics tiles of 300

x 150mm laid to match with wall skirting up to ceiling soffit on 12mm cement plaster. Fig 5.32 below shows the section of the proposed Lokoja shopping plaza.

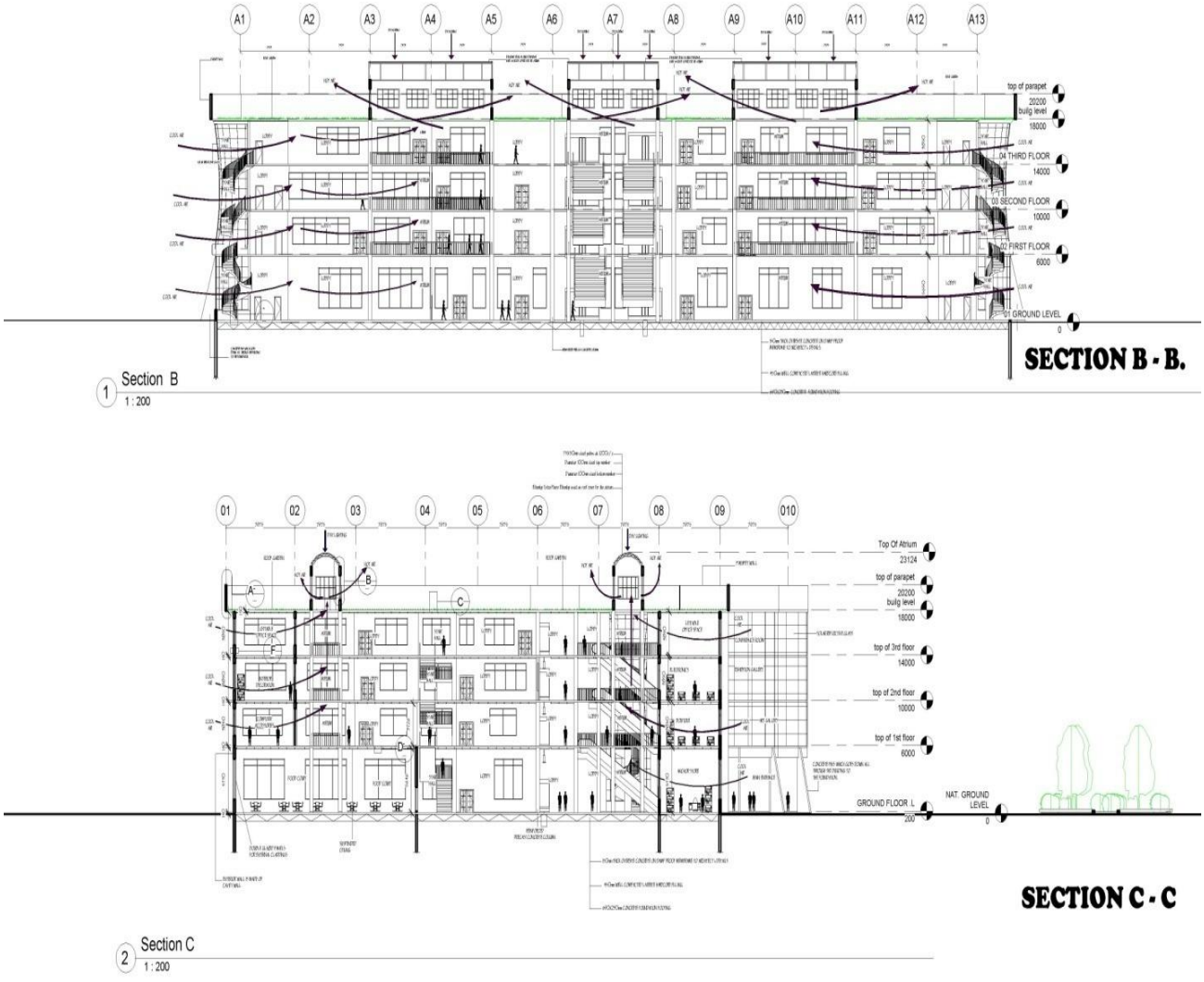


Fig 5.32: Sections of the proposed Lokoja shopping plaza

5.8.5 Ceiling

The major material for all the ceiling construction was suspended ceilings which were done to manufacturer's details. Only the lettiable offices made use of pop ceiling material which was done to manufacturer's details.

5.8.6 Foundations requirements

Strength and Stability: The foundation is rigid and stable to safely bear and transmit the load of the building to the soil. This helps to hold down the structure against the wind uplift.

5.8.7 Foundation choice

The choice of the foundation for any kind of building is largely determined by the structure, and the nature of the soil, even possibly the soil movement. For this research, the site chosen is characterized with laterite soil which has great compressibility and compatibility features, under heavy loads. The choice of foundation is continuous strip foundation.

5.9 MATERIALS, FINISHES AND SERVICES

Shopping plaza is a commercial building with different functions. For each separate function, the materials used for the internal finishing will be based on; initial and long term cost, durability, maintenance, quietness, comfort, thermal conductivity and appearance.

The main materials used in this design are solar reflective glass, high tensile pre-tensioned wires and reinforced concrete; others include steel, aluminum stainless steel and timber. These materials were purposely chosen due to their advantages.

The primary structural materials used were concrete and pre-tensioned wires. Concrete is one of the most important building materials used in the plaza because of its plasticity and

hardening properties. Concrete is strong in compression. High tensile pre-tensioned wires bond to the concrete induce in it the required compressive force. This enables the pre-tension wires the capacity to span for 10-12 meters. Steel also has good structural properties which include: high strength; equal strength in tension and compression; high density; high strength to weight ratio which makes its components light weight in relation to their load carrying capacity. These properties make steel suitable for a full range of structural elements such as columns, beams and roof.

Glass also plays an important role in the structure of the building. The curtain wall structure is made of glass which enhances the feeling of transparency, spaciousness, lightness and invitation to the shoppers thereby connecting the interior to the immediate exterior environment. Glass was also used for exhibition stands and show glass. Glass curtain walls have two basic methods of installation namely: the stick and the unitized system. In the stick system, the curtain wall frame and glass are installed and connected together piece by piece while in the unitized system the curtain wall is composed of large units that are assembled and glazed in the factory, shipped to the site and erected on the building.

Reinforced concrete floor slabs were used on the different levels of the plaza. The floor slabs support suspended ceiling which accommodates the electrical installations like the air conditioning ducts and the lighting fittings. Other materials used are ethylene tetra flouro ethylene used as roof cover for the atrium, granite floor tiles for floor finishes; suspended ceiling for ceiling and roof garden was used on the roof deck.

In a building of this magnitude, it is important to consider the services such as:

(i) Fire
(ii) Security
(iii) Disposal System
(iv) Plumbing/Water Distribution System
(v) Storm Water Drainage
(vi) Power Supply

5.9.1 Fire

Fire incidence is often associated with storey buildings, so it is mandatory that fire preventive mechanisms be incorporated into the scheme. This is because the safety of the plaza and the containing assets need to be guaranteed.

Fire hydrants for easy water collection by fire fighters, fire extinguisher and smoke detectors are provided in the centre, but competent professional should be involved in determining the numbers and location of the fire fighting systems.

5.9.2 Security

Security cameras and screen mirrors are centrally located in strategic areas of the stores, supermarkets and other spaces so as to aid monitoring of people within and around the plaza. Security personnel are also employed to foster security. Burglarproof materials and security alarm systems are further incorporated into the design. This is because goods worth millions of naira would be stored in the building. Security measures are aimed at preventing the following incidences:

i. Burglary
ii. Mob attack of persons

5.9.3 Disposal System

Refuse collection within the plaza would be done daily by the maintainace unit. Refuse would be collected from different locations within and around the plaza into a central local incinerator where the garbage would later be disposed from time to time.

5.9.4 Plumbing/ Water Distribution System

Water supply into the plaza is necessary. Hence, it would be provided to serve the following purposes.

i. Anti-fire protection
ii. Ancillary purpose
iii. Any other purpose

5.9.5 Storm water drainage

The slope of the site being relatively gentle will encourage natural drainage of storm water off the site. But drainage channels are provided in the parapet walls to take care of water run-off from the roof garden.

5.9.6 Power supply

Power shall be tapped from the Power Holding Company of Nigeria (PHCN)'s national grid. However, the design shall also cater for its own power needs. There is provision for sunlight tubes for interior lighting with power generating sets and synchronization panel, to cater for power failure.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 INTRODUCTION

This chapter focuses at conclusion of the thesis write up, it contribution to knowledge and vital recommendations.

6.2 CONCLUSION

In a world where there is increasing concern over climate change, dwindling energy sources coupled with inconsistent nature of power supply from the central electricity supply, using passive design principles to enhance energy efficiency is ideal for a shopping plaza because it is cost effective and environmentally friendly. Using mechanical means should however be optimized in terms of design, operation and control to enhance energy efficiency. For the hot-humid climatic zone of Nigeria, energy efficiency is achieved with open forms having large surfaces with the principal axis lying along north-south direction, increasing window openings, efficient landscape design, use of shading devices, optimal day lighting.

The proposed Lokoja shopping plaza incorporates the following: use of roof garden which reduces energy cost by 25% (National Resource Defence Council, 2012), application of Sun light tube and atria to enhance interior day lighting thereby reducing energy cost by 10% (Evolve Energy System, 2004), use of insulated cavity walls to reduce total heating and cooling by 30% (Sustainable Energy Authority, 2002), good landscape design which serves as an effective means of protecting the building from unwanted solar gains and redirecting the wind flow to enter the building for natural ventilation thereby reducing cooling cost and heating cost to as much as 25% (Nyuk and Yu, 2005).

6.3 CONTRIBUTION TO KNOWLEDGE

This thesis main focus has been on how energy efficiency can be enhanced using passive design principles in a hot-humid climate. The concept of passive design principles has been used to create a sustainable energy efficient design and it can be deduced that:

i. Passive design helps to enhance energy efficiency by keeping design feasible both technically and economically while responding to the local climate. This translates in enhancing energy efficiency and reduction in cost of energy consumption of a building.

ii. Passive design approach creates a good enabling environment for indoor climate and occupant comfort.

6.4 RECOMMENDATION

From the cases studied in Nigeria, it is apparent that much still need to be done in applying the concept of passive design principles in enhancing energy efficiency in shopping plazas in Nigeria. I strongly recommend to both the Nigeria Institute of Architect and Architect Registration Council of Nigeria to organize more symposiums where issues on energy efficiency and passive design will be discussed. Thereby educating the practicing architects on recent researches and innovations on these issues since the architectural profession has a leading role to play in adopting passive design principles.

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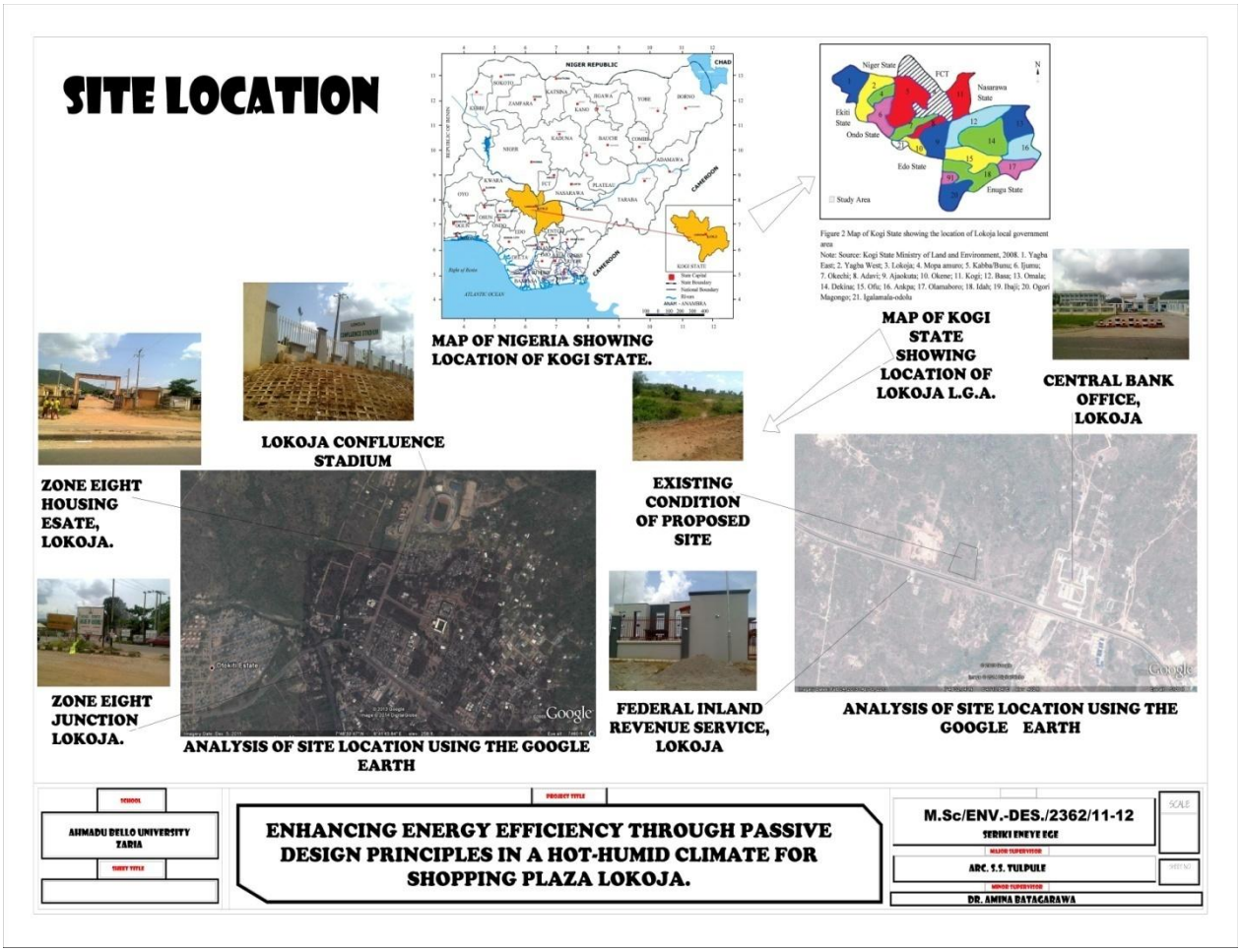
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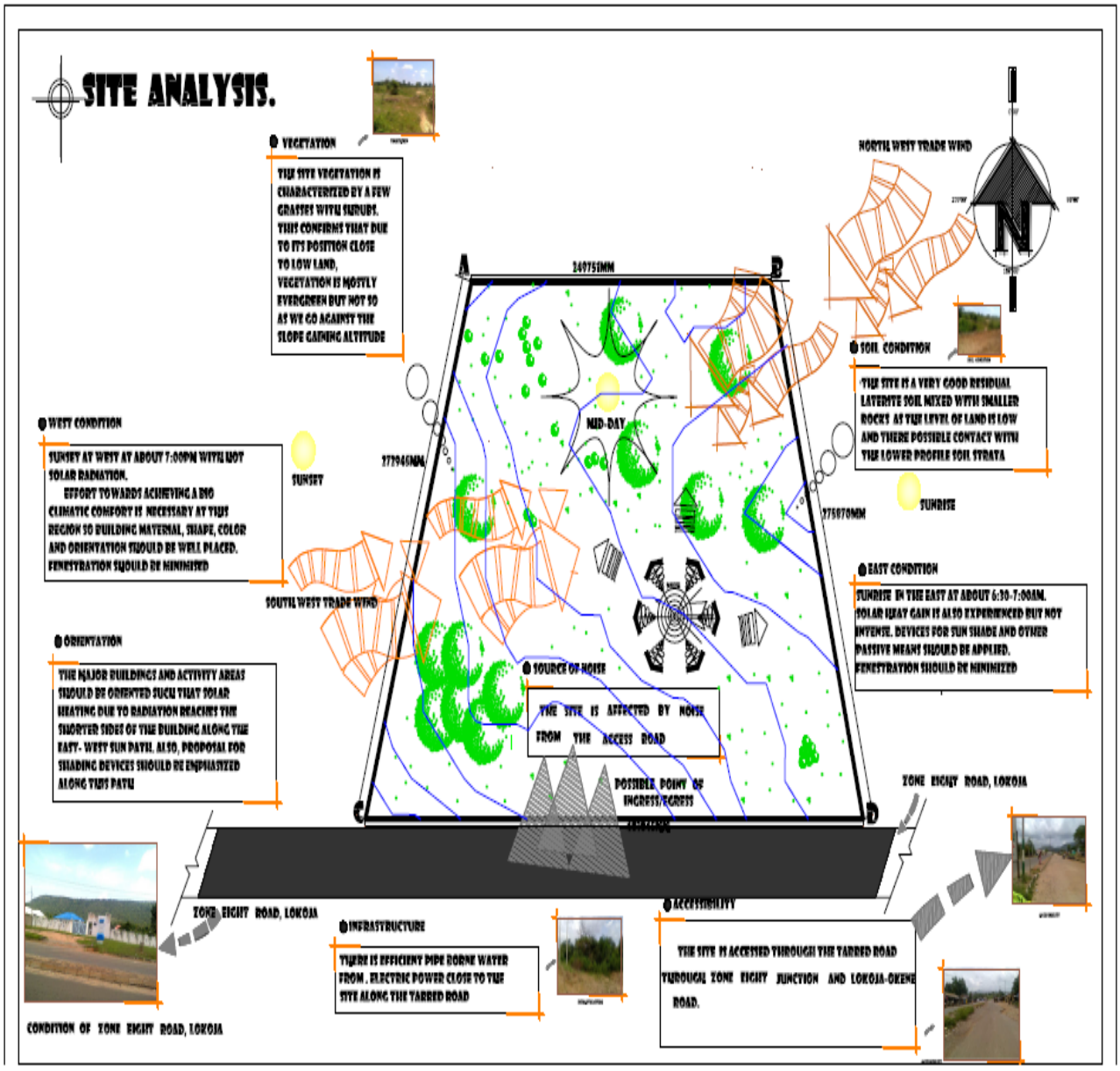
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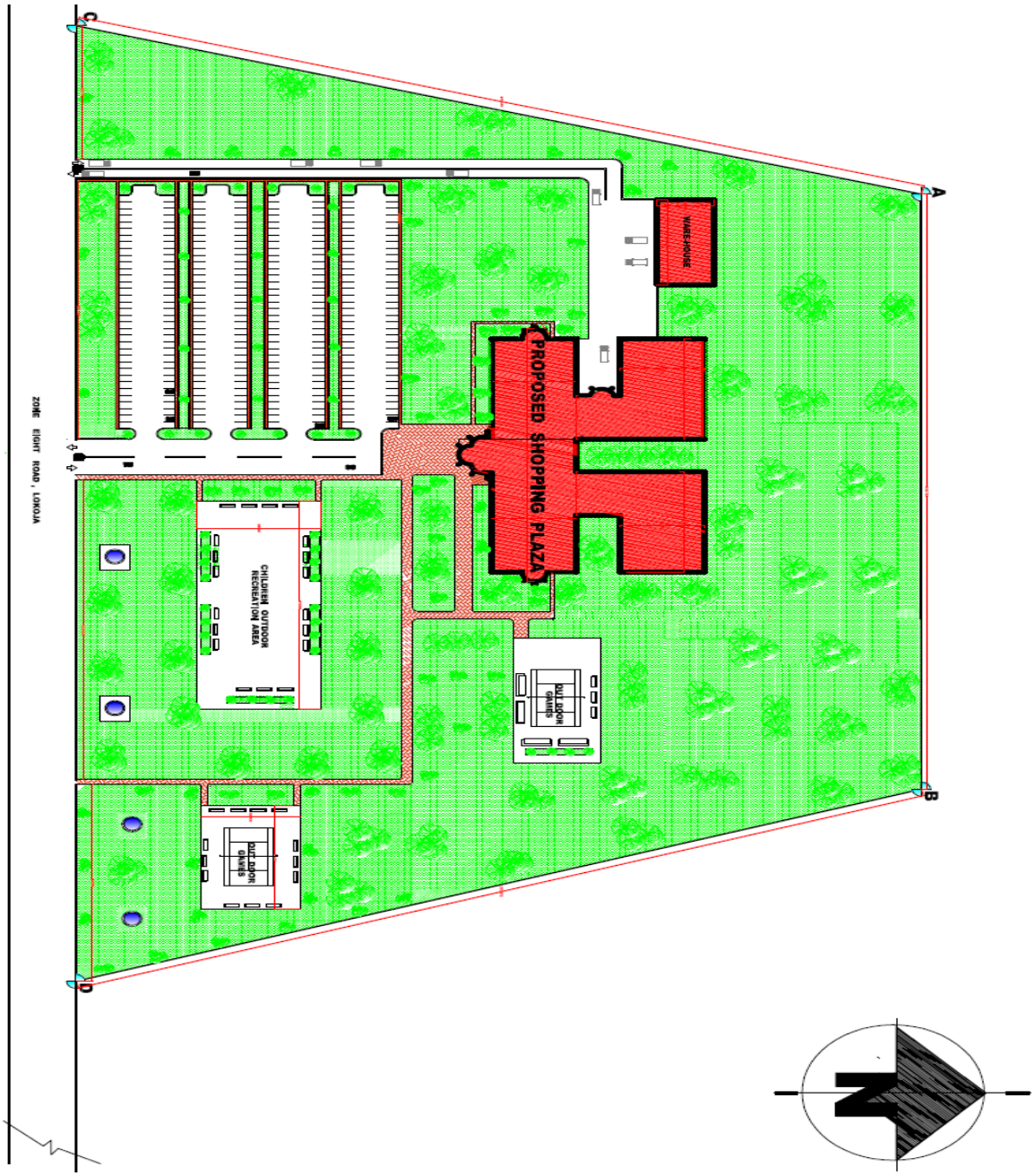
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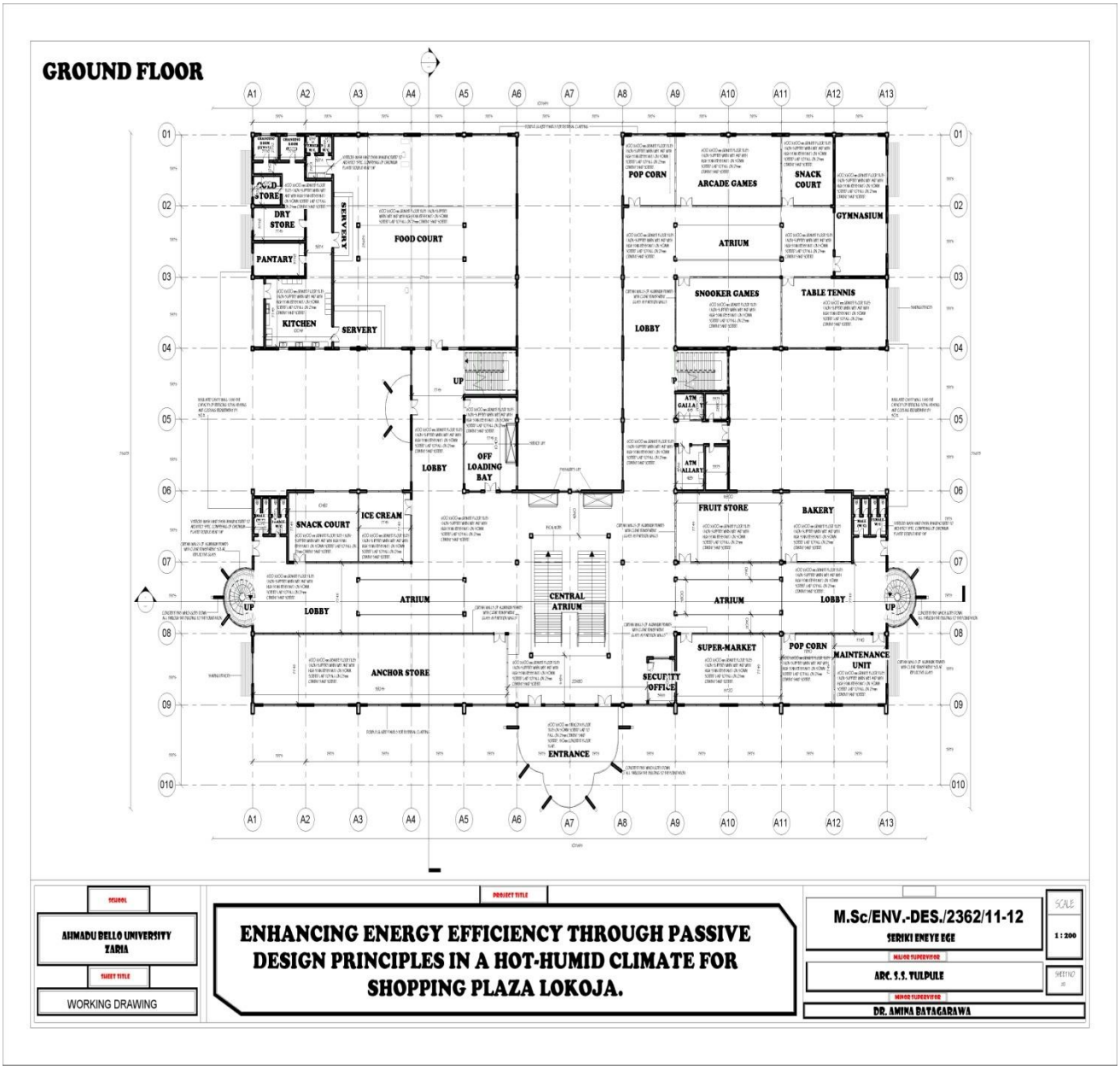
APPENDIX 1 : SITE LOCATION



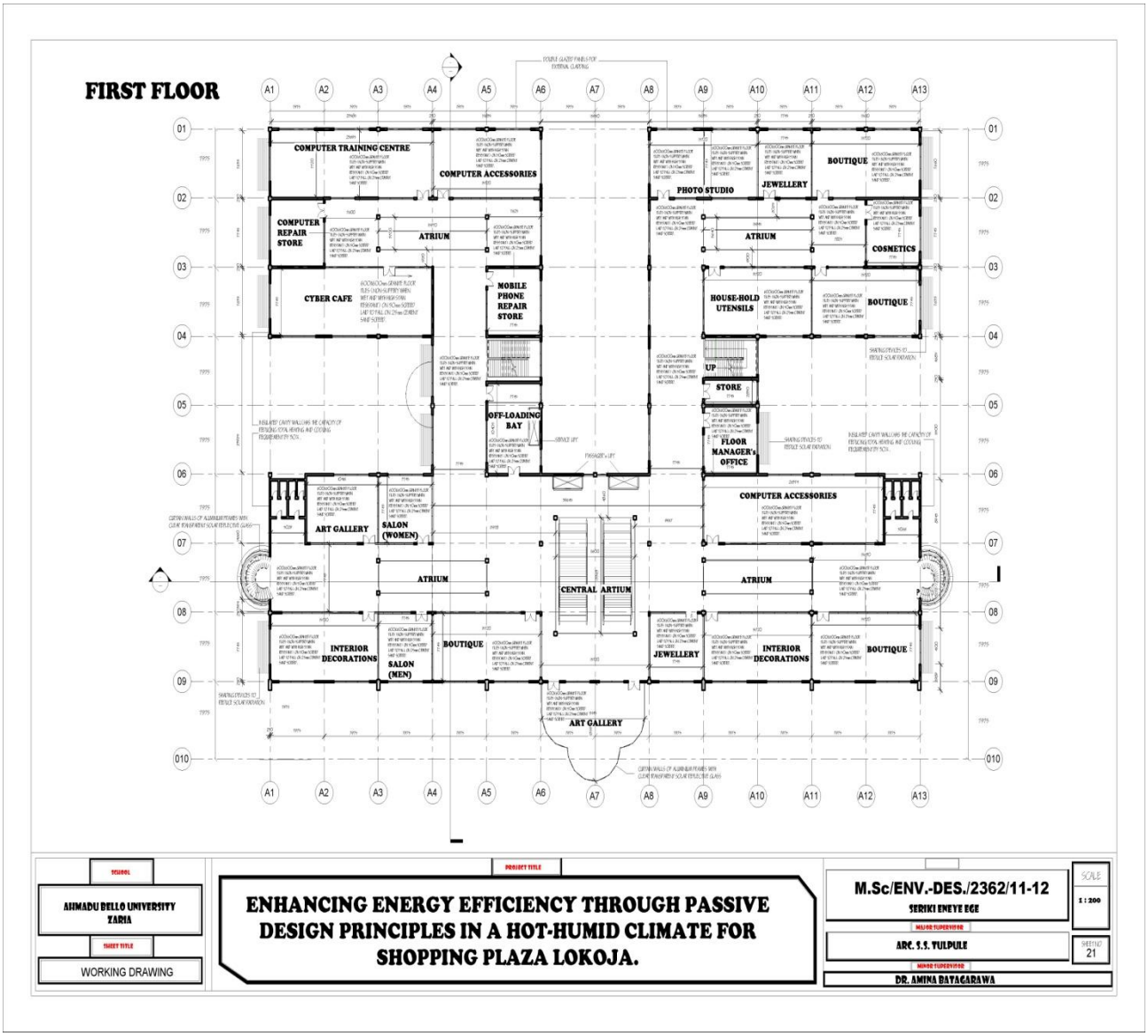
APPENDIX 2 : SITE ANALYSIS



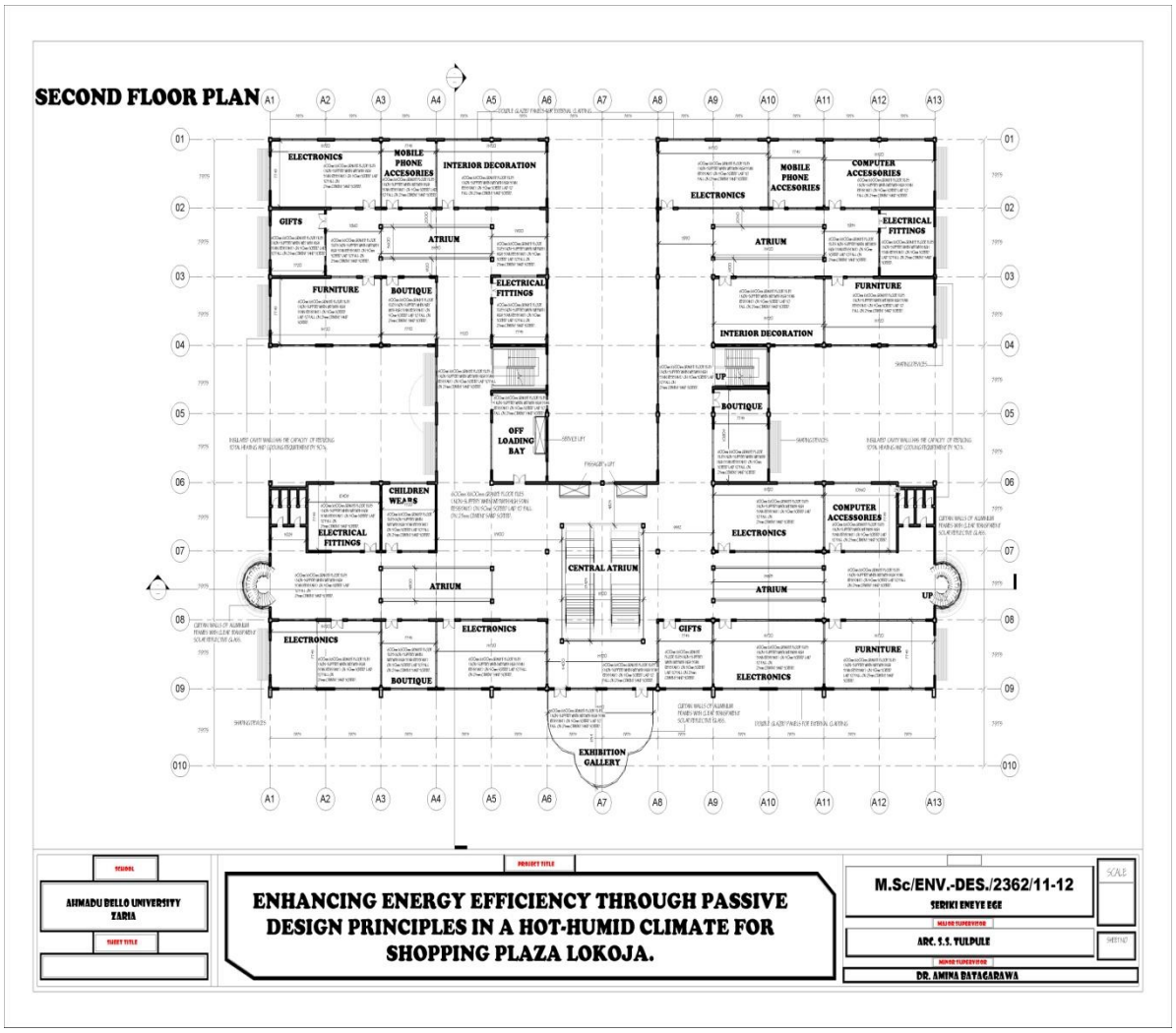
APPENDIX 3 : SITE PLAN



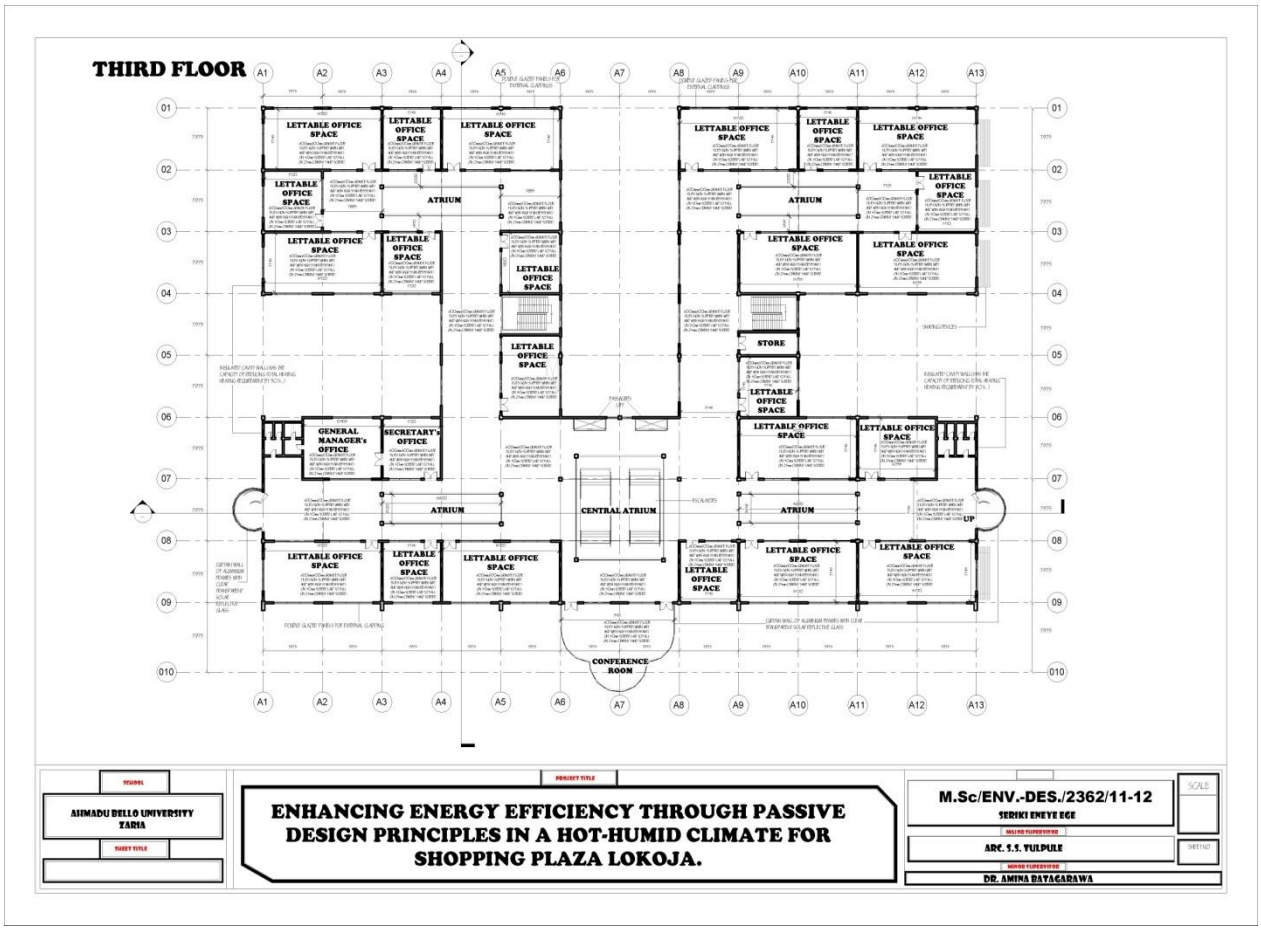
APPENDIX 4 : GROUND FLOOR PLAN (WORKING DRAWING)



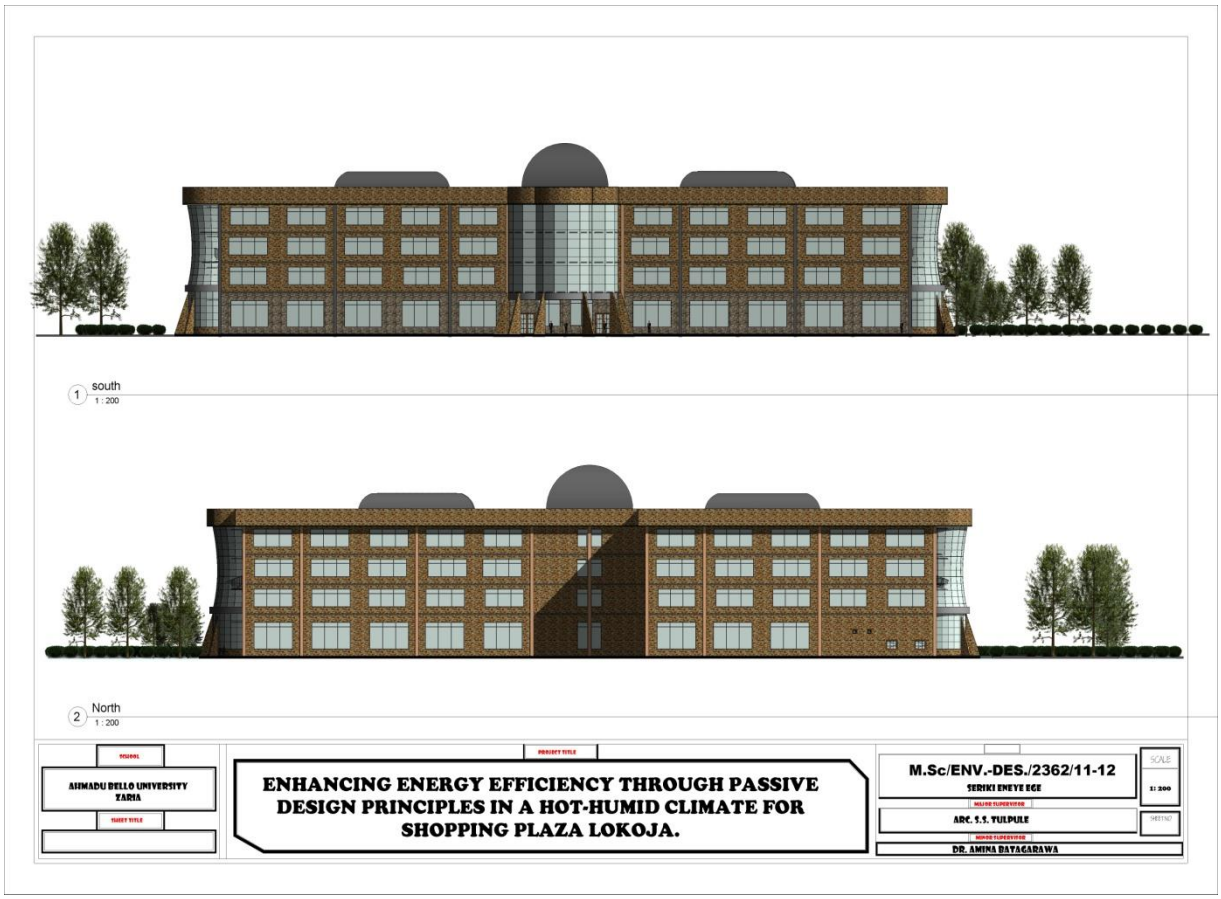
APPENDIX 5 : FIRST FLOOR PLAN (WORKING DRAWING)



APPENDIX 6 : SECOND FLOOR PLAN (WORKING DRAWING)



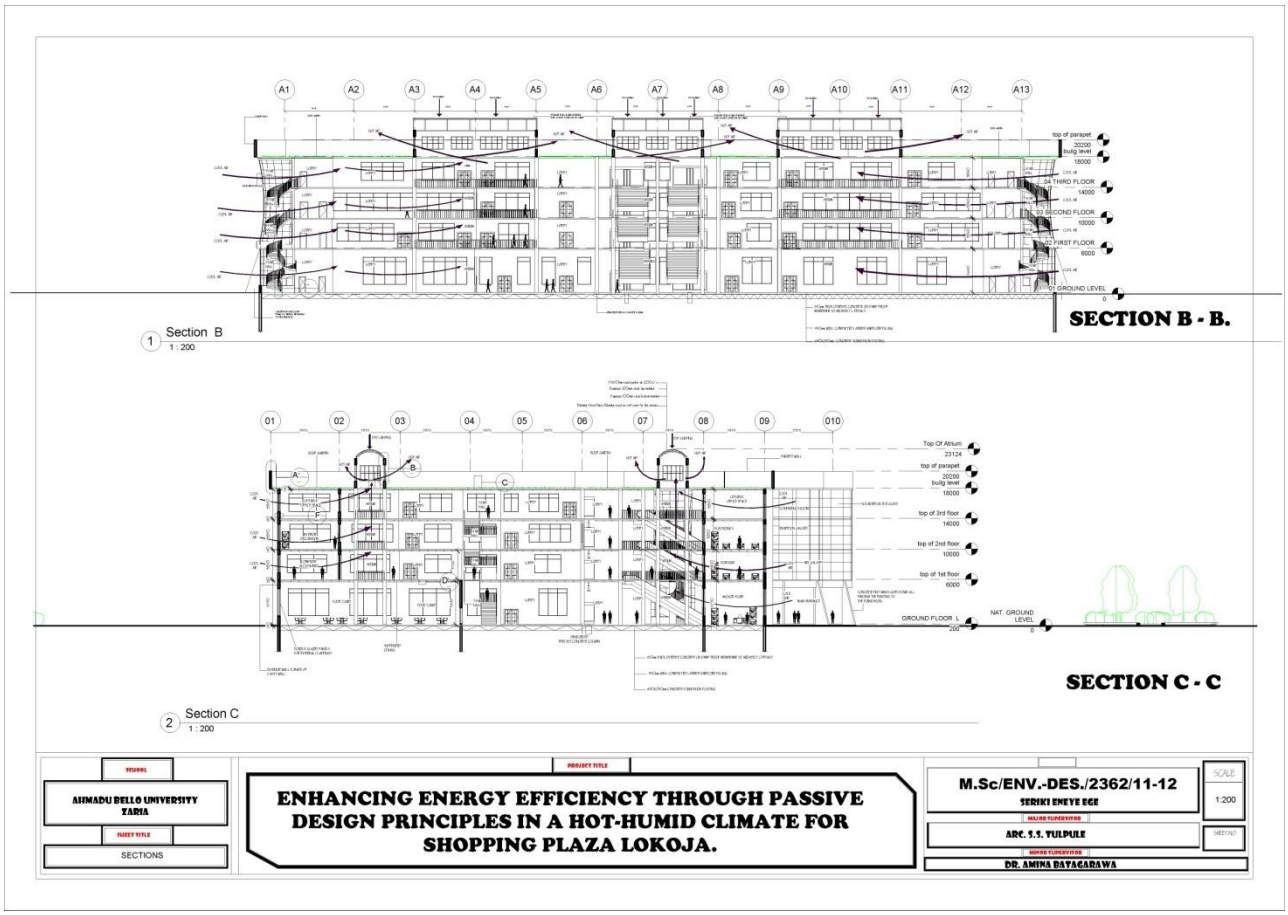
APPENDIX 7 : THIRD FLOOR PLAN (WORKING DRAWING)



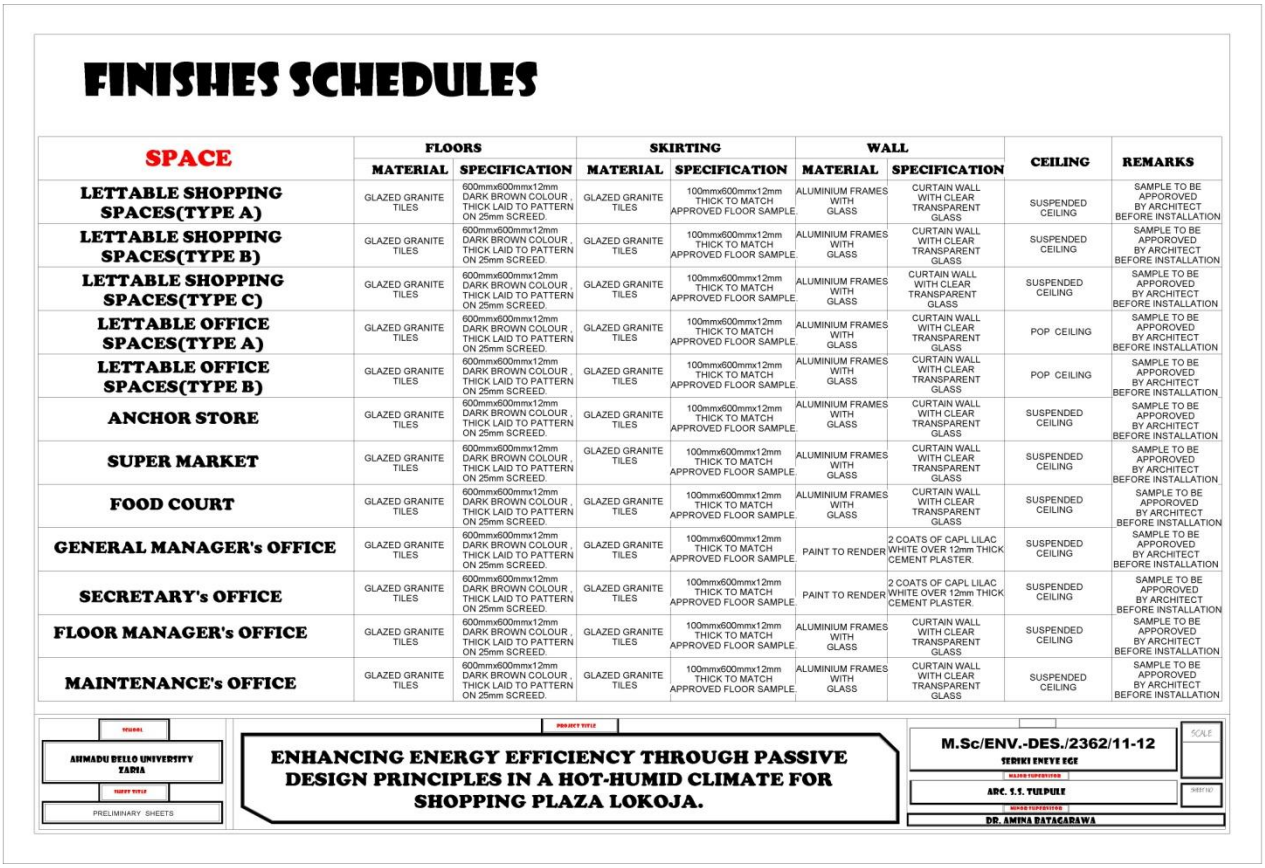
APPENDIX 8 : ELEVATION (PRESENTATION DRAWING)



APPENDIX 9 : ELEVATION (PRESENTATION DRAWING)



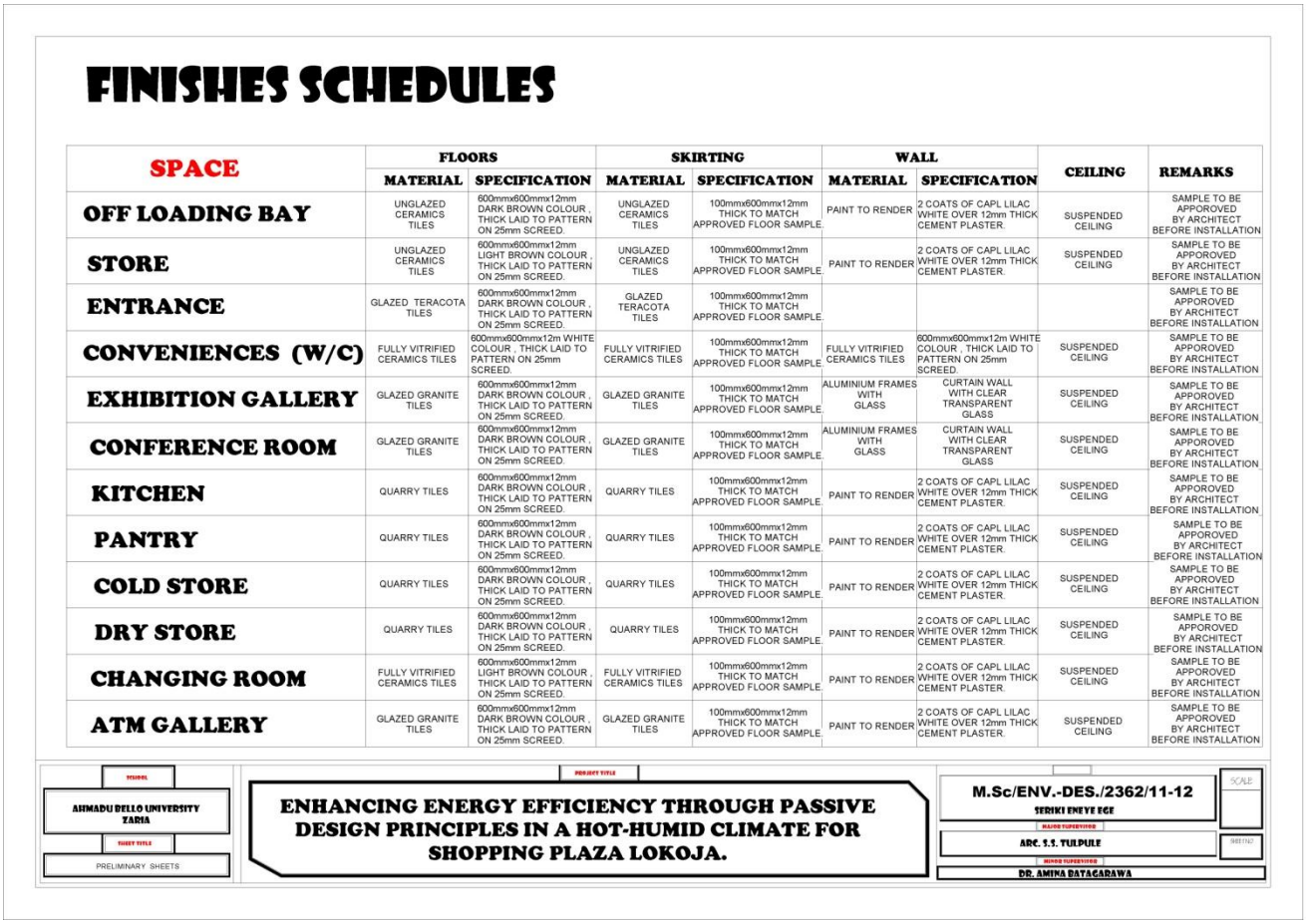
APPENDIX 10 : SECTIONS



FINISHES SCHEDULES

SPACE	FLOORS		SKIRTING		WALL		CEILING	REMARKS
	MATERIAL	SPECIFICATION	MATERIAL	SPECIFICATION	MATERIAL	SPECIFICATION		
LETTABLE SHOPPING SPACES(TYPE A)	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
LETTABLE SHOPPING SPACES(TYPE B)	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
LETTABLE SHOPPING SPACES(TYPE C)	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
LETTABLE OFFICE SPACES(TYPE A)	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	POP CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
LETTABLE OFFICE SPACES(TYPE B)	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	POP CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
ANCHOR STORE	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
SUPER MARKET	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
FOOD COURT	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
GENERAL MANAGER's OFFICE	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
SECRETARY's OFFICE	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
FLOOR MANAGER's OFFICE	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
MAINTENANCE's OFFICE	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION

APPENDIX 11 : FINISHES SCHEDULES



FINISHES SCHEDULES

SPACE	FLOORS		SKIRTING		WALL		CEILING	REMARKS
	MATERIAL	SPECIFICATION	MATERIAL	SPECIFICATION	MATERIAL	SPECIFICATION		
OFF LOADING BAY	UNGLAZED CERAMICS TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	UNGLAZED CERAMICS TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
STORE	UNGLAZED CERAMICS TILES	600mmx600mmx12mm LIGHT BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	UNGLAZED CERAMICS TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
ENTRANCE	GLAZED TERACOTA TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED TERACOTA TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.				SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
CONVENIENCES (W/C)	FULLY VITRIFIED CERAMICS TILES	600mmx600mmx12m WHITE COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	FULLY VITRIFIED CERAMICS TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	FULLY VITRIFIED CERAMICS TILES	600mmx600mmx12m WHITE COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
EXHIBITION GALLERY	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
CONFERENCE ROOM	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	ALUMINIUM FRAMES WITH GLASS	CURTAIN WALL WITH CLEAR TRANSPARENT GLASS	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
KITCHEN	QUARRY TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	QUARRY TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
PANTRY	QUARRY TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	QUARRY TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
COLD STORE	QUARRY TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	QUARRY TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
DRY STORE	QUARRY TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	QUARRY TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
CHANGING ROOM	FULLY VITRIFIED CERAMICS TILES	600mmx600mmx12mm LIGHT BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	FULLY VITRIFIED CERAMICS TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION
ATM GALLERY	GLAZED GRANITE TILES	600mmx600mmx12mm DARK BROWN COLOUR , THICK LAID TO PATTERN ON 25mm SCREED.	GLAZED GRANITE TILES	100mmx600mmx12mm THICK TO MATCH APPROVED FLOOR SAMPLE.	PAINT TO RENDER	2 COATS OF CAPL LILAC WHITE OVER 12mm THICK CEMENT PLASTER.	SUSPENDED CEILING	SAMPLE TO BE APPOROVED BY ARCHITECT BEFORE INSTALLATION

APPENDIX 12 : FINISHES SCHEDULES

DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: PROFESSOR ABDULLAHI MUSTAPHA;Bsc (Hons) Pharm (A.B.U.), Ph.D. (London), FPSN.

Ref: A/2.27

14th June, 2013

TO WHOM IT MAY CONCERN:

Dear Sir,

LETTER OF INTRODUCTION: SERIKI ENEYE EGE
(M.Sc/Env. Des./2362/2011-2012)

I write to introduce the above named Postgraduate student of this Department. He is currently conducting Thesis Research on Enhancing Energy Efficiency through Passive Design Principles in a hot and humid climate for shopping plaza, Lokoja. Kindly assist him with relevant information.

Thank you for your cooperation.

With Kind Regards,

Yours faithfully,

HEAD
Dept. of Architecture
Fac. of Environmental Design
A.B.U. Zaria Nigeria

Dr. M.D. Ahmed
HEAD OF DEPARTMENT

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. M.D. Ahmed

Telephone: +2348034507574
e-mail: architecture@abu.edu.ng

APPENDIX 13 : LETTER OF INTRODUCTION FOR CASE STUDY

APPENDIX 14 : INTERVIEW QUESTIONS

INTERVIEW QUESTIONS ASKED DURING THE COURSE OF CASE-STUDY IN PURPOSEIVELY SELECTED SHOPPING PLAZAS.

1. Can you give a general idea of the amount of energy consumed in this centre?
2. Would you regard this level of consumption as fair?
3. What efforts have been made to reduce the consumption level of this centre?
4. What are your future projections on energy consumption for this centre?
5. How do you manage the comfort conditions of your guests when faced with limited energy resources?
6. How would you regard the level of lighting (natural) in spaces in the centre without artificial means?
7. Has there been any attempt at using the natural resources such as sun or wind in generating energy such as sun or wind?

QUESTIONS ASKED DURING INTERVIEW WITH EXPERT IN THE FIELD OF SUSTAINABLE ARCHITECTURE AND CLIMATIC DESIGN.

1. What are your views on how energy efficiency could be enhanced in buildings in buildings in Nigeria and in the hot-humid climate in particular?
2. How do you think passive design principles can be incorporated in buildings? And do you think their principles have the capacity of enhancing energy efficiency in buildings?

APPENDIX 15 : ENERGY EFFICIENT ARCHITECTURAL FEATURES CHECK-LIST.

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
1.	Building Envelope	Suitability of the materials to the climate				
		Use of external insulation				
		Use of light colours				
2.	Natural Lighting	Wall to window ration (40%)				
		Use of specially transparent glass				
3.	Natural Ventilation	Use of operable windows				

S/N	VARIABLES	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
4.	Landscape Design	Use of soft landscape				
		Use of hard landscape.				
5.	Building Orientation	Sun Orientation (East -West)				
		Wind Orientation (South-West – North-East)				
6.	Building Form	Large building surface area.				