INTEGRATION OF ECO-FRIENDLY DESIGN PRINCIPLES IN THE DESIGN OF MIXED-USE BUILDING, ABUJA, NIGERIA

BY

YUSUF, Dahlia Hasia
MTech/SET/2017/7583

DEPARTMENT OF ARCHITECTURE,
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA

JULY, 2021

INTEGRATION OF ECO-FRIENDLY DESIGN PRINCIPLES IN THE DESIGN OF MIXED-USE BUILDING, ABUJA, NIGERIA

BY

YUSUF, Dahlia Hasia
MTECH /SET/2017/7583

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTech) IN ARCHITECTURE

JULY, 2021

ABSTRACT

Buildings account for a large amount of land use, energy and water consumption, air and atmosphere alteration. Considering the statistics and the impact of the built environment on human health as well as the natural environment, reducing the number of natural resources consumed by the buildings industry and the amount of pollution given off is seen as critical to achieve a sustainable environment. Eco-friendly buildings are expected to reduce greenhouse gases, save the natural resources and meet the users' justifiable demand for more comfort and safety; in addition to their promising projected value within the global economy. This study aimed at assessing the principles of eco-friendly design for its effective application in the design of mixed-use building developments in Nigeria. The methodology adopted is the descriptive research method which involved an in depth review of literature related to the study, observation schedule and selection of foreign and local Case studies to compare and deduce data concerning eco-friendly and mixed-use buildings, and field surveys to obtain data on some of the selected case studies. It employed the descriptive research method including review of literature related to the study, observation schedule and case study. This study established a design framework from the findings, through which a design proposal for a mixed-use building eco-friendly building in Abuja, Nigeria was developed while implementing eco-friendly design principles. The research concluded that eco-friendly building principles and techniques have five major components namely: energy efficiency and conservation, water efficiency and conservation, materials conservation, waste reduction, reuse and recycling and humane adaptation. Adopting these five criteria in the design and construction of buildings in Nigeria will improve the environment by reducing the negative impacts of buildings, as recommended by the study.

TABLE OF CONTENTS

CHAPTER TWO

CHAPTER THREE

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Our built environment has significant impacts on people, and the environment, it affects the air quality, transportation patterns of communities and the general way of life of both the present and the future generations (Michael *et al.*, 2007). It consumes natural resources, creates employment and property values, and provides shelter for our daily life. The built environment clearly has advantages and disadvantages, we the inhabitants of the earth enjoy the advantages of living in the built environment, while our natural environment suffers the disadvantages of the existence of our built environment. This therefore implies that the friendliest way to handle the natural environment is not to build. However, without the buildings, life can be miserable unbearable (Kolawole, 2005).

The solution is to create a dynamic equilibrium without any form of negative impact especially to the environment (Zubairu, 2012). This dynamic equilibrium will involve creating a built environment that has a significantly low impact on the natural environment. The negative environmental impacts of the built environment have led to the emerging concept of ’green buildings’ (Gunnell, 2009). Green/ Eco-friendly buildings are designed to be energy and water efficient, use non-hazardous materials and provide healthy productive environments and generally have little or no impact on the natural environment (Gunnell, 2009). Eco-friendly buildings represent environmentally friendly structures that have a significantly low impact on the environment.

According to Zane & Peter (2009), Eco-friendly buildings encompasses energy use, water use, and storm-water and wastewater re-use, they combine energy and water efficiency systems, Day Lighting strategies, Indoor Environmental Quality (IEQ) systems and efficient Building Envelope system to provide comfort and positive impact to the occupants and the environment.

Sustainability through Eco-friendly building practices approach building construction (from design conceptualization and construction to its material usage all through its life-span) with the aim of minimizing harmful effect on human health and environment. It attempts to conserve environmental factors such as air, water and the earth by employing eco-friendly building materials and construction practices.

Eco-friendly/ green building is adopted in developed countries like China, USA, UK, Germany, Japan, Korea and other developed nations, while in developing countries such as Nigeria, buildings with a holistic approach towards environmental sustainability are yet to be seen because the application of the concept of green design is almost completely ignored (Dalibi *et al.*, 2017).

1.2 Statement of the Research Problem

Buildings are one of the largest consumers of natural resources and account for a substantial amount of the greenhouse gas emissions (Yi-Kai *et al.*, 2010). According to UNEP (2007), the building sector accounts for 30–40% of global energy use, buildings not only use resources such as energy and raw materials but they also generate waste and potentially harmful atmospheric emissions (Alnaser *et al.*, 2008). Lippiatt (1999) argued that construction damages the fragile environment because of adverse impacts of construction, this impacts include resource depletion, biological diversity losses due to raw material extraction, landfill problems due to waste generation, adverse human health due to poor indoor air quality, global warming, acid rain, and smog due to emissions generated by building product manufacture and transport that consumes energy.

It is necessary to address the challenges of unsustainable building practices and their effects by adopting sustainable building approach such as eco-friendly architecture. The concept of sustainable development has been studied by many in both developed and developing countries due to increasing impacts of global warming (Akadiri *et al.*, 2012). In the developed world, studies on sustainable development in the construction industry revealed that there are similarities of sustainable practices at the design stage in the North America, Europe and Asia even though there are differences in practices throughout the life-cycle of a building Bunz *et al.* (2006). In Sub-Saharan Africa, Olomolaiye *et al.* (2012) developed a framework for environmentally sustainable building design practices throughout the buildings life cycle i.e. from design to demolition stage.

In Nigeria there are no buildings with a holistic approach to sustainable design, the operating climate for construction remarkably differs from what obtains in Western Europe for instance where there is a strong sustainability drive in the construction sector and a lot of the sources of information helping to shape the practice of sustainable construction originate from outside of Nigeria (Mohammed & Abbakyari, 2016). Thus, this represents a gap between empirical knowledge of eco-friendly building principles adapted to buildings in Western Europe and the principles adapted to buildings in Nigeria. This study evaluates the concepts of eco-friendly designs and the integration of adoptable eco-friendly design principles in Nigeria.

1.3 Aim and Objectives of the Study

The aim of this study is to assess principles of eco-friendly design for its effective application in the design of mixed-use building developments in Nigeria.

The main objectives of this thesis includes to:

i. Evaluate the principles of eco-friendly building design applicable to mixed-use building design.
ii. Identify the principles of eco-friendly building design applicable to mixed-use building design.
iii. Develop/propose a design framework for the application of eco-friendly design principles in mixed-use building.
iv. Demonstrate the application of the eco-friendly design principles in the design of mixed-use building

1.4 Research Justification

In Nigeria, green concept, sustainability and environmental issues are hardly put into consideration when designing a new building or renovating an old one. According to Otegbulu (2011), these results in a short fall in user satisfaction, functional space planning, service type and in addition sustainable building components are often neglected during design and construction. The study is expected to influence policy directives to ensure that environmentally sustainable design practices as a means of reducing energy consumption in Nigeria, managing natural resources and also minimize the impact of buildings on the environment.

The gaps established by this study are expected to influence further empirical studies on environmentally friendly building design practices at the design stage of a building project, the benefits that can be accrued due to the adoption of the practices as well as the challenges that may be faced.

1.5 Scope and Limitation

The study was focuses on the implementation of eco-friendly architecture in building design and construction in Nigeria to ensure energy and water efficiency, waste reduction, use of non-toxic materials, improved indoor air quality and green built environment. The design proposal will consist of residential, commercial, office and leisure areas for the occupants. It shows how eco-friendly strategies can be integrated in the design thereby reducing the negative impact of building design, construction and operation on the natural environment while safeguarding the health and well-being of its occupants or users.

1.6 Limitations

The factors that limited the study are confines from collecting data by observation in some of the case studies due to security reasons and company policies, time constraints and limited access to information due to its unavailability. But however, other measure such as the internet was utilized in collecting data made available by reliable sources such as the LEEDs website.

1.7 Contribution to Knowledge

This thesis contributes to the already existing knowledge on the eco-friendly building in Nigeria. It will provide information on the use of construction techniques, design principles and materials that have low impact on the environment, and also provide optimum comfort to the users of the building. It will also contribute to the worldwide movement of sustainable building and living for a better tomorrow.

1.8 The Study Area

Abuja, the Federal Capital Territory of Nigeria (FCT) has a total area of 8000 sq. km and is bounded in the north by Kaduna State, in the west by Niger State, in the east by Nassarawa State and in the south by Kogi State. Abuja officially became the Federal Capital Territory (FCT) in 1991 replacing Lagos after 15years of planning and construction.

It is a planned city that was built mainly in the 1980's. Abuja's geography is defined by Aso rock, a 400meter (1,300ft) monolith left by water erosion. The city is located between latitude 8.25 and 9.25 north of the equator and longitude 6.45 and 7.39 east of the Greenwich Meridian, in a scenic valley of rolling grasslands which is relatively underdeveloped.

Wuse district is the north-western part of the city, with Maitama District to its north and the Central District to the south. The District is numbered zones one (1) through six (6), the site for the proposed building is located in Wuse district zone 4.

Landmarks in Wuse Include;

1. The national park for recreation
2. The national mosque
3. Arts and crafts village
4. Millennium park
5. Silverbird cinema
6. Shehu Musa Ya'radua center
7. Wuse clinic
8. Wuse market

The location of the site is chosen because of its accessibility to the target users and also the availability of the important utilities there.

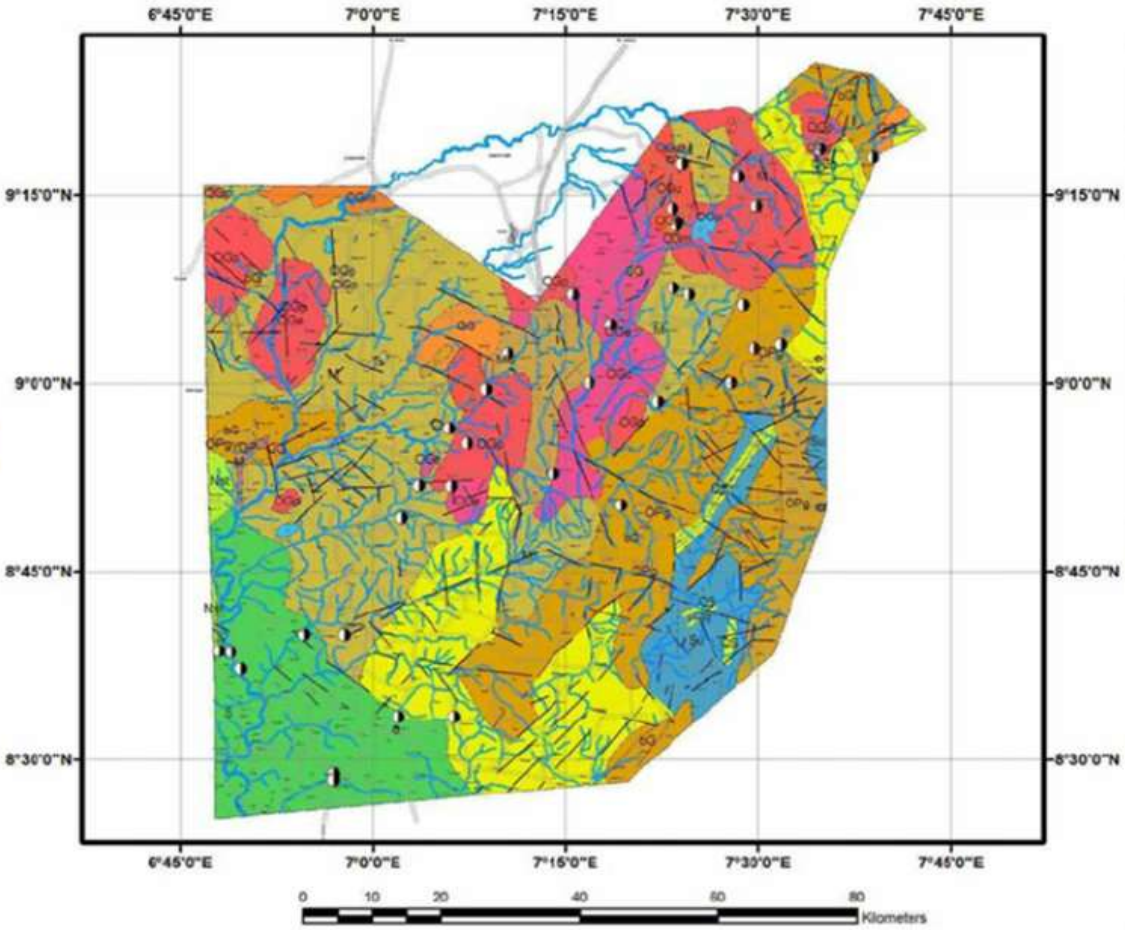


Figure 1.1: A Map of Abuja
Source: Research gate (2019)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Development of Mixed-Use Building

Mixed-use development is the practice of allowing more than one type of use in a building or set of buildings. In planning terms, this can mean some combination of residential, commercial, industrial, office, institutional or other land uses (Grant, 2002). This arrangement creates shorter distance between work, residence and recreation and goes a long way to enhance the livelihood of the inhabitants. Mixed-use buildings vary in variety and scale. In terms of scale, they range from mixed-use spaces and mixed-use buildings. They vary from the seamstress who uses her living room as her workspace (mixed-use spaces) to the shopkeeper who lives on the first floor and operates a shop on the ground floor (mixed-use buildings) right through to huge mixed-use developments covering several acres of land. Also in terms of variety, they range from the transit oriented development (TOD) right through to the satellite towns. Hence the research was conducted from facilities of various scales and typology in order to come up with a comprehensive and adaptable conclusion.

Throughout human history, the majority of human settlements developed as mixed-use environments. People lived in close proximity to their work. Walking was the primary way that people and goods were moved about, sometimes assisted by animals such as horses or cattle. Most people dwelt in buildings that were places of work as well as domestic life, and made things or sold things from their own homes. Increase in population and civilization led to the creation of markets and market towns. Most buildings were not divided into discrete functions on a room by room basis, and most neighbourhoods contained a diversity of uses, even if some districts developed a predominance of certain uses, such as metalworkers, or textiles or footwear due to the socio-economic benefits and natural endowments. People lived in close proximity to each other and at times at very high densities because the amount of space required for daily living and movement between different activities was determined by walkability and the scale of the human body. As population increased leading to the rise in towns and cities, several modifications were made between domestic and occupational life. For example, in some places the ground floor of buildings was often devoted to some sort of commercial or productive use, with living space upstairs.

2.2 Configurations of Uses

Vertical Integration of Uses

1. Low-rise to Mid-rise Structures (2 to 6 Stories)
2. High-rise Towers (7 Stories +)
3. Integrated Multi-Story Structures

Horizontal Integration of Uses

1. Town Centers
2. Urban Villages

2.4 The Concept of Mixed-Use Development

The Mixed-use district requires mixed-use developments to provide the community with a mix of mutually-supporting retail, service, office and residential uses. It promotes cohesive site planning and design which integrates and interconnects two or more land uses into a development that are mutually supportive. Mixed use development provides incentives to develop a higher-density, active, urban environment than generally found in a suburban community which is further expected to achieve goals and objectives of the community framework plan and the comprehensive plan. Mixed use development enhance liability, environmental quality and economic vitality, accommodate and respect surrounding land uses by providing a gradual transition adjacent to lower density neighbourhoods that may encircle a potential mixed-use site ,maximize efficient use of public facilities and services, provide a variety of housing types and densities, reduce the number of automobile trips and encourage alternative modes of transportation and Create a safe, attractive convenient and eco-friendly environment (Caleb, 2009).

2.4 Benefits of Mixed-Use Design

1. Mixed-use designs are generally pedestrian Friendly
2. It increases social connectivity
3. It provides civic Amenities/ Spaces
4. It ensures public safety
5. Public Infrastructure and parking spaces are shared
6. Less dependence on auto-mobile transportation
7. Focuses the population density (vs Sprawl)
8. Supports Transit

2.5 The Theory of Eco-Friendly Architecture

The term eco-friendly architecture is also known as sustainable design, green architecture, eco-design, earth-friendly architecture, environmental architecture, natural architecture (USGBC, 2002). Eco-friendly architecture is an approach to building that minimizes harmful effects on human health and the environment. The "green" architect or designer attempts to safeguard air, water, and earth by choosing environmentally friendly building materials and construction practices (Roy 2008). Eco-friendly architecture defines an understanding of environment-friendly architecture under all classifications, and contains some universal consent (Burcu, 2015).

Eco-friendly architecture focuses on saving energy production and consumption because while buildings could be the highest carbon emitters, they could equally represent the best means of reducing environmental, economic impact and energy use, effectively. It approaches building construction (from design conceptualization and construction to its material usage all through its life-span) with the aim of minimizing harmful effect on human health and environment. Eco-friendly architecture attempts to conserve environmental factors such as air, water and the earth by employing environmentally friendly building materials and construction practices (Watson & Balken, 2008).

While most green buildings do not have all of features that improve the environment, the highest goal of eco-friendly architecture is to be fully sustainable. Such buildings use an average of 30% less energy than conventional building (Economist, 2004). Material waste generated during construction is reduced or recycled; energy efficiency is improved, by relying on the use of natural light and ventilation or solar power. Less water is used, or rainwater harvesting system is installed to ensure wiser use. Measures taken to make buildings and construction more sustainable rely increasingly on life cycle approaches.

2.6 Sustainable Development

According to the World Commission on Environment and Development of the United Nations, sustainability means meeting the needs of the present without compromising the ability of the future generations to meet their own needs (UNFCCC, 2006). Users of this definition cite the "three-legged stool" of sustainability: social, economic and environmental (Holdren, 2008). Sustainable development, presented as almost synonymous with "sustainability," is challenged by authors who argue that "development" itself is antithetical to sustainability because development is inherently unsustainable: human development must occur without overwhelming the natural ecosystems that we depend on for survival (Wood, 2015).

The term Sustainable is often used to characterize a technology with a lower environmental impact on a single environmental problem (climate change and water resource use) often quantified in terms of reduced resource use or pollution emissions as a fraction or percentage. Sustainability should address the complex interactions among social-ecological systems (Michael & Sander 2015). According to UNFCCC **(**2006), Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. A primary goal of sustainability is to reduce humanity's environmental or ecological footprint on the planet. Sustainable development has given rise to eco-friendly buildings commonly known as green buildings.

2.6.1 Environmental sustainability

Eco-friendly buildings are designed with environment management in mind. It takes drastic measures to reduce wastage as well as environmental degradation to a barest minimum. It also takes into consideration the comfort of the end-users. It aims at total safety and sustainability of the eco-system and advocates the use of materials, methods, and technology that favour this primary objective.

2.7 Impact of Buildings on the Environment

The International Energy Agency (2006) released a publication that estimated that existing buildings are responsible for more than 40 percent of the world's total primary energy consumption and for 24 percent of global CO2 emissions. This implies that the building sector uses more energy than other sectors like the industrial and transportation sectors. Due to increase in urban population and attendant residential pressures, energy consumption is projected to rise in buildings especially in fast growing countries (Odebiyi, 2010).

The world's population continued growth has led to the implementation of resource-efficient measures in all areas of human activities especially in the built environment which has a significant impact on all resources while also affecting the air quality and transportation patterns of communities; both the present and the future generations (Dalibi, 2012). Eco-friendly architecture in the African context is the indigenous approach of building practices with the goal of sustaining the ecosystem. It puts into consideration the easily affordable local resources and the development of concepts that sustain the socio-cultural value system within the building sector. Buildings are the dominant energy consumers in modern cities but their consumption according to Dalibi (2012) can be largely cut back through improving efficiency. Energy demand for heating and cooling is greater than ever, as most available energy is based on fossil fuel, the increased energy demands contribute significantly to more greenhouse gas emissions (Kolawole & Anigbogu, 2005).

Urbanization trends in developing countries are accelerating the growth of this sector relative to residential buildings, according to the World Business Council on Sustainable Development (WBCSD, 2016). Reducing these emissions is therefore a cornerstone intention and responsibility of green building initiatives. The green building will improve the environment through environmental sustainability and greenhouse gas emission reduction.

2.8 Eco-Friendly Building Principles

The eco-friendly building design process begins with an intimate understanding of the site in all its beauties and complexities. An ecological approach to design aims to integrate the systems being introduced with the existing on-site ecological functions performed by Mother Nature.

These ecological functions provide habitat, respond to the movements of the sun, purify the air as well as catch, filter and store water. Eco-friendly architecture defines an understanding of environment-friendly architecture under all classifications, and contains some universal consent (Burcu, 2015). The principles and criteria of eco-friendly building support of the use of the USGBC, LEED Green Building Rating System, but focuses on principles and strategies rather than specific solutions or technologies, which are often site specific and will vary from project to project (USGBC, 2002). The principles and techniques of eco-friendly building therefore are theories and practices in the construction industry that serve as the criteria for evaluating the impacts of the building project. According to Shafique & Zeyaul (2016), the major elements of green building design are sustainable site design, water conservation and quality, energy and environment; indoor environmental quality, and conservation of materials and resources.

According to Akadiri *et al.* (2012) the principles to be considered when designing for eco-friendly building include energy efficiency and conservation, water efficiency and conservation, choice of materials, waste reduction and recycling and humane adaptation energy use.

2.8.1 Energy efficiency and conservation

Gillingham *et al.* (2009) defined energy efficiency as the energy services provided per unit of energy input and energy conservation as the total reduction in the amount of energy consumed. Buildings consume energy and other resources throughout its life cycle, from design and construction through operation and demolition (Schumacher *et al.*, 2011).

The amount of energy used in this process affects the flow of greenhouse gases to the atmosphere affecting the environment adversely (Lenzen & Treloar, 2002). As a result of the increasing awareness of climate change, building designers have started to consider how energy efficient their buildings are (Schlueter & Thesseling, 2009). Eco-friendly buildings can help generate 40% more savings from energy conservation and perform 40% better than traditional buildings (Lockwood, 2006). In any building, improving the energy efficiency and conserving energy reduces the gas emissions usually generated from electricity usage for Heating, Ventilating, and Air-Conditioning (HVAC). Improving the energy efficiency and energy conservation of an office building will reduce the emissions of carbon dioxide (US Department of Energy, 2008).

Carbon dioxide is an important source of energy for plant growth but too much of it is harmful to both plants and human. Plants are usually suffocated with high concentrated CO_2, which prevents the uptake of nutrients, and consequently destroying the plant. It can also result into death in humans through continuous suffocation, disorientation, depression and dizziness. According to Farrar *et al.* (1999), depression of the central nervous system (CNS) with protracted exposure to concentrated CO_2 can cause death in human. This means that high CO_2 emissions from office buildings are not environmentally friendly. Therefore, it is advisable to reduce electricity consumption by using renewable energy sources such as solar. In conducting environmental sustainability test for an office building, it is required that energy use audit is undertaken to find avenues for alternative sources of energy which is more energy efficient and set benchmarks for energy use (Institute of Local Government, 2013).

To provide an energy efficient building, the design should make room for energy-conscious site planning (Kim & Rigdon, 1998). By this, the resources at the site could be taken advantage of. For example, taking advantage of a water body in the site, planting vegetation to serve as shade and as a buffer for strong winds. Passive heating and cooling as well as insulation of the building envelope also helps with the conservation of energy as heat transfer will be reduced. This is also termed as passive design where natural ventilation, orientation and day lighting are employed in the design (Akadiri *et al.,* 2012 and Lockwood, 2006). Low emission glazing is also strongly recommended to reduce the heat transfer into the building. Alternative sources of energy such as solar and wind should also be investigated into at the design stage.

Energy-efficient appliances and equipment should be considered as vital since the operation cost of these equipment could exceed the construction cost of the building over its lifetime (Kim & Rigdon, 1998; Akadiri *et al.,* 2012). Other ways of improving energy efficiency is the utilization of improved efficient HVAC system. This does not use chlorofluorocarbon, hydro chlorofluorocarbon refrigerants which deplete the ozone and consume more energy (Lockwood, 2006).

2.8.2 Water efficiency and conservation

The depletion of water resource is becoming an environmental issue of great worry worldwide due to the fast development of global economies (Akadiri *et al.,* 2012). Since water is an indispensable resource for quality living and growth of varied economic sectors. However, with the water consumption rate tripling in the last 60 years on the planet, it has become very important to find methodologies to conserve water and use it efficiently (Rodrigues *et al.*, 2012). Efficient use of water will have a direct economic impact in a structure as the water and waste water systems of buildings are powered by energy. It results in a reduction of cost arising from the more efficient water processes of distribution, treatment and abstraction (Rodrigues *et al.*, 2012).

Energy used to pump water and distribute to all sections of the building entail treatments and delivery which consumes energy (Kim & Rigdon, 1998). The increase of water efficiency also adds to the decrease in waste production arising from their treatment, thus improving environmental sustainability. Excessive water use in buildings therefore means excessive use of energy which will increase gas emissions endangering the environment. Water efficiency basically looks at the 5R principle as asserted by (Silva-Afonso & Pimentel-Prdrigues, 2011). These are i) reduction in consumption, ii) reduction in loss and waste, iii) re-use of water, iv) recycling of water and v) resorting to alternative sources. Ultimately, in conserving and using water efficiently, there will be energy savings and a reduction in greenhouse gas effects on the environment (Silva-Afonso & Pimentel-Prdrigues, 2011).

Based on the previously mentioned principles, Akadiri *et al.* (2012) suggests the i) use of water efficient plumbing fixtures, ii) design for dual plumbing, iii) rain water harvesting, iv) designing low demand landscape, v) pressure reduction in rate of flow and vi) employing re-circulating system. (Kim & Rigdon, 1998; Institute of Local Government, 2013; Lockwood, 2006) on the other hand proposes additional i) The reuse of water on-site from rain water to gray water and ii) a reduction in consumption.

2.8.3 Material conservation

Material conservation has to do with the choice of materials that are specified in the design and is associated with green buildings. Materials specified to be used for construction should be renewable and have a low embodied energy. Green buildings are infrastructures constructed with recyclable, renewable, reusable and nontoxic materials that have zero or low volatile organic compounds (VOCs) (US Department of Energy, 2008). Ljungberg (2007) defines renewable materials as materials which are formed again in a short time and give no or very little impact on the environment. In his view, wood is more preferable than plastic since it can be renewed in a short time than plastic. In the assertion by Gustavsson & Sathre (2006), the use of wood for construction generally results in a lower energy consumption and carbon dioxide emissions. In addition, when the tree is burnt its ashes can be used as organic manure. This means the use of wood materials for buildings are environmentally sustainable compared to plastic materials.

In the study by Reddy & Jgadish (2003), it was observed that the total embodied energy of a masonry wall can be reduced by half if an energy efficient building material is used. This was also reiterated by Thormark (2006) in a submission that in low-energy buildings, the embodied energy accounts for a considerable part of the total energy use of the building and so making it imperative to pay particular attention to the choice of materials. Since buildings are responsible for the bulk of energy consumption and atmospheric emissions, the choice of materials is worth investigating into (Huberman & Pearlmutter, 2008). Renewable materials could be in the form of strawboard made from wheat, linoleum flooring made from jute and linseed oil, acoustic ceiling tiles made from recycled materials and materials like recycled carpets and heavy steel (Lockwood, 2006).

Locally, materials like straw, laterite, mud, bamboo, wood, etc. are renewable materials that if used helps to create a healthier and safer environment. Aside this, the use of local materials save on transportation energy (Kim & Rigdon, 1998). Akadiri *et al* (2012) affirms that material conservation should take into consideration i) design for waste minimization, ii) specification of durable materials, iii) specification of natural and local materials, iv) designing for pollution prevention and specification of non-toxic or less-toxic materials. (Kim & Rigdon, 1998) also adds that material specified in the design of buildings should be re-usable, recyclable and non-toxic.

2.8.4 Waste reduction, recycling or reuse

Buildings generate a considerable amount of waste with the industry generating about half of the waste (Ferguson *et al.,* 1995; Bossink & Brouwers, 1996). Treatment of the waste has been a major environmental issue (Chan, 1998). Reuse, reduction and recycling of waste are considered as viable methods of recovering waste (Tam & Tam, 2006). Designers have a significant role to play in the reduction of waste by focusing on designing out waste (Osmani *et al.,* 2008). By this, the waste management ought to be considered at the design stage. It is for this reason that materials specified in design to be used for the construction should be reusable or recyclable and as much as possible waste reduced or eliminated. It is important to note that recycling of building waste can greatly reduce the need for energy and natural resources, while also decreasing the amount of materials to landfill sites (Thormark, 2001). In order to safeguard the environment, efforts are being made to recycle different wastes and utilize them in value added applications (Pappu *et al.,* 2007). An example is the use of aggregates from recycled construction for concrete (Rao *et al.,* 2007). Regarding the reduction of waste, designers were recommended to use models to prepare designs which have a lower potential to cause site waste during construction (Ekanayake & Ofori, 2004). Waste reduction is equally economically feasible and also plays a vital role for environmental management improvement (Begum *et al.*, 2006).

Faecal waste, paper waste and food waste are particularly common to office buildings and are generated in huge quantities. Increase paper waste endangers the environment since it means falling down more trees, which increases the effects of climate change, thus making the building unsustainable. Owners of buildings are advised to institute and implement detailed waste reduction and reuse programmes in their buildings as well as implement a comprehensive waste reduction and recycling program in agency offices and facilities to create awareness of employees on waste reduction. Besides, improper handling of faecal and food waste can be environmentally unfriendly. To make the building environmentally sustainable, faecal and food waste can be recycled to produce biogas which can be used as a source of energy and organic manure for agriculture purposes (Karki, 2005).

2.8.5 Humane adaptation

Designing for humane adaptation looks at protecting human health and comfort as well as the protection of physical resources (Akadiri *et al.*, 2012). Kim & Rigdon (1998) however, includes urban design site planning as an additional strategy for achieving humane adaptation. In designing to preserve the natural conditions, the designer ought to value the topography of the site, preserve the vegetation and not temper with the water table, thus addressing the external effects on the environment. Buildings should also be designed bearing in mind the climatic conditions of the area in which the site falls (Omer, 2008).

Thermal comfort and indoor air quality are two crucial aspects of indoor environmental quality that have a substantial attention by building designers, although thermal comfort is ranked higher by building occupants to be of greater importance and seems to influence a higher degree of overall satisfaction with indoor environmental quality (Frontczak & Wargocki, 2010). In modern society, where persons spend most of their time indoors, an emphatic role of designers is to design for occupants' health, physiological satisfaction, physiological comfort and productivity (Akadiri *et al.*, 2012). Indoor- air quality refers to the quantum of air generated by the materials used in the building as interior design. It is a major determinant of personal exposure to pollution (Walsh *et al.*, 2000). The materials range from flooring, upholstery and positions of fixtures and furniture, which ensure good ventilation thus keeping the building cool and ultimately reducing energy consumption. The importance of improved indoor-air quality cannot be overemphasized. Studies by the Indoor Environment Department California, USA in 2002 revealed that improved indoor-air quality by using green materials reduces Sick Building Syndrome (SBS) symptoms such as dizziness, nausea, etc. by 20% to 50%; cold and influenza are reduced by 9% to 20% whiles allergies and asthma reduced by 8% -20% (Lockwood, 2006).

In achieving design for comfort, (Akadiri *et al.,* 2012) looks at six major methods as i) thermal comfort, ii) acoustic comfort, iii) day lighting, iv) natural ventilation, v) aesthetics and vi) functionality. Kim and Rigdon (1998) rephrases the methods of designing for human comfort as i) provision of thermal, visual and acoustic comfort, ii) provision of visual connection to the exterior, iii) provision of operable windows, iv) provision of clear fresh air, v) utilisation of non-toxic materials. The above mentioned methods help people to perform well in the building. Good lighting, acoustic privacy and thermal control are the key to occupants' productivity and satisfaction (Akadiri *et* *al.*, 2012). Operable windows are equally essential for occupants to control temperature, lighting and ventilation in the workspace. Non-toxic interior paintings should be used as long term exposure to toxic and out gassing materials can have a damaging effect on health (Hussein, 2012; Lockwood, 2006). Typical examples are volatile organic compounds (VOCs) which emanate from paints, varnishes, preservatives and solvents (Jones, 1999). Building functionality and aesthetics should similarly be catered for to enable the smooth operation of activities for which the building was design.

The amount of energy used in this process affects the flow of greenhouse gases to the atmosphere affecting the environment adversely (Lenzen & Treloar, 2002). As a result of the increasing awareness of climate change, building designers have started to consider how energy efficient their buildings are (Schlueter & Thesseling, 2009). Eco-friendly buildings can help generate 40% more savings from energy conservation and perform 40% better than traditional buildings (Lockwood, 2006). In any building, improving the energy efficiency and conserving energy reduces the gas emissions usually generated from electricity usage for Heating, Ventilating, and Air-Conditioning (HVAC). Improving the energy efficiency and energy conservation of an office building will reduce the emissions of carbon dioxide (US Department of Energy, 2008). Carbon dioxide is an important source of energy for plant growth but too much of it is harmful to both plants and human. Plants are usually suffocated with high concentrated CO_2, which prevents the uptake of nutrients, and consequently destroying the plant. It can also result into death in humans through continuous suffocation, disorientation, depression and dizziness.

According to Farrar *et al.* (1999), depression of the central nervous system (CNS) with protracted exposure to concentrated CO_2 can cause death in human. This means that high CO_2 emissions from office buildings are not environmentally friendly. Therefore, it is advisable to reduce electricity consumption by using renewable energy sources such as solar. In conducting environmental sustainability test for an office building, it is required that energy use audit is undertaken to find avenues for alternative sources of energy which is more energy efficient and set benchmarks for energy use (Institute of Local Government, 2013).

However, to provide an energy efficient building, the design should make room for energy-conscious site planning (Kim & Rigdon, 1998). Ideally, the decision to build green should be made before the site is selected, as all of the eco-friendly building criteria are affected by site characteristics and some sites are inappropriate for certain green projects. By this, the resources at the site could be taken advantage of. For example, taking advantage of a water body in the site, planting vegetation to serve as shade and as a buffer for strong winds. Passive heating and cooling as well as insulation of the building envelope also helps with the conservation of energy as heat transfer will be reduced. This is also termed as passive design where natural ventilation, orientation and day lighting are employed in the design (Akadiri *et al.*, 2012; Lockwood, 2006).

Low emission glazing is also strongly recommended to reduce the heat transfer into the building. Alternative sources of energy such as solar and wind should also be investigated into at the design stage. Energy-efficient appliances and equipment should be considered as vital since the operation cost of these equipment could exceed the construction cost of the building over its lifetime (Kim & Rigdon, 1998; Akadiri *et al.,* 2012). Other ways of improving energy efficiency is the utilization of improved efficient HVAC system. This does not use chlorofluorocarbon, hydro chlorofluorocarbon refrigerants which deplete the ozone and consume more energy (Lockwood, 2006).

2.9 Eco-Friendly Buildings in Nigeria

In Nigeria, green concept, sustainability and environmental issues are hardly put into consideration when designing a new building or renovating an old one. According to Otegbulu (2011), these results in a short fall in user satisfaction, functional space planning, service type and in addition sustainable building components are often neglected during design and construction.

2.10 Green Building Rating Systems

The basic aim of any building environmental assessment scheme is to set criteria against which to rate a building and then to provide a score or descriptive rating for that building. This rating can be used to show the building's environmental credentials and can have commercial value in terms of promoting a sustainable, eco-friendly image. In addition, a rating system allows a comparison to be made between the performances of similar building types. Although most assessment schemes were originally voluntary and optional, there is a trend in some countries to make assessment and rating mandatory to complement existing legislation on the minimum excellence required by regulations and codes (Bougdah & Sharples 2010). According to Fowler & Rauch (2006) using a single sustainable building rating system in a country allows for comparisons and benchmarking of existing buildings as well as a mechanism to track public buildings' progress toward designing and operating the best buildings for their occupants.

According to Nguyen & Altan, (2011) and the WBDG Sustainable Committee (2009), the following are the major building assessment tools and rating systems currently in use and considered in this study for selection.

1. **The Building Research Establishment's Environmental Assessment Method (BREEAM)**

BREEAM, the first environmental certification system was created in 1990 for the UK's building market and is administered by the BRE Global Sustainability Board, which oversees BRE Global guides, publications, Excellents and certification programs (referred to as "schemes"). The Board represents a wide cross section of stakeholders from the UK's construction industry. It reports to the BRE Global Governing Body, which provides an independent overview of BRE Global schemes and activities. Further, the United Kingdom Accreditation Service (UKAS) has accredited all of BREEAM schemes, which means the UKAS also monitors and oversees the management of BREEAM (Aubree, 2009; BRE Global, 2012).

2. **Comprehensive Assessment System for Building Environmental Efficiency**

CASBEE, developed in Japan by the Japan Sustainable Building Consortium is a cooperative academic, industrial and government initiative charged with creating a nationally authorized green building rating system was launched in 2004 with four basic versions/assessment tools that corresponds to the individual stages of the building lifecycle, i.e. pre-design, new construction, existing buildings and renovation (CASBEE, 2006; CASBEE, 2009; Saunders, 2008).

3. **Green Globes System**

The Green Globes environmental assessment and rating system evolved out of BREEAM, which was brought to Canada as BREEAM Canada for Existing Buildings in 1996. Since then, it has gone through several iterations on its way to becoming Green Globes. The Building Owners and Manufacturers Association of Canada adapted Green Globes for Existing Buildings in 2004 under the name Go Green Comprehensive now known as (Go Green Plus or Go Green). Also, in 2004 the Canadian federal government adopted Go Green Plus for all its buildings. More than 500 buildings in Canada have been assessed using Go Green Plus, including more than 300 Canadian government buildings (GBI 2009; Bryan & Skopek, 2008).

4. Green Star

Green Star is a voluntary building rating system that evaluates the environmental design and construction of all Australian buildings. The Green Building Council of Australia (GBCA), a national, non-profit, member-based organization that is committed to developing a sustainable property industry for Australia, launched Green Star in 2002. Members represent a broad spectrum of both the building industry and governments across Australia. The GBCA objective in creating Green Star is to encourage the Australian building industry to embrace sustainable building by promoting green building programs, technologies, design practices and operations. New Zealand and South Africa have adapted Green Star to rate and certify sustainable buildings in those countries (GBCA, 2009; NZGBC, 2009).

5. IGBC Green Homes Rating System

Indian Green Building Council (IGBC) Green Homes is the first rating programme developed in India, exclusively for the residential sector. It is based on accepted energy and environmental principles and strikes a balance between known established practices and emerging concepts. The system is designed to be comprehensive in scope, yet simple in operation. Measurement is in five areas: sustainability site development;

water savings; energy efficiency; materials selection and indoor environment quality. The strength of Green Homes Rating System is that it has a strong social component; however, the weakness of Green Homes Rating System is that that there is an increase in cost of construction.

6. Hong Kong Building Environmental Assessment Method

Hong Kong Building Environmental Assessment Method (HK-BEAM) developed in 1996 by the BEAM Society. HK-BEAM rewards buildings that are built operated and maintained using sustainable building practices throughout the buildings' lifecycles. But because Hong Kong is a subtropical, high-density and high-rise community, HK-BEAM emphasizes indoor environmental quality (IEQ) more than other green building rating systems. To that end, HK-BEAM embraces (in order of priority) safety, health, comfort, function and efficiency while protecting local, regional and global ecosystems throughout a building's life cycle (BEAM Society, 2003).

7. Leadership in Energy and Environmental Design

In 1998 the LEED ® Green Building Rating System was introduced based quite substantially on the BREEAM system (Nguyen & Altan, 2011). LEED was founded by Robert Watson of the United States Green Building Council (USGBC) in 1993 and consists of a suite of rating systems for the design, construction and operation of high-performance green buildings, homes and neighborhoods. The LEED Green Building Rating System is a voluntary Excellent for sustainable buildings - that facilitates consistent application of sustainable design principles and serves as a measure of accomplishment (Buttler & Stoy, 2009). The LEED 2009 building certification program is a point-based system. Building projects earn points for satisfying green building criteria for specific credits. Projects also may earn Regional Priority bonus points for implementing green building strategies that address important local environment issues. Each rating system is organized into five environmental categories: Sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. An additional category, innovation in design (or operation), focuses on sustainable building expertise as well as design measures not covered in the other categories (USGBC, 2009).

2.11 Review of Past Relevant Research Work

The International Energy Agency (2006) estimated that existing buildings are responsible for more than 40 percent of the world's total primary energy consumption and for 24 percent of global CO2 emissions. Odebiyi (2010) projects that the increase in urban population and attendant residential pressures, energy consumption is projected to rise in buildings especially in fast growing countries. To reduce this negative impact, human development must occur without overwhelming the natural ecosystems that we depend on for survival (Wood, 2015). Therefore, an ecological approach to design will integrate the systems being introduced with the existing on-site ecological functions performed by Mother Nature. These ecological functions provide habitat, respond to the movements of the sun, purify the air as well as catch, filter and store water. Eco-friendly architecture attempts to conserve environmental factors such as air, water and the earth by employing environmentally friendly building materials and construction practices (Watson & Balken, 2008). However, to achieve this balance, certain criteria have to be met. According to Shafique & Zeyaul (2016), the major elements of green building design are sustainable site design, water conservation and quality, energy and environment; indoor environmental quality, and conservation of materials and resources while Akadiri *et al.* (2012) suggests that the criteria to be considered when designing for eco-friendly building include energy efficiency and conservation, water efficiency and conservation, choice of materials, waste reduction and recycling and humane adaptation energy use. Going by the major elements stated by Shafique & Zeyaul (2016) are included in the criteria stated by Akadiri *et al.* (2012).

The mixed use building according to Caleb (2009) provides uses with a mix of mutually-supporting retail, service, office and residential uses. Mixed use development enhances liability, environmental quality and economic vitality, accommodate and respect surrounding land uses by providing a gradual transition adjacent to lower density neighbourhoods that may encircle a potential mixed-use site ,maximize efficient use of public facilities and services, provide a variety of housing types and densities, reduce the number of automobile trips and encourage alternative modes of transportation and Create a safe, attractive convenient and eco-friendly environment.

2.12 Conceptual Framework

The very concept of mixed-use building is in sync with eco-friendly building design and the criteria for eco-friendly building can be easily integrated into the design and construction of mixed-use building. To achieve eco-friendly mixed use buildings, the five criteria; energy efficiency and conservation, water efficiency and conservation, material conservation, waste reduction, recycle or reuse and human adaption have to be emphasised on (Akadiri *et al.,* 2012). Before beginning to design for eco-friendly building, the site should be picked first. When working on the site, minimize urban sprawl and needless destruction of land, habitat and green space, which results from inefficient low-density development. Encourage higher density urban development, urban re-development and urban renewal, and Brownfield development as a means to preserve valuable green space (Shafique & Zeyaul, 2016). Preserve key environmental assets through careful examination of each site. Engage in a design and construction process that minimizes site disturbance and which values, preserves and actually restores or regenerates valuable habitat, green space and associated eco-systems that are vital to sustaining life. To increase energy efficiency and conservation, minimize adverse impacts on the environment (air, water, land, natural resources) through optimized building siting, optimized building design, material selection, and aggressive use of energy conservation measures. Resulting building performance should exceed minimum International Energy Code (IEC) compliance level by 30 to 40% or more. Maximize the use of renewable energy and other low impact energy sources. For materials, minimize the use of non-renewable construction materials and other resources such as energy and water through efficient engineering, design, planning and construction and effective recycling of construction debris (Lockwood, 2006).

Maximize the use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible. Maximize the use of re-usable, renewable, sustainably managed, bio-based materials. Remember that human creativity and our abundant labor force is perhaps our most valuable renewable resource (Ljunberg, 2007). The best solution is not necessarily the one that requires the least amount of physical work.

Preserve the existing natural water cycle and design site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems. Emphasis should be placed on retention of storm water and on-site infiltration and ground water recharge using methods that closely emulate natural systems. Minimize the unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and gray water (Akadiri *et al.,* 2012). For excellent indoor air quality, provide a healthy, comfortable and productive indoor environment for building occupants and visitors. Provide a building design, which affords the best possible conditions in terms of indoor air quality, ventilation and thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment (Hussein 2012).

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this chapter is to introduce the research strategy and the empirical techniques applied in order to evaluate and assess the principles of eco-friendly design for its effective application in the design of mixed-use building developments in Nigeria.

3.2 Research Method

This research work was achieved using a descriptive survey method that required extensive literature review on the study area which was obtained using various web search engines like google and research gate for journals and publication, case studies both local and foreign and observation checklist. According to Denzin & Lincoln (2003), descriptive research involves an explanatory, realistic approach to its subject matter thus seeking to understand phenomena within specific contexts, it identifies the relationships between variables, and generalizes those results to the world at large. The case study method according to Meyer (2001), enables the researcher to study many different aspects, examine them in relation to each other and view the process within its total environment. Yin (2003) further explains that a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries are not clearly stated. Unlike many other forms of research, the case study approach makes use of multiple methods of data collection such as interviews, document reviews, archival records, direct and participant observations.

3.3 Data Type and Sources

This research aims to collect qualitative data, such data will be gathered from field visits to selected case studies, existing literature and research work. The data used in this research work were primary and secondary data.

3.4 Criteria for Case Study Selection

All case studies were selected based on their relation to the study, the selection criteria were reliant on the building's function, LEED (Leadership in Energy and Environmental Design) certification and LEED registration. The five samples studied show how effectively the variables stated in 3.6 are applied in the design and construction of the buildings.

3.5 Population of Study

The research population for this study are mixed-use eco-friendly buildings from Nigeria and the USA based by adopting purposive sampling.

3.5.1 Sample Size and Sampling Technique

Sampling involves a subset of the research population selected to represent the research population (LoBiondo & Haber, 2006). For the purpose of this research, nonprobability sampling was used and the selection was purposive where five eco-friendly buildings were selected based on their functions, LEED certification and registration. The sampling was limited to five mixed-use buildings within the research scope which are AVA little Tokyo, Nestoil towers, the Heritage place, the U.S embassy annex and No.4 Bourdillon building.

Table 3.1: Selected samples, functions, LEED registrations and LEED certifications

Sample	Function		LEED Registration	LEED Certification
AVA Little Tokyo	Mixed-use building	Residential, Commercial,	Certified	LEED Gold (71.5/110)
Heritage place	Mixed-use building	Commercial, office	Certified	LEED Certified (45/110)
Nestoil Tower	Mixed-use building	Commercial, office	Certified	LEED Silver (50/110)
U.S Embassy Annex	Mixed-use building	Residential, office	Certified	LEED Gold (65/110)
No4-Bourdilon Building	Mixed-use development	Residential, Commercial	Registered	LEED (Certification in progress)

Source: Author's compilation

3.6 Method of Data Collection

Primary and secondary sources of information were used to gathered information for the research. The primary source of data includes data from the case studies, field survey, checklist, photographs, sketches and notes. Subsequently, the secondary source of data is discussed as information from literature review.

3.6.1 Primary source of information

The various sources of data selected for primary information in this research includes: Field survey, checklist, photographs, sketches and notes. Field survey was adopted to validate the data that cannot be collected through other means because of the nature of the research. It contained the list of variables which were gotten from the literature. Photographs were taken to support the notes taken during the visit and for record. The photographs also provided a significant source of visual data about the case to outside observers. The photographs of relevant areas were taken in order to show the fundamental features of eco-friendly building, the cases possessed as well as the extent to which they were applied.

These sketches were considered vital to form an opinion on the physical setting and spatial organisation of the case studies in order to explain the research. In carrying out these case studies basic knowledge of eco-effective technologies, the general layout of a ground station was observed. The sole purpose was to observe and document information obtained from these buildings, and create a design that puts into consideration all the merits and flaws of these buildings.

3.6.2 Secondary source of information

This refers to the evidence generated for the study other than the primary source of information. This comprised of the literature used in developing the conceptual framework. Here, information pertaining to the case study buildings already documented was used as well. The desktop literature was used for two primary purposes: i) to provide the general framework that set the tone for the literature and ii) to serve as evidence to support the analysis of the primary data drawn from the above-mentioned respondents in order to achieve the set objectives.

3.7 Variables of the Study

The basic principles of eco-friendly architecture were adopted as variables for the study. These variables include

i. energy efficiency

ii. water efficiency,

iii. material conservation,

iv. humane adaptation

v. reduction and recycling of waste (Akadiri *et al.*, 2012)

3.8 Method of Data Analysis and Presentation

The method of data analysis refers to the techniques employed to provide potential answers to relevant questions raised in the research work. This is done through the analysis of data gotten from the various sources for the research. The data gotten was analyzed descriptively and presented using tables, figures and other data analysis techniques are used to provide space analysis of the proposed design.

Table 3.2: Sample of checklist used in data collection

Eco-friendly design checklist **Scale Factor: Excellent=5. Adequate=4, Good=3, Fair=2, Poor=1**
Energy efficiency and conservation
Water management
Materials conservation
Waste management
Humane adaptation

Source: Author's compilation

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Preamble

In this chapter, details of the analysis and results of the survey attained and results from literature and empirical evidence were discussed. Descriptive statistics was performed to indicate the significance of the variables identified from available literature. These variables include energy efficiency, water efficiency, material conservation, humane adaptation and reduction and recycling of waste. Samples were selected purposively based on the research scope. The selected samples for case studies are the AVA little Tokyo, Nestoil towers, the Heritage place, the U.S embassy annex, and No 4 Bourdillon building. Consequently, results of the overall measurement are reported.

4.2 Case Studies

4.2.1 Case study 1: AVA little Tokyo

4.2.1.1 Background information

AVA little Tokyo is a residential mixed-use building. As shown in Fig 4.1, It is located on 236 South Los Angeles, Little Tokyo District, Los Angeles. The building has earned a LEED pilot credit for street network and great density of intersections in the surrounding area. The building consists of 280 apartment units, ground floor retail, restaurant space, indoor chilling lounge, a gym, social bar and movie hall.

Figure 4.1 Google Satellite Map of AVA Little Tokyo's Location
Source: Google maps (2019)

4.2.1.2 Eco-friendly strategies adopted in the design and construction of the building of AVA Little Tokyo

a) Energy Efficiency: AVA Little Tokyo exceeds California excellent for energy usage by more than 18%. This was achieved by installing high-efficacy lighting throughout the building and in all units. Ductwork is well sealed only allowing 6% or less leakage. This means that most of the conditioned air in units will be delivered to the occupant and not interstitial spaces. Superior insulation allows for a comfortable unit that requires less heating and cooling. All these measures save tenants about 30% on energy cost annually.

b) Water Efficiency: turf or grass, which generally requires large amounts of watering, was not installed on the project. Drought-tolerant plants with drip line irrigation controller prevent watering in the event of rain. High-efficiency fixtures, including low-flow showers, faucets, and toilets, were installed in every unit. The resulting savings in indoor water use is more than 20% compared to other like-kind projects.

c) Material Conservation: 80% of waste generated by construction was reused, recycled, or otherwise diverted from landfills. Environmentally preferable wood products were used throughout the project. The foundation's aggregate and insulation in building both contain recycled content helping reduce the need for new resources. During the design process the project team developed a detailed cut list for the lumber used in framing the building. The pre-cut lumber was delivered to the construction site reducing the waste that comes from cutting lumber on site.

d) Humane Adaptation

i. Indoor Air Quality

Indoor Air Quality is an important factor in green building and contributes to the health and wellbeing of the tenants. AVA Little Tokyo is a smoke-free building reducing exposure of occupants to second-hand smoke. The MERV 8 air filters are above industry excellent and help trap and capture more a greater number of airborne - pollutants. All units provide fresh air directly to units and a low volume, continuously running exhaust fan helps ensure stagnant or moist air is not trapped for extended periods of time. Bath fans have automatic humidistats which turn on automatically when moisture levels increase within bathrooms.

Paints, primers, sealants and glues, as well as carpeting and flooring, used on the project contain low quantities of harmful volatile organic compounds (VOCs), which are harmful when inhaled. Combined, these measures help ensure better indoor air environment and may help minimize a condition known as sick building syndrome. The building envelope as shown in Plate I improves thermal comfort and indoor air quality by providing a significant amount of insulation and natural ventilation.

Plate I: Building Envelope and Building Interior
Source: Avalon Communities (2019)

ii. Sustainable Site

The heat island effect is caused by the sun’s heat striking surfaces such as parking lots, steel, and glass structures which absorb then give off heat. Vehicle parking for AVA Little Tokyo is located entirely underground, which maximizes space and helps to minimize the urban heat island effect.

AVA Little Tokyo’s roof consists of a white membrane, which keeps upper units cool and which helps reduce the heat island effect. Cooler units also mean air-conditioning systems will operate less – saving tenants about 15% to 20% on cooling costs and saving ownership wear-and-tear on equipment.

e) Reduction and recycling of waste: all water waste on the site is recycled for use in flushing toilets and watering plants. The water from the pool shown in Plate II is recycled to be used in flushing the toilets and watering the green areas. All recyclable materials during construction were reused on the site. The organic waste is sold to the farms in the vicinity as manure, inorganic waste is given to the waste management agency for the purpose of recycling and upcycling.

Plate II: The pool
Source: Avalon Communities (2019)

4.2.1.3 Observation: merits and demerits of the eco-friendly practices adopted by AVA Little Tokyo

Table 4.1 shows a summary of the findings on AVA Little Tokyo based on the researcher's assessments and the eco-friendly features in the building.

Table 4.1: Summary of findings on AVA little Tokyo

Eco-friendly design Checklist
Scale Factor: Excellent=5. Adequate =4, Acceptable=3, Fair=2, Poor=1

Variable	Features	Method Adopted	Scale Factor	Remarks
Energy efficiency	Efficient HVAC system ducts and low e devices	Use of properly sealed ducts and high efficacy lighting	5	Excellent
Water efficiency	Drought resistant plants, low flow fixtures.	Use of drought-tolerant plants to reduce need for constant watering and use of low flow fixtures	4	Adequate
Material conservation	Environmentally friendly wood, recycled foundation	Foundation aggregate and building insulation were from recycled construction materials.	4	Adequate
Humane adaptation	MERV air filters, paints, primers and sealants.	Use of filters to purify indoor air, and low impact volatile organic compound for the indoor environment.	3	Acceptable
Waste reduction and recycling	Recycled building materials, water and inorganic waste	Reuse of water on site, use of inorganic waste for compost	3	Acceptable

Source: Author's fieldwork (2019)

4.2.2 Case study 2: Heritage Place Ikoyi

4.2.2.1 Background information

Heritage Place Ikoyi as shown in Figure 4.2 sits in a prime location in Lagos advantageously situated at the cross roads of Lugard avenue Kingsway road. The project is registered with the U.S green building council for leadership in energy and environment design (LEED) certification, and rated at 45/110 points. It Comprises 15,600 sq. m of office space over eight floors, and five levels of parking for the building users and surrounding users. The large floor plates offer great flexibility and efficiency to the modern occupier and are fitted to internationally recognized Grade A standard, available from 450 sq. m to 2,000 sq. m. All the offices have equal access to the reception, meeting and dining area on the ground floor and over 350 private car parking spaces.

Figure 4.2: Satellite Map Location of Heritage Place
Source: Google maps (2019)

4.2.2.2 Eco-friendly strategies adopted in the design and construction of the building.

a. Energy Efficiency: Heritage Place building has low energy consumption to reduce operational costs. It is powered by generator diesel tanks to provide 7 days autonomous building operation, hence possesses full power redundancy from standby generators. The building has automatic presence detectors and high-efficiency lighting reduces and resupplies energy when and where it is needed. The building's orientation maximizes natural light and ventilation, and minimizes solar exposure, reducing the energy requirements for cooling, heating and air quality systems. High efficiency glazing and external thermal envelope as shown in Plate III reduces demand on cooling requirements. Between 30–40% reductions in energy use (compared to common practice building in Lagos). Use of natural light and natural ventilation (mixed mode) to minimize energy demand, and Sun pattern driven orientation to minimize solar exposure and energy requirements for cooling. Heat in the building could be recovered through a centralized fresh air supply system (cooling).

Plate III: Building Thermal Envelope and Section
Source: Heritage Place (2019)

b. Water Efficiency: all water in the building is recycled, such water includes water from rain water harvesting to water re-use in the irrigation of the gardens. There's an accurate control system in the bathroom facilities to reduce wastage. The building water demand was minimised though rain water harvesting and condensate recovery from cooling units. Water is harvested for toilet flushing and irrigation and motion sensor-controlled hand-wash basins and urinals contributing to reduced potable water demand. All storm water is passed through a reduce in attenuation tank proposed to limit discharge/flow rates of foul and storm water to the local sewers in Lugard Road. Water storage to allow four days' potable water storage.

c. Material Conservation: a large quantity of waste generated by construction was reused, recycled, or otherwise diverted from landfills. Pulverised fuel ash* (PFA or fly ash) may be used as a cement replacement for part of the cement content. PFA is recycled from power plants and has low embodied energy as well as being environmentally friendly.

Plate IV: Curtain Walls and Balconies
Source: Heritage Place (2019)

d. Humane Adaptation

a. Indoor Air Quality

A management plan was set up to ensure good indoor air quality, through the use of a centralised unit that provides fresh air directly to the office floors, making the heritage place is a smoke-free building reducing exposure of occupants to smoke. Adhesive sealants and glues, as well as carpeting and flooring, used on the project contain low quantities of harmful volatile organic compounds (VOCs), which are harmful when inhaled. All these measures were taken to ensure good indoor air quality. Fig 4.6 shows balconies and curtain walls with windows of Heritage building that improve indoor air quality by allowing natural ventilation and lighting.

b. Sustainable Site

The heritage place is strategically located close to the good access to public transportation access and community connectivity. It has bicycle storage to encourage the use low impact transportation around the area. The building covers minimum space and makes up for alterations to the site by adding green features and green areas.

e. Reduction and Recycling of Waste: all water on the site is recycled for re-use. Use of water harvested for toilet flushing and irrigation. Materials used for construction included pulverised fly ash and recycled construction materials from the site.

4.2.2.3 Observation: merits and demerits of eco-friendly design methods used in Heritage building design

Table 4.1 shows a summary of the findings on the Heritage place based on the researcher's assessments of the eco-friendly features applied in the building design, construction and operation.

Table 4.1: Summary of findings on The Heritage Place Ikoyi

Eco-friendly design Checklist
Scale Factor: Excellent=5. Adequate=4, Acceptable=3, Fair=2, Poor=1

Variable	Features	Method Adopted	Scale Factor	Remarks
Energy efficiency	Use of shading devices to reduce heat gain, and use of generator for electricity.	Use of shading devices, high efficiency glazing and high efficiency lighting.	4	Adequate
Water efficiency	Water storage, attenuation tanks,	Recycling of water for flushing and harvesting of rain water.	3	Adequate
Material conservation	Pulverised fly ash.	Use of low embodied energy material and low VOC adhesive and paint	3	Acceptable
Humane adaptation	Centralised air purification and supply to the building. low impact adhesive and paint.	Use of low impact volatile organic compound for the indoor environment and favourable site location.	3	Acceptable
Waste reduction and recycling	Recycled building materials and water	Reuse of water on site, use of recycled material for construction.	4	Adequate

Source: Author's fieldwork (2019)

4.2.3 Case study 3: Nestoil tower

4.2.3.1 Background information

The Nestoil tower as shown in Figure 4.3 is located on plots 41/42 Akin Adesola street Victoria Island Lagos. It is a mixed-use development located at the intersection of two major business districts, not quite far from Eco Atlantic hotel and the Atlantic Ocean. The structure stands at a height of 75m with 15 floors with a silver LEED rating of 50/110.

Figure 4.3: Nestoil Tower
Source: Google maps (2019)

4.2.3.2 Eco-friendly strategies adopted in the design and construction of the building.

a. Energy Efficiency: The Nestoil tower building has low energy consumption to reduce operational costs. As shown in Plate V, the building has double glazed curtain walls and high efficiency external thermal envelope to minimize solar gain and energy requirement for heating ventilation and air conditioning, it is lit through the use of natural lighting during the day and low energy bulbs at night. The source of energy to the structure is a petrol/diesel powered generator.

b. Water Efficiency: source of water to the building is the use of borehole, this means that it has water efficient landscape.

c. Material Conservation: not all materials were locally sourced or recycled. Materials containing volatile organic compounds were used in the building construction and finishing.

Plate V: Building Interior and Exterior Building Envelope
Source: Nestoil Tower (2019)

d. Humane Adaptation

i. Indoor Air Quality

Natural ventilation and lighting was increased by use of windows and double glazing to reduce ultraviolet rays. Thermal comfort design and Interior air quality management plan was used during the construction. Adhesives, glue, paints and primers used contained volatile organic compounds.

ii. Sustainable Site

The tower is located close to transit to encourage the use of mass transit to reduce emissions through transportation. Plate VI shows the neighbouring structures and roads for accessing transit from the building. Some already existing plants on the site were transplanted to keep the ventilation in check.

Plate VI: Nestoil Tower, Neighbouring Structures and Roads
Source: Nestoil Tower (2019)

e. Reduction and Recycling of Waste: waste is disposed through the town's waste disposal companies. Waste generated during construction was reused in the building construction. None of the waste generated on site is recycled.

4.2.3.3 Observation: merits and demerits of eco-friendly design features used in Nestoil Tower

Table 4.2 shows a summary of the findings based on the researcher's assessments and the eco-friendly features in Nestoil Tower.

Table 4.2: Summary of findings on the Nestoil Tower Victoria Island

Eco-friendly design Checklist

Scale Factor: Excellent=5. Adequate=4, Acceptable =3, Fair=2, Poor=1

Variable	Features	Method Adopted	Scale Factor	Remarks
Energy efficiency	Double glazed curtain wall. Natural lighting during the day and low energy bulbs at night. Petrol/diesel powered generator.	high efficiency external thermal envelope to minimize solar gain and energy requirement for heating ventilation and air conditioning	4	Adequate
Water efficiency	Borehole, and stored water in tanks	water efficient landscape through the use of borehole and water recycling for reuse on site	4	Adequate
Humane adaptation	A centralised unit for ventilation, low – e adhesives and glue.	Use of a centralised unit that provides fresh air directly to the office floors. Adhesive sealants and glues, used contain small quantities of harmful volatile organic compounds (VOCs)	3	Acceptable
Material conservation	Recycled materials, sand, cement and gravel	A large quantity of waste generated by construction was reused, recycled, or otherwise diverted from landfills.	3	Acceptable
Waste reduction and recycling	Recycled waste and re-used building	Recycled water for domestic use	4	Adequate

Source: Author's fieldwork (2019)

4.2.4 Case study 4: US embassy annex

4.2.4.1 Background information

The Embassy building covers a 9-acre site in the central business district of Abuja Nigeria. It includes a new office annex a marine security residence support annex with underground parking garage and community facilities. The structure is designed to be consistent with the architecture of the existing chancery building and provide a modern, high performance work environment. The compound has view of the mountain to the north and plentiful green spaces throughout as the site as shown in Plate VII the open floor plan allows for natural light through much of the work area as well as spaces for collaboration.

Plate VII: US Embassy Annex
Source: US Embassy Annex (2019)

4.2.4.2 Eco-friendly strategies adopted in the design and construction of the building

a. Energy Efficiency: the major means of heat gain reduction is the placement of properly oriented sunshades at the sides of the building with the highest amount of heat gain. The building has a 293-kW array of photovoltaic panels on the top deck of the parking structure, solar thermal hot water heater, occupancy sensor, light shelves at the windows and LED lighting.

b. Water Efficiency: to reduce water consumption and wastage in the building, water is recycled on the site and sourced from the borehole drilled on site and the rainwater is harvested on the site during the rainy season. Plate VIII shows some of the Locally appropriate plants that are being grown on the site to reduce the amount of water used in watering the plants.

Plate VIII: Locally Appropriate Vegetation
Source: US Embassy Annex (2019)

c. Material Conservation: all the waste generated during construction was reused and recycled on the site for further construction. All the materials used on site are locally sourced. Sustainable building materials such as glass, concrete, and sand and all recycled or repurposed materials.

d. Humane Adaptation

i. Indoor Air Quality

All the Adhesive sealants and glues, as well as carpeting and flooring, used on the project contain low quantities of harmful volatile organic compounds (VOCs), which are harmful when inhaled. An indoor air quality management was set in place before the construction of the building.

ii. Sustainable Site

The building site was selected based on the zoning of the town, the zone in which the site is located is the central business district. This district is composed of other commercial services, embassies, hotels and recreational areas. The district is a fast growing one with an easy link to other districts of the FCT. Provision is made for the users of bicycles, low emitting vehicles and fuel-efficient transportation means. As shown in Figure 4.4, the US Embassy Annex is located in an area where transit is easy to access. The site is developed in a manner that maximizes space, for example, underground parking is used on the site to avoid the need to construct one on another part of the site, and this method of design ensures minimum space consumption by the building.

Figure 4.4: US Embassy Annex Map Location and Adjacent Structures
Source: Google maps (2019)

e. Reduction and Recycling of Waste: all waste water on the site is recycled for reuse. All waste materials on the site are reused for construction purposes, the organic waste produced in the building is used as compost in gardens and plants.

4.2.4.3 Observation: merits and demerits of eco-friendly techniques adopted by US Embassy Annex

Table 4.3 shows a summary of findings based on the researcher's assessments of the eco-friendly features in the building.

Table 4.3: Summary of findings on the U.S EMBASSY ANNEX

Eco-friendly design Checklist
Scale Factor: Excellent=5. Adequate=4, Acceptable =3, Fair=2, Poor=1

Variable	Features	Method Adopted	Scale Factor	Remarks
Energy efficiency	properly oriented sunshades, photovoltaic panel, solar thermal hot water heater, occupancy sensor	Use of properly oriented shading to reduce heat gain. Smart technology to turn off lights when not in use.	5	Excellent
Water efficiency	Recycled water and water processing plant.	Water is recycled on the site and sourced from the borehole drilled on site and rainwater the is harvested on the site during the rainy season.	5	Excellent
Material efficiency	Glass, concrete and other locally sourced materials.	Waste generated during construction was reused and recycled for construction. Most of the materials locally sourced	4	Adequate
Humane adaptation	Low voc materials were used indoors.	All the Adhesive sealants and glues, used contain low quantities of harmful volatile organic compounds (VOCs)	4	Adequate
Waste reduction and recycling	Recycled water	All waste water on the site is recycled for reuse.	4	Adequate

Source: Author's fieldwork (2019)

4.2.5 Case study 5: No. 4 Bourdillon

4.2.5.1 Background information

No. 4 Bourdillon is a 25-storey residential building as shown in Plate IX, it consists of a tennis court, pools a club house, leisure room, gymnasium, lifts, gardens, and parking space for the users. it is located close to easy access for transit. Residences in the building include 3-bedroom apartments, and 4-bedroom duplex apartments.

Plate IX: No. 4 Bourdillon
Source: No. 4 Bourdillon (2019)

4.2.5.2 Eco-friendly strategies adopted in the design and construction of the building

a. Energy Efficiency: low energy bulbs are used to power the building the balconies shown in Plate X allows natural ventilation and lighting in the building. the Primary source of electrical power to the building is the national grid. The secondary source of electricity to the building is fuel powered generator and photovoltaic solar panels. Solar thermal heaters are used for heating water; smart technology is powers the lights to ensure all lights are turned off when not in use.

b. Water Efficiency: primary source of water to the building is the state's water board. To reduce water consumption and wastage, water is recycled on the site, rainwater is harvested on the site during the rainy season. Locally appropriate plants are also being grown on the site to reduce the amount of water used in watering the plants.

c. Material Conservation: locally sourced building materials such as cement, sand and glass were used as the major materials in the building construction. Waste generated during construction was recycled on the site for use in the construction of the foundation of the structure. Renewable materials such as sustainable wood and bamboo weren't used in the building design.

Plate X: No. 4 Bourdillon's Balconies
Source: No. 4 Bourdillon (2019)

d. Humane Adaptation

i. Indoor Air Quality

Construction management plans were adopted during the construction of the building, low-emitting adhesives, sealants, paint coating, floor system, composite woods and agrifiber products were used in sealing, finishing and flooring the building. The thermal comfort of the building was taken into consideration by the provision of highly efficient heating ventilation and cooling system with filters to purify air.

Plate XI: No. 4 Bourdillon's Adjacent Structures and Roads for Easy Communal Transit
Source: No. 4 Bourdillon (2019)

ii. Sustainable Site

The embassy is located close in the central business district of Abuja, this gives the users great access and connectivity to public services such as transportation and amenities. Plate XI shows the adjacent structures and roads located around the building such as hospitals, recreational areas, parks and great access to public transportation. The building covers minimum space, the underground parking and the maximum utilization of vertical space was designed to achieve this. The embassy has flexible spaces and makes up for alterations made to the site by adding green features and green areas.

e. Reduction and Recycling of Waste: all waste water on the site is recycled for reuse. Rain water is harvested to be reused for watering plants and flushing toilets. all waste materials on the site are reused for construction purposes, the organic waste produced in the building is used as compost in gardens and plants.

4.2.5.3 Observation: merits and demerits of eco-friendly building techniques adopted by No. 4 Bourdillon building

Table 4.4 shows a summary of the findings based on the researcher's assessments and the eco-friendly features in the building.

Table 4.4: Summary of findings on the No.4 Bourdillon

Eco-friendly design Checklist
Scale Factor: Excellent=5. Adequate=4, Good=3, Fair=2, Poor=1

Variable	Features	Method Adopted	Scale Factor	Remarks
Energy efficiency	low energy bulbs, balcony, photovoltaic solar panels, Solar thermal heaters	Low energy bulbs for lighting in the evening and natural lighting and ventilation through windows and balconies.	4	Adequate
Water efficiency	Locally appropriate plants, water efficient equipment.	Water is sourced from the water board, borehole and harvested rain water.	4	Excellent
Material efficiency	cement, sand and glass	locally sourced building materials such as cement, sand and glass.	4	Adequate
Humane adaptation	low-emitting adhesives, sealants, paint coating, floor system, composite woods and agrifiber products	construction management plans were adopted during the construction of the building to ensure high indoor air quality	4	Adequate
Waste reduction and recycling	Recycled water and materials	the organic waste produced in the building is used as compost in gardens and plants. all waste water on the site is recycled for reuse	5	Excellent

Source: Author's fieldwork (2019)

4.3 Deductions

From the comparative analysis below, it shows that AVA Little Tokyo has the highest use of eco-friendly building principles, through the adoption of as many eco-friendly building practices as possible. The Heritage place Ikoyi has the lowest use of eco-friendly building principles, mostly because it depends more on non-renewable energy sources, the building envelope is not very energy efficient. There is a general lack of use of locally sourced materials among the Nigerian case studies and hardly any innovation in the use of recycled materials except in the case of the heritage place where pulverised fly ash is mixed with the cement to reduce the amount of cement required for construction. Table 4.5 shows a comparative analysis of the results obtained from the four selected case studies.

4.3.1 Comparative analysis of case studies

Table 4.5: Comparative Analysis of the four selected Case Studies

Case study **Variables**	**AVA Little Tokyo**	**Heritage place Ikoyi**	**Nestoil tower**	**US Embassy Annex**	**NO.4 Bourdillon**
Energy efficiency	High efficiency lighting. Use of efficient duct work and high-grade insulation.	High efficiency glazing, use of sun shading device and proper building orientation to reduce heat gain.	Optimal thermal envelope for thermal comfort through natural ventilation and lighting.	Use of renewable solar energy, use of smart technology to control energy use.	Low energy bulbs, natural lighting during the day through the use of balconies and windows.
Water efficiency	Use of drought resistant plants. Use of low flow water fixtures.	Harvesting rain water and recycling of water on site	Use of water efficient landscape and recycling of water on site	Recycling water in the water processing plant on site	Use of locally appropriate plants to reduce watering. Use of water efficient equipment.
Material efficiency	Re-use of 80% of construction waste. Use of pre-cut to reduce wastage.	Recycled construction waste and use of pulverised fly ash.	Use of recycled and locally sourced building materials	Use of locally sourced and recycled building materials.	Use of locally sourced building materials with low embodied energy.
Humane adaptation	Merv air filters to purify air. Low VOC primers, paint and sealants.	Centralised purification system, low impact paints, adhesives and sealants.	Centralised air unit. Use of low VOC finishes in the interior.	Low emitting primers, paints and finishes. Sustainable site selection	Implemented construction management plans. Use of low emitting adhesives and finishes
Waste reduction and recycling	All waste on and off-site are recycled	Recycled construction waste and water on site.	Recycled construction Waste and water on site.	Recycled construction waste and organic waste on-site	

Source: Author’s fieldwork (2019)

Discussion

From the Table 4.5 above, the case studies adopted the use of high efficiency lighting, double glazing, sun shading devices and proper building orientation to reduce heat gain reduce energy required to maintain thermal comfort in the buildings. The air ducts are properly sealed to minimise leakage, central cooling systems and an efficient thermal envelope are used to improve heating, ventilation, cooling and energy conservation in the operation of the structure. The U.S Embassy building adopted the use of renewable energy as an alternate source while the Heritage place and Nestoil tower use diesel powered generators as an alternative source of energy which is a disadvantage because the fumes from the generator is harmful to the natural environment.

To ensure water conservation, AVA Little Tokyo adopted the use of drought resistant plants and low flow water fixtures to minimise wastage resulting from plant watering and other activities. Bourdillon uses locally appropriate plants to eliminate the need for any extra requirements that foreign plants may have. Nestoil Tower, Heritage Place and the U.S Embassy harvest rain water and recycle water to reduce wastage. Up to 80% of the waste generated during construction was reused on the site, all building materials were locally sourced to reduce embodied energy accumulated during transportation and in the construction of the Heritage place, pulverised fly ash which is gotten from recycled power plant waste was used along with the cement to reduce quantity of cement required on the site. Waste generated during building operation is recycled on site while the rest of the waste is collected by the environmental protection agency.

Centralised purification systems, low VOC finishes, paints and adhesive were used in the interiors to ensure optimum indoor air quality. The Site location was selected based on proximity to transit, places of worship, schools, social amenities and other utility.

Generally, methods used by the selected case studies can be applied in the construction and design of mixed use buildings in Nigeria to reduce the negative impacts of building design construction, and operation on the environment.

4.4 The Site

4.4.1 Site location

The proposed site for the building is located along Sani Abacha way opposite Ladi Kwali Street Wuse district Abuja Municipal Area Council of Abuja. The site is also easily accessed from all parts of Abuja Nigeria, because it’s in the central business district area.

Figure 4.5: Site Location Map
Source: Google map (2019)

4.4.2 Site selection criteria

The selection of a suitable site shown in Figure 4.5 for the proposed mixed-use building is based on the following criteria;

1. Conformity with the master plan proposed by Development Control

The site has been set aside by the Development control under the Federal Capital Development Authority for the development of this facility as a major Millennium development goal of the Federal Government of Nigeria.

2. Proximity to users

The proximity of the site to the target users who are the working population of the central business district of Abuja. Because of the location of the site, the users can easily join the transit to be transported from that point to other points of the FCT.

3. Proximity to aid

The fire service and police station are located within 3km of the site.

4. Adequacy of land

The site size is ideal for the proposed building because it is 3.2 hectares and the building estimated building area is 21,743m², this means that adequate space can be left around the building for circulation, setbacks and other building regulation laws.

5. Orientation and landscaping

The longer side of the site faces the north, eliminating the need to position the building at an obtuse angle; this means that the longer side of the building can be aligned with the longer side of the site. This implies that the shorter side of the building gains more sun, therefore, the solar panels and the shading devices can be placed accordingly. The landscape of the site allows proper vegetation and water efficient landscape.

6. Availability of utilities

The district has fairly sufficient electricity and water, there will be need to rely on renewable energy sources as a secondary energy source to for the building to operate. It also has a proper waste disposal system.

4.4.3 Site justification

The site is located in the central business district, and is easily accessed from any part of Abuja. The access roads around the school makes it easier to navigate the site, there are adequate utilities, efficient landscape and topography developing this site will have no negative impacts on the overall eco-system of the region. The site is also located around buildings and activities that complement the proposed structure. These include transit for commuters, the national park for recreation, the national mosque, arts and crafts village, cinemas, clinics and supermarkets. The site has been set aside by the Development control Abuja Master Plan as shown in Figure 4.6 under the Federal Capital Development Authority for the development of this facility as a major Millennium development goal of the Federal Government of Nigeria.

Figure 4.6: Master Plan of Abuja
Source: Development control (2017)

4.4.4 Site characteristics

This refers to the Inventory of features that exist on and off the site. The site has a dense vegetation of shrubs and grasses with a few deciduous trees. It is relatively flat with gentle hills on the North eastern part.

4.4.5 Climatic data of Abuja

a. Rainfall

Abuja has two seasons; rainy (April to October) and dry (November to March). It is recorded to experience rainfall between April and October as shown in Figure 4.7. The tendency for concentration which is mostly between July, August and September is about 225mm of mean monthly distribution.

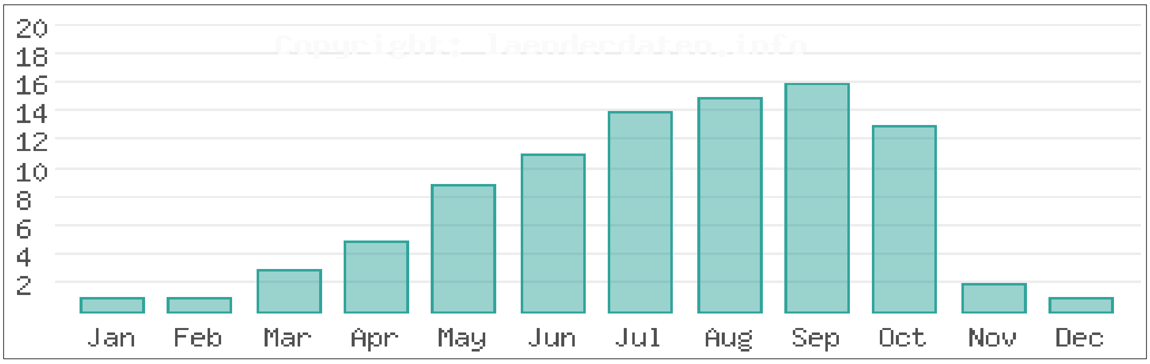


Figure 4.7: Mean Monthly Rainfall of Abuja
Source: Abuja Climate (2017)

b. Temperature

As shown in Figure 4.8, the highest temperature experienced in Abuja is during the dry season which is as high as 40ºC (104ºF). Night time temperature in the dry season is 12ºC (58ºF). During the rainy seasons which generally have considerably lower temperatures of about 28ºC (82ºF) during the day time and between 22ºC (71.6ºF) to 23ºC (73.4ºF) at night.

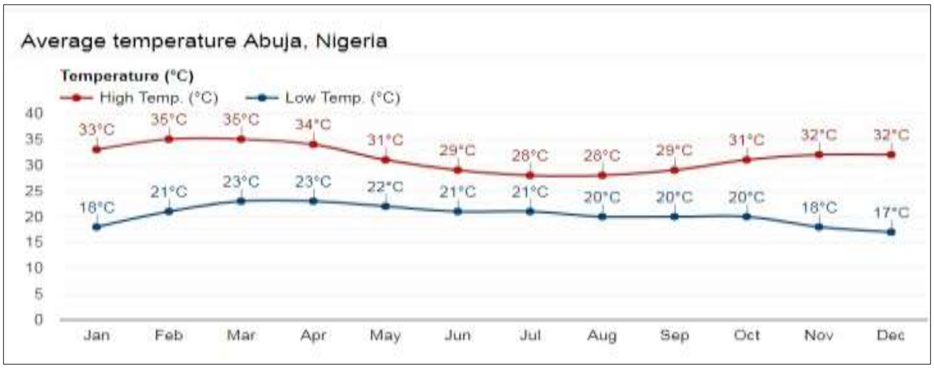


Figure 4.8: Monthly Temperature Ranges
Source: Abuja Climate (2017)

c. Humidity

During the dry season, the relative humidity drops as low as 20% while it is higher in the rainy season which is as high as 95%. The annual average relative humidity is about 84%. This rather low relative humidity, coupled with the high afternoon temperatures account for the desiccating effect of the dry season, the afternoon relative humidity rises everywhere to above 50%. Figure 4.9 shows March to November as the most humid months of the year.

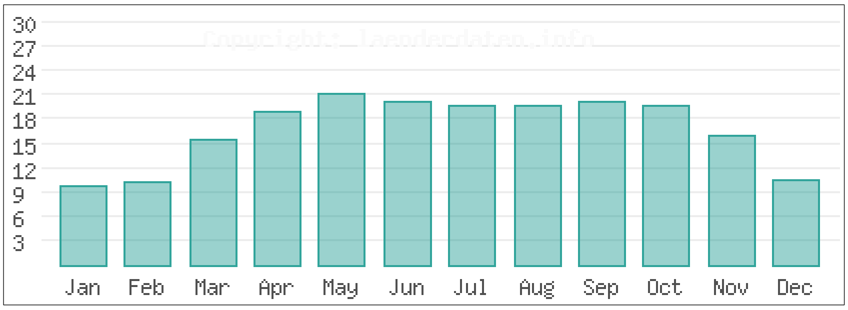


Figure 4.9: Mean Relative Humidity
Source: Abuja Climate (2017)

d. Solar Data

The sun rises in the east at about 6:21am and sets in the west at about 6:30pm as shown in Figure 4.10. The figure below shows the analyses of the sun path. During the dry months (November- April) the monthly variation in the amount of sunshine hours becomes more intense as the rainy season progresses and reaches its lowest values in the month of August. At this time, there is actually an inversion in the site where there is less sunshine hours than in the Southern parts of the FCT.

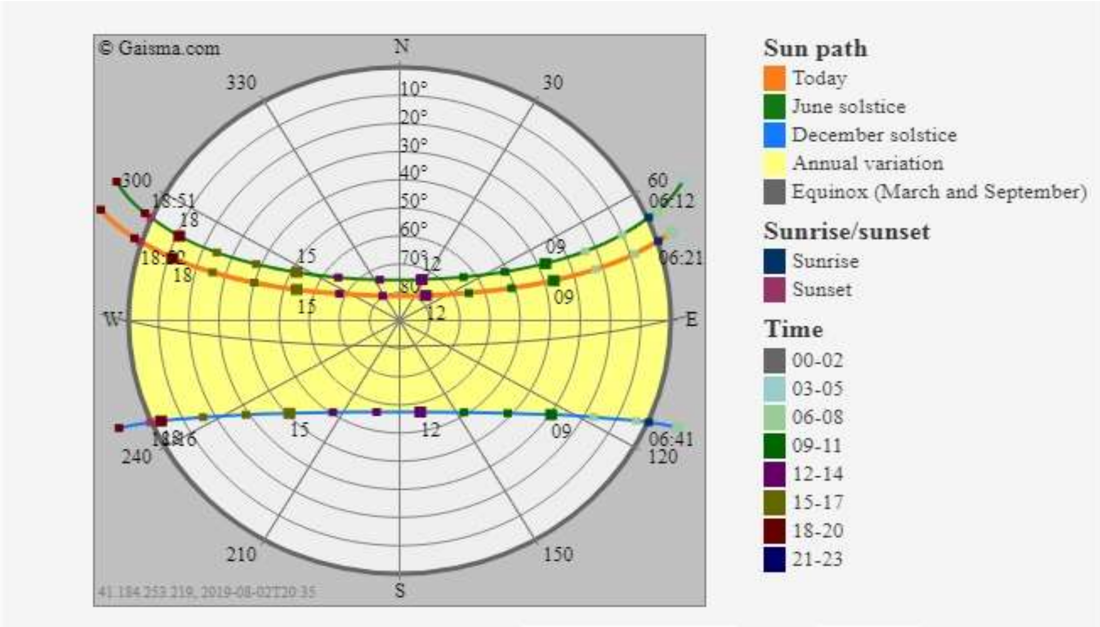


Figure 4.10: Sun Path Analysis
Source: Abuja Climate (2017)

4.4.6 Site planning bye laws and regulations

Development control is the local planning authority in Abuja. It is parasternal under the FCDA which oversees all infrastructural developments from inception stage to the completion, ensuring that the development is in accordance with the bye laws of the state and follows the Abuja master plan.

The planning regulations in terms of maximum site usage and building setbacks in Abuja according to the Development Control Manual (DCM) 1976 is as follows:

Plot size-1200m² and above

Coverage of site-40%

Building height 1-25 storey

Set backs

Front 6m, Sides 3m and Back 3.5m

Fence wall-1.5m

Front edge of plot to edge of access road-3m

Accessibility- access road of 6-9m

Parking- single parking is allowed on the street

4.4.7 Site analysis

i. Geographical Location

Wuse district is the north-western part of the city, with Maitama district to its north and the central district to the south. The district is numbered zones one (1) through six (6), the site for the proposed building is located in Wuse district zone 4.

Landmarks in Wuse Include;

1. The national park for recreation
2. Arts and crafts village
3. Millennium park
4. Silverbird cinema
5. Shehu Musa Ya'radua center
6. Wuse clinic
7. Wuse market
8. The national mosque

ii. Accessibility

The site is accessible from the road (Sani Abacha way) parallel to the shorter end of the site, a new one will have to be created adjacent the site to improve access to the site. The present road is linked to Ladi Kwali Street.

iii. Sunrise and Sunset

The sunrises at about 6:30am in the morning and sets at about 6:30pm in the evening on the site. The east and west side of the building should be shaded from the sun; solar panels can also be placed on the building to utilise the sun light hitting that part of the building to generate energy for the building.

iv. Vegetation

The site is characterized by grasses and shrubs with a scanty spread of trees; region specific plants that require less amount of water can be planted on the site to improve site vegetation.

v. Topography

The site is relatively flat; it is characterised by gentle hill on the borders of the north eastern side. A proper site survey will be carried out to determine the actual site slope from its cross section. This will aid both the Architect and the Structural Engineer in designing a stable structure.

Vi. Soil Type

The site is characterised by humus soil. Humus soil is great for growing plants, this means that the soil will encourage the growth of all kinds of plants for vegetation and soft landscaping on the site.

Vii. Prevailing Winds

Abuja has two prevailing winds; the tropical maritime mass and the tropical continental air mass. The tropical maritime air mass emanates from the Atlantic Ocean over the south of Nigeria. It moves inland in a south-west to north-west direction. The tropical continental air mass is over the Sahara Desert and therefore it is warm and dry. It blows in a north-east to south-west direction. The actions of these two prevailing winds are what cause the seasons.

Trees and other plants will serve as wind breakers in windy seasons, and water can be harvested for use on the site in the rainy seasons. Also perennial plants will be planted on the site to ensure that there are trees all year round.

4.5 Design Report

4.5.1 Design brief

The built environment has an enormous has an impact on its immediate environment and the eco system. This impact can be reduced by the adoption of eco-friendly building design methods through careful attention to low impact design and construction practices in the design and construction of the building. The considerations and criteria for low impact design and construction according to LEED include water, energy, waste, materials, sustainable site and indoor air quality.

The proposed mixed-use building is comprised of a combination of residential, office and commercial uses. The residential spaces have one bedroom, two bedrooms and three bedrooms' apartments with indoor and outdoor planting chute, and equal access to the elevator and stairs. The office floors are of two kinds; the executive floor and the open plan office. The commercial floor consists; business centre, restaurant, service centre, coffee lounge, swimming pool, and an event centre. The building has and underground parking which will serve as parking area for the users of the building.

4.5.2 Schedule of accommodation

The proposed mixed-use building is made of 20 floors in the super-structure and 3 floors in the sub structure, the sub-structural floors serve as the underground parking; the super-structural floors are divided into the commercial floor, the office floor, green area, and residential floor.

Table 4.6 shows the accommodation schedule on each floor for the proposed mixed-use building in Abuja.

Table 4.6: Floor area per floor

SN	FLOOR	AREA (m²)	No of Rooms
		Podium floors	
1	**Ground floor**	2,320	
	Water processing plant	830	1
	Storage	18	2
	Exhibition	529.4	1
	Loading Area	72.2	1
	Service Center offices	228.6	6
	Toilet	36	2
	Coffee lounge	124.9	1
2	**First floor**	3,624	
	Kitchen	118.2	1
	Tech	355.24	1
	Lobby	225.11	1
	Toilet	36	2
	Service centre	94.6	1
	Business centre	261.6	1
	Restaurant	273.8	1
	Library	224.66	1
3	**Second floor**	2,485	
	Garden	702.07	1
	Lobby	225.11	
	Swimming pool	662.4	1
	Sports and leisure center	151.32	2
	Toilet	36	2
4	**Third floor**	1,872	
	Preparation kitchen	78	1
	Pantry	60	2
	Gallery	145.45	1
	Hall	116.23	1
	Tech	114	1
	Auditorium	687	
	Bars and lounge	114.8	
		Tower floors	
5	**Fourth floor**	890	
	Open office cubicle	584	18
	Toilet	36	
6	**Fifth floor**	970	
	Open office cubicle	724	21
	Toilet	36	2
7	**Sixth floor**	1,030	
	Open office cubicle	686	16
	Conference	59.82	2
8	**Seventh floor**	1,085	
	Open office cubicle	822	18
	Conference	72.33	2
9	**Eighth floor**	1,150	
	Lounge	20.25	1
	Toilet	36	4
	Conference	96.9	2
	Office	45	1

Table 4.6: Floor area per floor (continued)

	Green area		**1**
	Offices	251.88	10
10	**Ninth floor**	1,200	
	Lounge	20.25	1
	Toilet	36	
	Conference	96.9	1
	Executive Office	45	1
	Green area		
	Offices	251.88	5
11	**Tenth floor**	1,259	
	Green area	865	
	Toilet	36	2
12	**Eleventh floor**	1,307	
	Bedroom	202.5	4
	Living room	193	4
	Toilet	36	2
	Kitchen	45	4
13	**Twelfth floor**	1,350	
	Bedroom	202.5	4
	Living room	193	4
	Toilet	36	2
	kitchen	45	4
14	**Thirteenth floor**	1,389	
	Bedroom	240.96	6
	Living room	193	3
	Dining	36	3
	Bathroom	36	3
	Kitchen	42	3
15	**Fourteenth floor**	1,415	
	Bedroom	240.96	6
	Living room	193	3
	Dining	36	3
	Bathroom	36	3
	Kitchen	42	3
16	**Fifteenth floor**	1,440	
	Bedroom	240.96	6
	Living room	193	3
	Dining	36	3
	Bathroom	36	3
	Kitchen	42	3
17	**Sixteenth floor**	1,458	
	Bedroom	240.96	6
	Living room	193	3
	Dining	36	3
	Bathroom	36	3
	Kitchen	42	3
18	**Seventeenth floor**	1,476	
	Bedroom	240.96	6
	Living room	193	3
	Dining	42	3
	Bathroom	45	6
	Kitchen	42	2
	Game room	150	2
19	**Eighteenth floor**	1,484	

Table 4.6: Floor area per floor (continued)

	Bedroom	**240.96**	**6**
	Living room	193	3
	Dining	42	3
	Bathroom	45	6
	Kitchen	42	2
	Game room	150	2
20	**Nineteenth floor**	1,486	
	Bedroom	240.96	6
	Living room	193	3
	Dining	42	3
	Bathroom	45	6
	Kitchen	42	2
	Game room	150	2
21	**Twentieth floor**	1,354	
	Bedroom	240.96	6
	Living room	193	3
	Dining	42	3
	Bathroom	45	6
	Kitchen	42	2
	Game room	150	2
		Basement floors	
22	**Basement floor 1**	7,180	
	Storage	66.2	1
	Tech	76.9	4
	Parking	12.5	45
23	**Basement floor 2**	7,180	
	Storage	66.2	1
	Tech	76.9	4
	Parking	12.5	45
24	**Basement floor 3**	7,180	
	Storage	66.2	1
	Tech	76.9	4
	Parking	12.5	45
25	Total	53584	
	Stairs	13.5	6
	Elevators	12.25	6

Source: Author's fieldwork (2019)

4.5.3 Design considerations and planning principles

The aim goal of the design is to minimize adverse impacts of the proposed building on the environment (air, Water, land, natural resources) through optimized building siting, optimized building design, materials selection, and thorough use of energy conservation measures. The factors considered in this design therefore include;

1. Sustainable site

a. The Site was selected based on the location and possible orientation of buildings in order to optimize the use of passive solar energy, natural day lighting, and natural breezes and ventilation.

b. The design and construction process should cause minimum site disturbance, value, preserve and actually restore or regenerate valuable habitat, green space and associated eco-systems that are vital to sustaining life.

c. Urban heat island effect should be reduced by decreasing the building and site development footprint, maximizing the use of pervious surfaces, and using paving, and walkways. Buildings and paved areas should be shaded with trees and other landscape features. Reduce impervious areas by carefully evaluating parking and roadway design.

d. Utilize existing mass transit systems in the site location and make the site pedestrian and bike friendly, including provisions for safe storage of bicycles.

2. Energy conservation

a) Maximize the use of renewable energy and other low impact energy sources, resulting building performance should exceed minimum International Energy Code (IEC) compliance level by 30 to 40% or more.

b) Use high performance low-e glazing, which can result in significant year-round energy savings. Consider insulated double glazing, triple glazing or double pane glazing with a suspended low-e film. Window frames, sashes and curtain wall systems should also be designed for optimum energy performance including the use of multiple thermal breaks to help reduce energy use.

c) Optimize the value of exterior insulation and the overall thermal performance of the exterior envelope assembly of the proposed building. Consider advanced/high performance envelope building systems such as structural insulated panel systems (SIPS) insulated concrete form systems (ICF's) that can be applied to light commercial and institutional buildings and reflective sunscreen skin can be adopted to shade the building structure and reduce heat gain.

d) Use high efficiency, heating, ventilation and air conditioning (HVAC) and plumbing equipment, chillers, boilers, and water heaters. Use variable speed drives on fan and pump motors. Use heat recovery ventilators and geothermal heat pump technology for up to 40%energy savings.

3. Waste management

a) Construction waste should be recycled on site to eliminate wastage of building materials and to reduce the impact made on the environment by embodied energy of building materials which is mostly generated from manufacture and transportation.

b) Maximize the benefits of organic waste by providing means of collection in the proposed building for further conversion into manure and gas. Collected inorganic waste should be reduced reused and recycled.

4. Water management

a) Preserve the existing natural water cycle and design the site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems. Emphasis should be placed on retention of storm water and on-site infiltration and ground water recharge using methods that closely emulate natural systems. Minimize the unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and graywater.

b) Design and locate buildings and site improvements to optimize use of low-impact storm water technologies such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs, and other technologies that support on-site retention and groundwater recharge. Storm water that leaves the site should be filtered and processed naturally or mechanically to remove trash and debris, oil, grit and suspended solids.

c) Conserve water and preserve site and ground water quality by using only indigenous, drought resistant and hardy trees, shrubs, plants and turf that require no irrigation, fertilizers, pesticides or herbicides.

5. Material management and conservation

   a) Minimize the use of non-renewable construction materials and other resources such as energy and water through efficient engineering, design, planning and construction and effective recycling of construction debris.

   b) Maximize the use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible. Maximize the use of re-usable, renewable, sustainably managed, bio-based materials. Remember that human creativity and our abundant labor force is perhaps our most valuable renewable resource. The best solution is not necessarily the one that requires the least amount of physical work.

c) Optimize the use of engineered materials which make use of proven engineering principles such as engineered trusses, composite materials and structural systems , structural insulated panels (stress skin panels), insulated concrete forms, and frost protected shallow foundations which have been proven to provide high strength and durability with the least amount of material.

d) Recognize that transportation becomes part of a product or building materials embodied energy. Where practical, specify and use locally harvested, mined and manufactured materials and products to support the regional economy and to reduce transportation, energy use and emissions.

6. Indoor air quality

a) Provide a healthy, comfortable and productive indoor environment for building occupants and visitors. Provide a building design, which affords the best possible conditions in terms of indoor air quality, ventilation, thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment

b) Maximize the use of natural day lighting. Optimize solar orientation and design the building to maximize penetration of natural daylight into interior spaces. Provide shades or daylight controls where needed.

c) Design building envelope and environmental systems that not only treat air temperature and provide adequate ventilation, but which respect all of the environmental conditions which affect human thermal comfort and health, including the mean radiant temperature of interior surfaces, indoor air humidity, indoor air velocity, and indoor air temperature.

7. Configuration of uses
    a) Ensure compatibility between uses, with high quality environment. Design parking that provides secure parking and safe interaction between vehicles and pedestrians.
    b) Common walls between uses should be constructed to minimize the transmission of noise and transmission of noise and vibration. Spaces should be zoned appropriately; noisy spaces should be separated from quiet places with buffer zones.
    c) Ensure that retail/commercial spaces on the lower floor are appropriately designed to promote uses that serve all the users of the building.
8. Functional requirements
    a) This functional requirement of the building includes; strength and stability, durability and maintenance and fire safety.
    b) The building should be designed and constructed such that the load bearing elements (foundations, walls, floors and roofs) have adequate strength and stability to support the dead loads of the construction and anticipated imposed loads on the roof, walls, floor and foundation without causing deflections that may compromise the entire building.
    c) Durability and freedom from maintenance where possible is important as well. The structural materials and system used should be durable enough to last through the building's life cycle without need for maintenance.
    d) The building should have a practical and safe means of fire escape, building materials used should have high fire resistance and fire prevention and control mechanisms should be adequate.

4.5.5 Application of research

1. On-site renewable energy

Sources of renewable energy adopted in the design include photovoltaic solar panels and wind turbines mounted on the building to generate solar and wind energy for the building to depend on as a secondary source of energy.

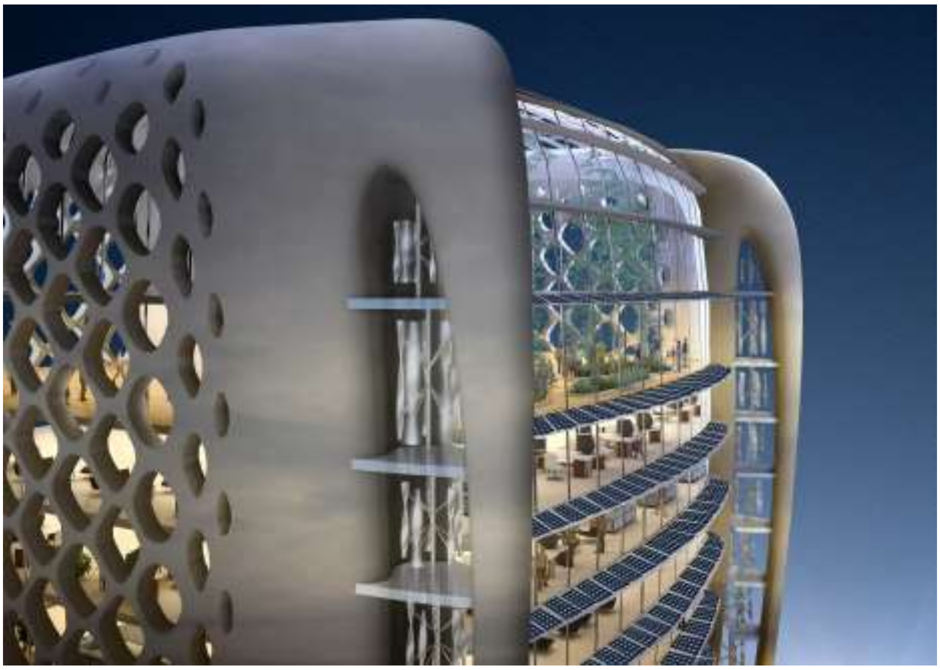


Plate XII: Wind Turbines and Photovoltaic Solar Panels for Generating Renewable Energy
(Source: Author's fieldwork, 2019)

2. Construction waste management

All waste expected to be generated during the construction of the building are to be reused on site or sent out to be sorted and recycled.

3. Sustainable sites

During site clearing, all the vegetation on the site is transplanted on the site as part of the landscape design for shading, aesthetics and security purposes, floor pavements are porous to allow water enter into the soil. The location of the site allows the building users to join the transit instead of driving personal cars and increasing pollution. There's no contribution to urban sprawl because of the site location and the maximum use of vertical space.

4. On-site water management

All water collected from rain and domestic uses is purified for reuse in the building's water processing plant. Water waste is reduced by the use of low flow showers, toilets and faucet. Most plants on the site are of local origin and draught resistant therefore they will not require constant watering.

5. Building materials

The materials used in the building construction are low embodied energy materials as shown in Plate XIII, these materials are mostly locally sourced, renewable and contain little or no volatile organic compounds. These materials include glass, wood, bamboo and glass.

Plate XIII: Interior of proposed mixed use design
Source: Author's fieldwork (2019)

6. Heat gain

To reduce heat gain, a sunscreen skin is used to shade the building from the sun. Low E glass is also used in the curtain walls to reduce heat gain and the effects of ultra-violet rays. The building orientation disallows heat gain on the side of the building with more openings.

7. Waste

All waste from the building is collected together from the chute as shown in Figure 4.11. Organic waste is collected for compost while non organic waste is collected to be recycled as much as possible. Waste during construction is recycled on and off site.

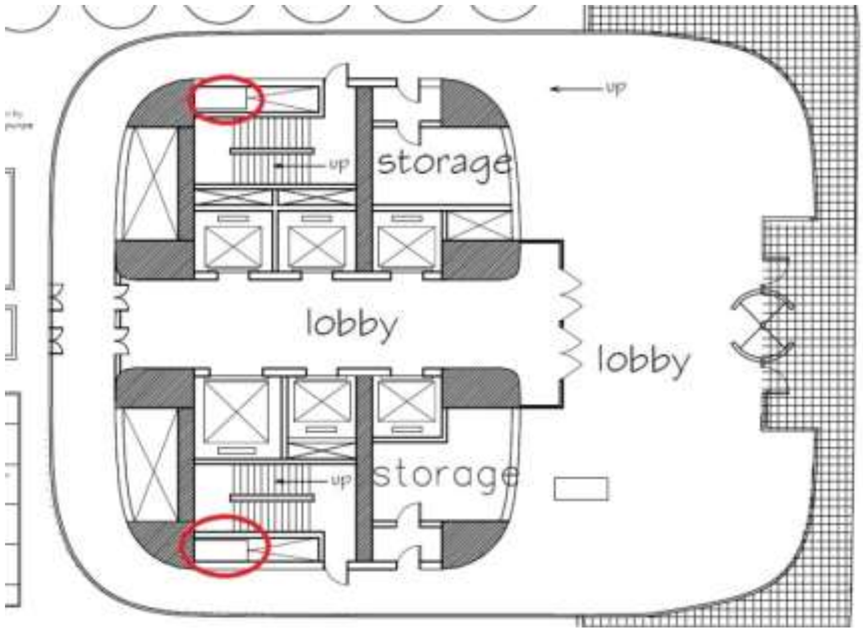


Figure 4.11: Chutes in the Proposed Building Available on all Floors
Source: Author's fieldwork (2019)

8. Indoor air quality

The building indoor environment is optimized by the use of centralised heating, ventilation and air conditioning system with filters to purify the air. Finishes, glues and adhesive contain low volatile organic compounds. The indoor air is further improved with the use of indoor plants and cross ventilation is achieved through the openable awing windows.

4.5.4 Design concept

The concept of the building design is the definition eco-friendly building, it imitates a self-sustaining living thing that can co-exist with the natural environment with minimal negative impact on the environment. This concept creates a balance between the built environment and the natural environment by preserving the natural environment while meeting the user's needs.

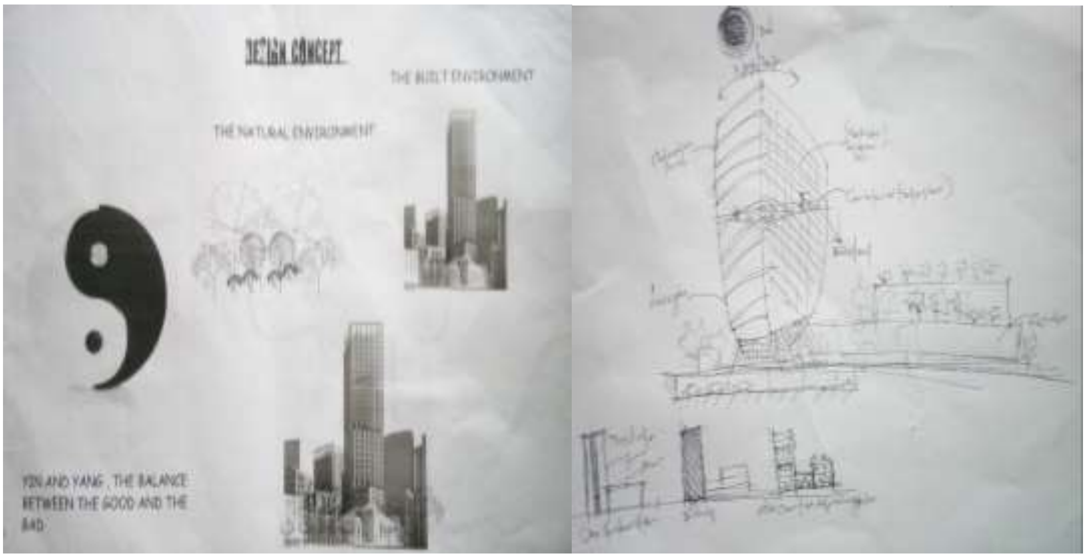


Figure 4.12: Showing Design Concept with Sketch
Source: Author's fieldwork (2019)

4.5.5 Construction

1. Foundation

   a) To optimally accommodate compression, tension and lateral forces that result from live load, dead load and imposed loads the foundation type proposed for the mixed use development is the driven pile foundation. To increase the load bearing capacity of the driven piles, the piles displace and compact the soil. This type of foundation causes minimal disturbances to the sub-soil by producing little soil for removal and disposal.

2. Basement

   a) In the design of basement, ground water and water levels are important, therefore to limit the penetration of water into the basement, rubber water stops are built across construction and expansion joints in the concrete walls and floors

   b) The walls and floors are also lined with thick layer of mastic asphalt in form of water proofing like a tank. Water proofing will increase the durability of the concrete as it will not allow water to reach the reinforcement in the concrete walls.

   c) The permanent retaining walls are designed to be suitable for lateral soil pressure, hydrostatic water pressure, surcharge pressure and lateral seismic earth pressures.

3. Structural system

a) Structural system adopted is the core system. This structural system serves to hold and channel the horizontal and vertical force load evenly on the core structural systems and supporting structures, so that the building can bear the horizontal and vertical load as well as lateral force.

b) This system is a vertical plane that forms an outer wall and surrounds a core structure. This allows open interior space that depends on the stretch ability of the floor structure. This system accommodates vertical mechanical transport systems, plumbing, mechanical and electrical system in the core of the building.

4. Walls

a) The load bearing walls in the proposed structure are shear walls constructed at the core of the structure to withstand gravitational and lateral loads while acting as a narrow deep cantilever beam. The building is supported by a shear wall at the core that encloses the building circulation system.
b) Non-load bearing walls are of structurally insulated panel walls and curtain walls. Walls that are located in shared spaces are highly insulated to minimize or eliminate transmission of noise and vibration.

5. Floors

a) The floor system is the composite slabs floor system, comprising lightly reinforced concrete cast on profiled steel decking. The slabs are reinforced using an upper layer of mesh and, occasionally, additional bars are added in the troughs to increase the period of fire resistance and heavy loads. A span of up to 4.5 m is achieved using trapezoidal decking (80 mm deep).
b) After completion, the ribs in the decking serve as void formers in the slab, thereby reducing the weight of floor construction. It is also possible to suspend services from the soffit of a composite slab, using anchors that are designed to slot into the decking profile.

6. Roofing

a) Light weight reinforced concrete slab will be used in areas were the roof is completely vegetated. The slabs are finished with a non-reinforced damp proof geo-membrane before the growing medium is been placed to prevent water from affecting the slab. Space frame covered with standing steam long span aluminum roofing sheets are used in the other areas.
b) A space frame or space structure system (3D truss) is used to roof the top of the building because of its rigidity and lightweight, ability to span large distances

without support. This roof system is sturdy because of the inherent rigidity of the triangles; flexing loads (bending moments) are transmitted as tension and compression loads along the length of each strut.

4.5.6 Materials and finishes specification

a) Foundations are pile foundations of reinforced concrete driven into the ground at engineer's specifications.

b) Non-load bearing walls are made of 150mm thick structurally insulated panels (SIPs) made of fiber cement and polyisocyanurate core because they're mould and formaldehyde with high moisture resistance. The curtain walls are designed and installed with 1800mm x 3500mm modular systems,150mm thick mullions and glazed with low-e glass to reduce heat gain

c) The building core is made of reinforced concrete with 450mm thick shear walls constructed to the structural engineer's specification.

d) Ground floor type is a 300mm thick composite steel floor made of profiled steel deck and concrete topping reinforced with wire mesh. This floor is finished with 300 x 600 mm vitrified non slip floor tiles on a 30mm screed. Other floors are of composite steel finished with linoleum, bamboo and vitrified floor tiles.

e) The roof is a space frame steel roof with trusses designed to the structural engineer's specification with isotherm insulation. Roof garden is made of concrete slab waterproofed with asphaltic impermeable membrane and insulated with XPS polystyrene foam.

f) The building interior is finished with low volatile organic compound paint, bamboo, ceramic tiles and linoleum.

4.5.7 Landscape and External Works

The landscape design sought to preserve and restore the region's natural habitat and heritage while emphasizing the use of indigenous, hardy, drought resistant trees, shrubs, plants and turf, already existing trees on the site are transplanted to avoid cutting down the trees and proposed plants are drought resistant to reduce water consumption through plat watering.

Permeable pavements are used to allow water pass through the ground. Parking is a multi-storey parking to maximize vertical space and reduce disturbance to horizontal floor space. Water is collected and recycled onsite.

4.5.8 Building services

a) Electricity and Lighting services

The facility will be powered from the national power grid. There will be a dedicated transformer to power the facility and renewable energy sources that include solar panels and wind turbines will be used as a secondary source of electricity because of the unstable power supply in the country. The entire cabling systems will be concealed in ducts and the lighting within the site will be trunked underground.

b) Mechanical (Heating, Ventilation and cooling)

The proposed design has taken into consideration natural means of ventilation through the provision of awing windows and indoor planting. However mechanical heating, ventilation and cooling systems will still be installed to improve indoor air quality. The condensers of the central air conditioning units will be placed on the roof deck and special consideration will be given to the reinforcement of the roof deck because of the load from the condensers.

c) Water supply

Water supply into the site will be from the National water supply board and from recycled water processed on-site in the water processing plant on the ground floor. An alternative water body will be sunk on the site. The water reservoir will be buried underground on the site and will be distributed into the building with the aid of mechanized pressure pumps. Water outlets would be installed around the gardens for the water features. Fire hydrants will also be installed around the site for the ease of firefighting.

d) Waste disposal

The building has a chute in its core of the building to collect organic and inorganic waste for recycling, refuse disposal cans will be placed at strategic locations on the site for effective waste disposal. All waste collected will be sent to the Environmental sanitation board. Small and aesthetically pleasing refuse bins will also be place in all interior spaces to ensure tidiness.

e) Drainage and Sewage disposal

In this design proposal, appropriate underground drainage channels will be constructed to ensure effective collection of waste from the building and the site to the underground drainage systems. The drainage system will be constructed of precast concrete and inspection chambers will be provided at intervals. Liquid waste from the building will be collected and drained into the soak way systems. Water from the green roofs will be drained via filters.

f) Fire safety

The precautionary measures incorporated in this building are fire detecting equipment's such as fire alarm, smoke detectors and fire extinguishers. Hydrants will also be positioned at strategic places on the site to compliment fire fighters. Building materials and elements with high fire resistivity will also be given attention to.

g) Acoustics

Trees will be planted to act as noise breakers in potential noise areas such as parking and power plants. Sound insulation materials will be used on walls in areas where unwanted sound will be distracting

h) Solar control

The effect of the sun on the interior spaces will be reduced by use of low-E glazing and perforated sunscreen skin. The building is oriented to face the side north side of the site to reduce direct solar heat gain.

i) Maintenance

Buildings deteriorate over time due to environmental effects during their life cycle, environment conditions, usage of the building, and method of design, materials used for construction, the methods and quality of construction. It is very essential to maintain buildings in order to sustain their life span. Therefore, planned preventive maintenance is recommended.

4.6 Summary of Findings

To reduce the effects of the building on the environment, deliberate steps have to be taken to control energy use and increase energy generated, water needs to be used efficiently managed through proper drainage channelling and on-site recycling , indoor air quality has to be optimum to maintain users health, waste has to be reduced, reused and recycled, the eco-system on the site to be developed should not be disturbed, sites should be located at points that make transit possible and building materials should be materials with low embodied energy and high positive effect on the building and the environment.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Eco-friendly building is considered as a way for the building industry to move towards protecting the environment. The aim of integrating of eco-friendly building practices and principles in building design and construction is to pursue a balance between the man-made environment and the natural environment. Integrating eco-friendly design principles is a way to reduce the negative impact of the building industry on our natural environment. In order to achieve this, the principles of eco-friendly design, energy efficiency, water efficiency, Material conservation, waste reduction, recycling, or reuse and humane adaptation. These principles form the basis for the planning, design and construction of eco-friendly buildings.

5.2 Recommendations

The recommendations that can be applied to implement eco-friendly design principles in the design of mixed use building in Nigeria are :

1. In the design of mixed-use development in Nigeria, the eco-friendly design framework as proposed by the study should be adopted as a design strategy
2. Renewable energy sources such as solar and wind energy should be adopted as primary source of energy and building materials should be recycled or locally sourced to reduce the embodied energy accumulated from the transportation of materials over long distances.
3. Low impact design and construction methods should be adopted to reduce energy consumption during construction and operation of mixed-use buildings. During site clearing, the eco-system of the site should be undisturbed, vegetation that needs to be removed should be transplanted and the use of vertical space

should be maximized to reduce disturbances caused to the earth during building construction.

REFERENCES

Abidin, N. Z. (2010). Investigating the awareness and application of sustainable construction concept by Malaysian developers. *Habitat International*, 34(4), 421-426.

Abuja Climate (2017a). Mean Monthly Rainfall of Abuja. Retrieved August 8 2019. From:https://en.climate-data.org/africa/nigeria/federal-capital-territory/abuja703/

Abuja Climate (2017b). Mean Monthly Temperature Ranges. Retrieved August 8 2019. From:https://en.climate-data.org/africa/nigeria/federal-capital-territory/abuja703

Abuja Climate (2017c). Mean Relative humidity. Retrieved August 8 2019. From https://en.climate-data.org/africa/nigeria/federal-capital-territory/abuja-703/

Abuja Climate (2017d). Sun path Analysis. Retrieved August 8 2019. From https://en.climate-data.org/africa/nigeria/federal-capital-territory/abuja-703/

Akadiri, P. O., Chinyio, E. A. & Olomolaiye, P. O. (2012). Design of a sustainable building, implementing sustainability in the building sector, *Open Access Building*, 2(12), 6-152. doi:10.3390/buildings.2020126

Alnaser, N. W., Flanagan, R. & Alnaser, W. E. (2008). Potential of making-over to sustainable buildings in the kingdom of Bahrain. *Energy and Buildings*, *40*(7), 1304-1323.https://doi.org/101016/j.enbuild.2007.11.010

AlSanad, S., Gale, A. & Edwards, R. (2011). Challenges of sustainable construction in kuwait: investigating level of awareness of Kuwait stakeholders. *World Academy of Science, Engineering and Technology*, 5(11), 2234-2241.

Aubree, A. (2009). BREEAM International, Retrieved May 2019 from http://www .fsr.is /lisalib /getfil e.aspx ?itemid=4690;www.breglobal.com

Avalon Communities (2019). *Gallery*, Retrieved March 24th, 2019, from https:// www. Avalon communities.com/california/los-angeles-apartments/ava-little-tokyo?utm _source =gmb & utm _medium =organic &utm_campaign=gmblist

BEAM Society (2003). *About US. Certified buildings. BEAM Excellents. BEAM International*, Retrieved November 2018 from http:// www.hk-beam.org.hk

Begum, R. A., Siwar, C., Pereira, J. J. & Jaafar, A. H. (2006). A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Condervation and Recycling*, 48(1), 86-98.

BCKL, Borough Council of King's Lynn (2009). *Solar Hot Water Heating* Res.2318-0609. Retrieved August 2019 from http://www.westnorfolk.gov.uk

Bossink, B. & Brouwers, H. (1996). Construction waste: quantification and source evaluation. *Journal of construction engineering and management*, 122(1), 55-60.

Bougdah, H. & Sharples, S. (2010), *Environmental Technology and Sustainability*, *Vol.2* Taylor and Francis Group, London.

Bryan, H. & Skopek, J. (2008), A Comparison of Two Environmental Rating Systems Using Dual Certified Buildings, *Proceedings of the Sustainable Building 2008 Conference*, 1-89 Retrieved July 2019 from http://www.thegbi.org

Bunz, K. R., Henze, G. P. & Tiller, D. K. (2006). Survey of sustainable building design practices in North America, Europe and Asia. *Journal of Architectural Engineering*, 12(1) doi: 10.1061/(ASCE)1076-0431

Burcu, G. (2015). *Sustainability Education by Sustainable School Design* Dokuz Eylul University, Department of Architecture, Turkey Procedia - Social and Behavioral Sciences 186(2015), 868-873.

Buttler, M. & Stoy, C. (2009), Comparing the benefit of international assessment methods, *16th annual European Real Estate Society ERES Conference Report*, Retrieved from: http://eres.architexturez.net/documents/series/Conferencce%202009.

BRE, Building Research Establishment (2012), *BRE Global Scheme Document*. 5, 1-9, Retrieved June 2019 from https://www.bre.co.uk>PDFPD-

Caleb P. (2009). Mixed-Use Development an Urban Design Approach to Cities in Developing Countries (Master of architecture) Kwame Nkrumah University of Science and Technology Ghana

CASBEE (2006). *An Overview of CASBEE*, Japan Sustainable Building Consortium. 2006. Retrieved August 2019 from http:// www.ibec.or.jp/casbee/english /index.htm.

CASBEE (2009). *CASBEE Certified Buildings*, Japan Sustainable Building Consortium. 2006. Retrieved July 2019 from http:// www.ibec.or.jp/CASBEE/english/certified_bldgs.htm.

Chan, K. (1998). Mass communication and pro-environmental behaviour: Waste recycling in Hong Kong. *Journal of Environmental Management*, 52(4), 317-325.

Chinese Society for Urban Studies (2008). *Green Building 2008*, Beijing: China Architecture & Building Press.

Dalibi S. G. (2012). Cost Impact Assessment of Green Buildings in China, A Case Study of Few Selected Green Building Projects in Shanghai, China. (Unpublished Msc Thesis), Hohai University Nanjing – Jiangsu Province of China.

Dalibi S. G., J C Feng, Liu S., Abubakar S., Bello, B. S. & Danja, I.I. (2017). 'Hindrances to green building developments in Nigeria's built environment: the project professionals' perspectives' *IOP Conf. Series: Earth and Environmental Science* 63, 1-4, doi :10.1088/1755-1315/63/1/012033.

Denzin, N. K. & Lincoln ,Y. S. (2003). Collecting and interpreting qualitative materials (2nd ed.) Thousand Oaks, CA: Sage.

Economist, (2004). Technology Quarterly, *The Rise of the Green Building*. Retrieved July 2019 http:// amp.economist.com/weeklyedition/

ECONorthwest (2001). Green Building: Saving Money and the Environment*; Opportunities for Louisiana*. doi:1010034-1067104.

Ekanayake, L. L. & Ofori, G. (2004). Building Waste Assessment Score: Design-Based Tool. *Building and Environment*, 39(7), 851-861.

Eric M. L., Peter, Y. & NAHB (1997). National Association of Home Builders, Deconstruction*: Building Disassembly and Material Salvage*, Malboro MA: Malboro Publications

Farrar, S. J., Whiting, P. J., Bonnert, T. P. & McKernan, R. M. (1999). Stoichiometry of a ligand-gated ion channel determined by fluorescence energy transfer. *Journal of Biological Chemistry*, 274(15), doi:10100-10104.

Ferguson, J., Kermonde, N., Nash, C. L., Sketch, W. A. & Husford, R. P. (1995). *Managing and Minimising Construction Waste* (1st ed.). London: Telford Publications.

Fowler, K. M. & Rauch, E. M. (2006). Sustainable Building Rating Systems Summary. Pacific Northwest National Laboratory. Retrieved July 2019 from: http://www.pnl.gov/main/publications/external/technical_reports/PNNL- 15858.pdf

Frontczak, M. & Wargocki, P. (2010). Literature Survey on how Different Factors Influence Human Comfort in Indoor Environments. *Building and Environment,* 46(4), 922-937.

Gillingham, K., Newell, R. G. & Palmer, K. (2009). Energy Efficiency Economics and Policy. *National Bureau of Economic Research (NBER) Working Paper Series,* 1(15031).

Gunnell, K. (2009). *Green building in South Africa: emerging trends,* Paper prepared for Department of Environmental Affairs and Tourism (DEAT) Directorate. Retrieved October 2019 from http://soer.deat.gov.za/Green_building_in_South_Africa_Emerging_Trends_GyzKE.pdf.file

Gustavsson, L. & Sathre, R. (2006). Variability in energy and carbon dioxide balances of wood and concrete building materials. *Building and Environment,* 41(7), 940-951.

Google maps (2019a). Google Satellite Map of Ava little Tokyo's location. Retrieved August 8 2019. From https://goo.gl/maps/7Y6cE1LmHugTo5js5

Google maps (2019b). Google Satellite Map of Heritage Place. Retrieved August 8 2019. From https://goo.gl/maps/nb1oMC1tqGWHpV7J6

Google maps (2019c). Nestoil Neighbouring Structures and Roads for Accessing Transit. Retrieved August 8 2019. From https://goo.gl/maps/wkwuLusDfJ3esv64A

Google maps (2019d). Google Satellite US Embassy Annex Location and Adjacent Structures. Retrieved August 8 2019. From https://goo.gl/maps/fAeAm8qEaxbRwpoB6

Google maps (2019e). Google Satellite No.4 Bourdillon's adjacent Structures and Roads for easy communal Transit. Retrieved August 8 2019. From https://goo .gl/ maps/fAeAm8qEaxbRwpoB6

Google maps (2019f). Site location. Retrieved August 8 2019. From https://goo.gl/ maps/r76mhSuxPHYkZ6jp6

Green Building Council of Australia (GBCA) (2009). *Green Star Overview, Certification*. Retrieved July 2019 from http://www.gbca.org.au.

Green Building Initiative (GBI) (2009). *History of the Green Globes System. Green Globes new Construction.* Retrieved January 2019 https://www.greenglobes.com

Heritage place (2019). *Gallery,* Retrieved March 24th, 2019,from http:// www .heritage place ik oyi.com/

Huberman, N. & Pearlmutter, D. (2008). A Life-Cycle Energy Analysis of Building Materials in the Negev Desert. *Energy and Buildings,* 40(5), 837-848.

Hussein, M. F. (2012). The ideal usage of sustainable materials and local resources of interior space design in Jordan. *Journal of Civil Engineering and Architecture,* 6(6), 1047-1058.

Indoor Environmental Department (2002). *Indoor Air Pollution in California.* Retrieved from: http://www. arb.ca.gov/research/indoor/ab1173/ab1173.html

Institute of Local Government (2013). *Sustainable Best Practices Framework.* California: Institute of Local Government.

International Energy Agency (2006). *World Energy Outlook. (2nd edition)*. France: IEA Publications.

Jonathan, A. (2003) Vegetation Climate Interaction: *How Vegetation Makes the Global Environment*. New York: Springer.

Jones, A. P. (1999). Indoor Air Quality and Health. *Atmospheric Environment,* 33(28), 4535-4564.

Ken, (2008). *Living Roofs and Walls*, Technical Report: Supporting London Plan Policy, Greater London Authority.

Karki, A. B. (2005). Biogas as Renewable Energy from Organic Waste. *Biotechnology, 10*, 1-9. Retrieved from http://www.eoiss.net

Kibert, C., Sendzimir, J. & Guy, G. B. (2000). *Defining an Ecology of Construction. Construction Ecology: Nature as the Basis for Green Buildings*. New York: Spon Press

Kolawole, J. O. & Anigbogu, N. A. (2005). 'Impact of Construction Activities on the Environment.' A Paper Presented at the National Conference *Towards a Sustainable Built Environment*. Ahmadu Bello University, Zaria – Nigeria. Sept. 21st – 23rd

Kim, J. J. & Rigdon, B. (1998). *Sustainable Architecture Module:Introduction to Sustainable Design.* Michigan: National Pollution Prevention Center for Higher Education.

Lenzen, M. & Treloar, G. J. (2002). Embodied Energy in Buildings: Wood Versus Concrete-Reply to Borjesson and Gustavsson. *Energy Policy,* 30:244-249.

Lippiatt, B. C. (1999). Selecting cost-effective green building products: BEES Approach. *Journal of Construction Engineering and Management*, 125(6), 448-55.

Ljungberg, L. (2007). Materials Selection and Design for Development of Sustainable Products. *Materials and Design,* 28, 466-479.

Lockwood, C. (2006). Building the Green Way. *Havard Business Review*. Retrieved March 2019 from http:// hbr .o/2006/06/building-the-green-way

LoBiondo-Wood, G. & Haber, J. (2006). Nursing research: *Methods and critical appraisal for evidence-based practice.* (6 ed.) St. Louis: Mosby Elsevier

Meyer, C. B. (2001). A Case in Case Study Methodology. Field Method. CA: Sage.

Michael B., Peter M. & Michael S. (2007). *Green Building: Guide book For Sustainable Architecture.* London New York: Springer Heidelberg Dordrecht http://doi.org/10.1007/978-3-64200635-7.

Michael, S. & Sander, V. L. (2015). The Shift toward Social-Ecological System Perspectives: Insights into the Human-Nature Relationship, *Nature's Sciences* 23(2), 166-174 doi: 10.1051/nss/2015034

Mohammed, A. & Abbakyari, M. (2016). Strategies for achieving sustainability in nigerian building design and construction industry. *Journal of Engineering and Applied Sciences,* 2(3), 103-108 ISSN: 2067-7720

Nestoil Tower (2019). *Gallery,* Retrieved March 24th, 2019, from http://nestoiltower.com/

New Zealand Green Building Council (NZGBC). (2009), "Green Star New Zealand Web site. New Zealand Green Building Council", 2009. Auckland, New Zealand. [Online] Available: http://www.nzgbc.org.nz/main/greenstar. (August 6, 2012).

Nguyen, B. K. & Altan, H. (2011), "Comparative Review of Five Sustainable Rating Systems", Procedia Engineering 21, 376 – 386. 2011. *International Conference on Green Buildings and sustainable*

No. 4 Bourdillon (2019). *Gallery,* Retrieved March 24th, 2019, from http://4bourdillon.com/

Odebiyi, S. O., Subramanian, S. & Braimoh, A. K. (2010). Green Architecture: Merits for Africa (Nigerian Case Study). *Journal of Alternative Perspective s in the Social Sciences,* (2)2, 746 -767

Ofori, G. (2000). “Challenges of Construction Industries in Developing Countries: Lessons from various Countries”. Proceedings of *The 2nd International Conference of the UB TG29 On Construction In Developing Countries Challenges facing The Construction Industry in Developing Countries* 15-17, November 2000, Gabarone, Botswana,1-3

Olomolaiye, P., Akadiri, P. O. & Chinyo, E. (2012). Design of a Sustainable Buidling: A Conceptual Framework for Implementing Sustainability in the Building Sector. *Buildings,* 2:126-152. doi10.3390/buildinggs2020126

Omer, A. M. (2008). Energy, Environment and Sustainable Development. *Renewable and Sustainable Energy Reviews,* 12(9), 2265-2300. doi: 10.016/jsrer.2007. 05.001

Osmani, M., Jacqueline, G. & Price, A. D. F. (2008). Architects’ Perspectives on Construction Waste Reduction by Design. *Waste management,* 28(7), 1147-58, doi:10.1016/j.wasman.2007.05.011

Otegbulu, A. C. (2011). Economics of green design and environmental sustainability. *Journal of Sustainable Development*, 240-245 doi :10.5539/jsd.v4n2p240.

Pappu, A., Saxena, M. & Asolekar, S. R. (2007). *Building and Environment*, 42(6), 2311-2320. doi: 10.10.6/j.builder2006.04.015

Polit, D. F. & Hungler, B. P. (1999). Nursing Research: Principles and Methods (6th edition). Philadelphia: J.B. Lippincott

Rao, A., Jha, K. N. & Misra, S. (2007). Use of Aggregates from Recycled Construction and Demolition Waste in Concrete. *Resources, Conservation and Recycling,* 50(1), 71-81.

Reddy, V. B. & Jgadish, K. S. (2003). Embodied Energy of Common and Alternative Building Materials and Technologies. *Energy and Buildings,* 35(2), 129-137.

Research Gate (2019). *Map of Abuja,* Retrieved March 24th, 2019, from https:/ /www. Research gate.net/figure/Map-of-Abuja-showing-the-six-area-councils_fig1_ 318653677

Richard, W., Konstantin, S., Tatyana, B., Stephan, L., Stefan, G., Arjan, de K., Jeroen, K., Helmut, S., José Acosta-F., Arkaitz, U., Moana, S., Olga, I., Jan, W., Jannick, H. S., Stefano, M. & Arnold, T. (2015). Sustainability Global Sustainability *Accounting Developing EXIOBASE for Multi-Regional Footprint Analysis*, 7, 138-163; doi:10.3390/su7010138

Rodrigues, F. M., Afonso, S. A. & Mariano, N. (2012). Water Efficiency in Buildings: A Contribute to Energy Efficiency. *International Symposium of CIB W062 on Water Supply and Drainage for Buildings.* 38, 32-39.

Roy, M. (2008). Importance of green architecture today. (*Dept. Of architecture*) Jadavpur university, Kolkata, India

Saunders, T. (2008), *A Discussion Document Comparing International Environmental Assessment Methods for Buildings,* BRE Global. Watford, United Kingdom.

Schlueter, A. & Thesseling, F. (2009). Building Information Model Based Energy/Exergy Performance Assessment in Early Design Stages. *Automation in Construction*, 18(2), 153-163.

Shafique, A. & Zeyaul, H. (2016). Fundamental principles of green building and Sustainable site design. *International Journal of Management and Applied Science,* (2)11, 2394-7926

Sheweka, S. & Magdy, N. (2011). The Living walls as an Approach for a Healthy Urban Environment, *Energy Procedia*, 6(11), 592–599.

Silva-Afonso, A. & Pimentel-Prodrigues, C. (2011). Water Efficiency in Buildings: Assessment of its impact on energy efficiency and reducing ghg emissions. *International Journal of Systems Applications, Engineering & Development, 5*(1).

Smith, Michael G., (2002). *The Case for Natural Building*, in Kennedy, Smith and Wanek. Retrieved August 2019 from https://www.sciencedirect .com/science/article/pii/S1877042815 0625 52 # bbib0050

Stephen M. Harrell, 2008, *Green-Livin* Retrieved May 2019 from http://green-livin.blogspot.com/2008/07/green-livin-graywater.html

Susan, Loh, 2008, *Living walls – Away to green the built* Retrieved January 2019 from www.environmentdesignguide.com.au/media/TEC26.pdf

Tam, V. W. & Tam, C. M. (2006). A Review on the Viable Technology for Construction Waste Recycling. *ELVISIER: Resources, Conservation and recycling,* 47(3), 209-221.

Thormark, C. (2001). Conservation of Energy and Natural Resources by Recycling Building Waste. *Resources, Conservation and Recycling,* 33(2), 113-130.

Thormark, C. (2006). The Effect of Material Choice on the Total Energy Need and Recycling Potential of a Building. *Building and Environment, 41*(8), 1019-1026.

UNEP, United Nations Environmental Program. (2007). *Building and climate change: Status, Challenges and Opportunities*. United Nation Environment Programme, United Nation.

UNFCCC, United Nations Framework Convention on Climate Change (2006). *UNFCCC Handbook. Bonn Germany*. Halesworth, UK: Technographic Design and Print Ltd

UN-HABITAT. (2006). *Public-Private Partnerships in enabling shelter strategies*. Nairobi: United Nations HABITAT information Services.

United Nations, (1987). Report of the World Commission on Environment and Development. General Assembly Resolution 42/187.

US Department of Energy. (2008). *Energy Efficiency Trends in Residential and Commercial Buildings.* Retrieved from https://www.energy.gov

US Embassy Annex (2019). *Gallery*, Retrieved March 24th, 2019, from https:// ng .usembassy .gov/ embassy-consulate/abuja/

USGBC, U.S. Green Building Council (2002). Building Momentum: *National Trends and Prospects for High-Performance Green Buildings*, Prepared for the U.S. Senate Subcommittee on Environmental and Public Works by the U.S. Green Building Council

USGBC, United State Green Building Council (2009). *The LEED Green Building Program at a Glance*, USGBC Press Kit. US Green Building Council. Washington, DC.

Walsh, P. J., Dudney, C. S. & Copenhaver, E. D. (2000). *Indoor Air Quality* (1990 ed.). Boca Raton, Florida: CRC Press.

Watson, R. & Balken, E. (2008). *Green Building Impact Report 2008/c2008*, Greener World Media, Inc. Retrieved from http://www.greenerbuilding.com

WBDG, Whole Building Design Guide. (2018) Sustainable Committee, *Sustainable*, Retrieved March 2019 from http://www.wbdg.org/designsustainable.php

WBCSD, World Business Council for Sustainable Development (2016). Sustainable Committee. Retrieved May 2019 from http://www.wbscd.org

Woolley, T. (2000). Green Building: Establishing Principles. *Ethics and the Built Environment*. Warwick Fox. Rutledge, London: 44-56.

Woolley T. 2006. *Natural Building: A Guide to Materials and Techniques*. Crowood Press. London

WU, Z. (2010). *Current Status and Future Trend of Green Building in China*. 2010 Shanghai EXPO. Retrieved from http://Shangaiexpo.org

Yi-Kai, J., Peng, G. & Jie, W. (2010). A hybrid decision support system for sustainable office building renovation and energy performance improvement. *Energy and Buildings*, *42*, 290-297.

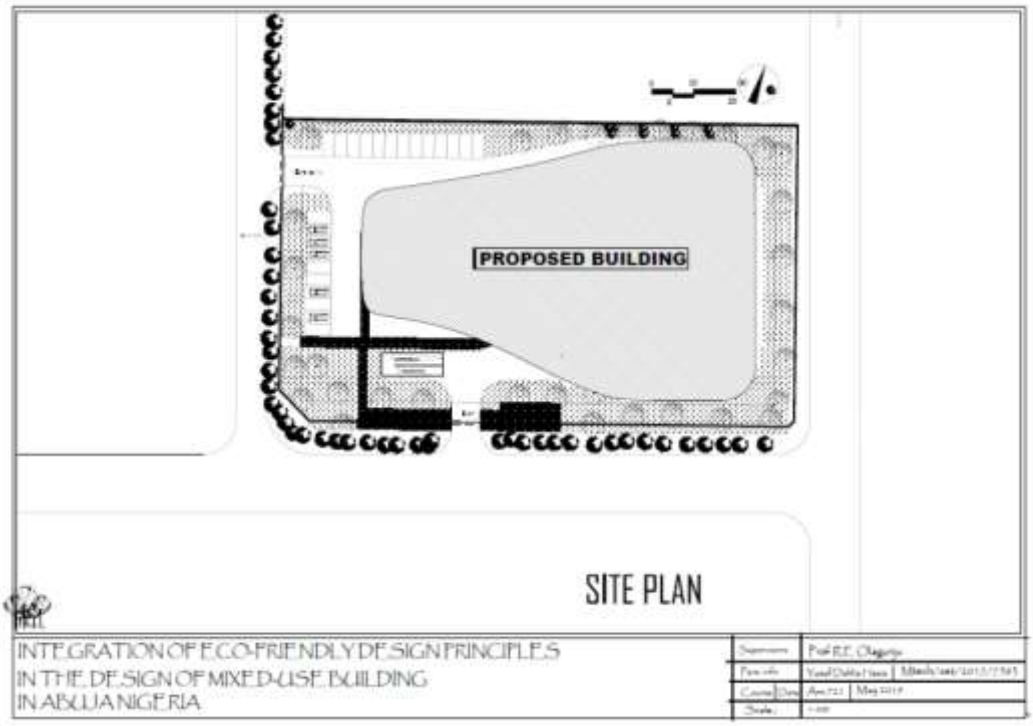
Yin, R. K. (2003). Case Study Research: Design and Methods. (3rd Edition), Thousand Oaks California: Sage publications

Zane, S. & Peter E. (2009). Tech Brief, *Green Building*, Virginia: The National Environmental Services Centre, (8)4, 1-4.

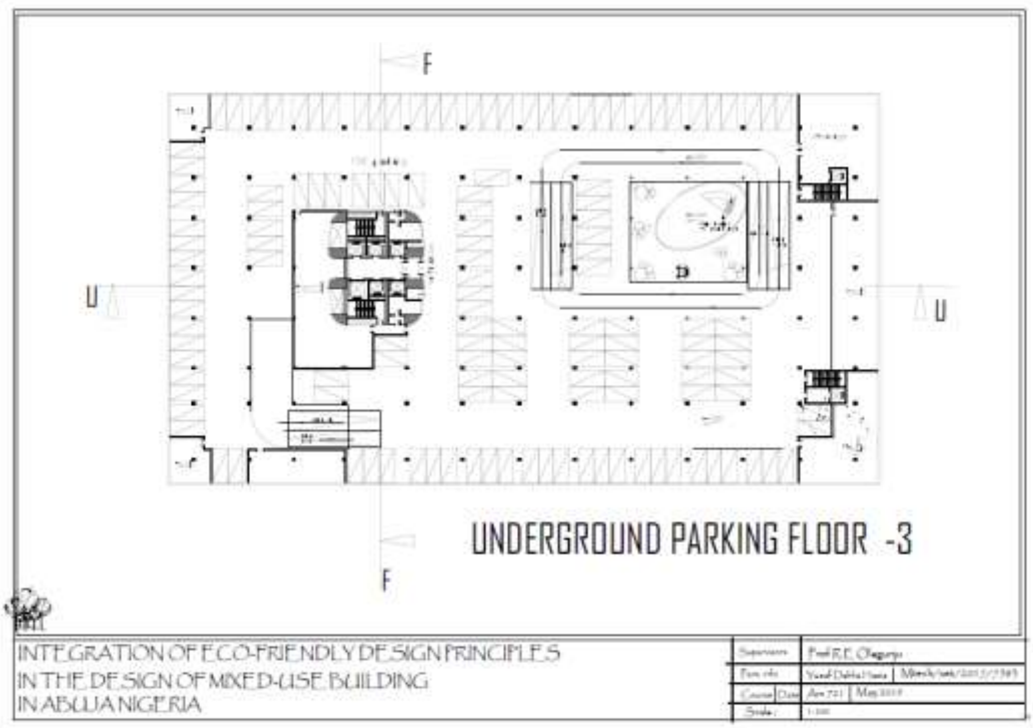
Zubairu, S. (2012). *The Importance of Evaluation and Sustainability in the Built Environment*, Proceedings of the 4th West Africa Built Environment Research (WABER) Conference, Retrieved July 2019 from http://www.academia.edu/ 175218 84/waber_conference

APPENDICES

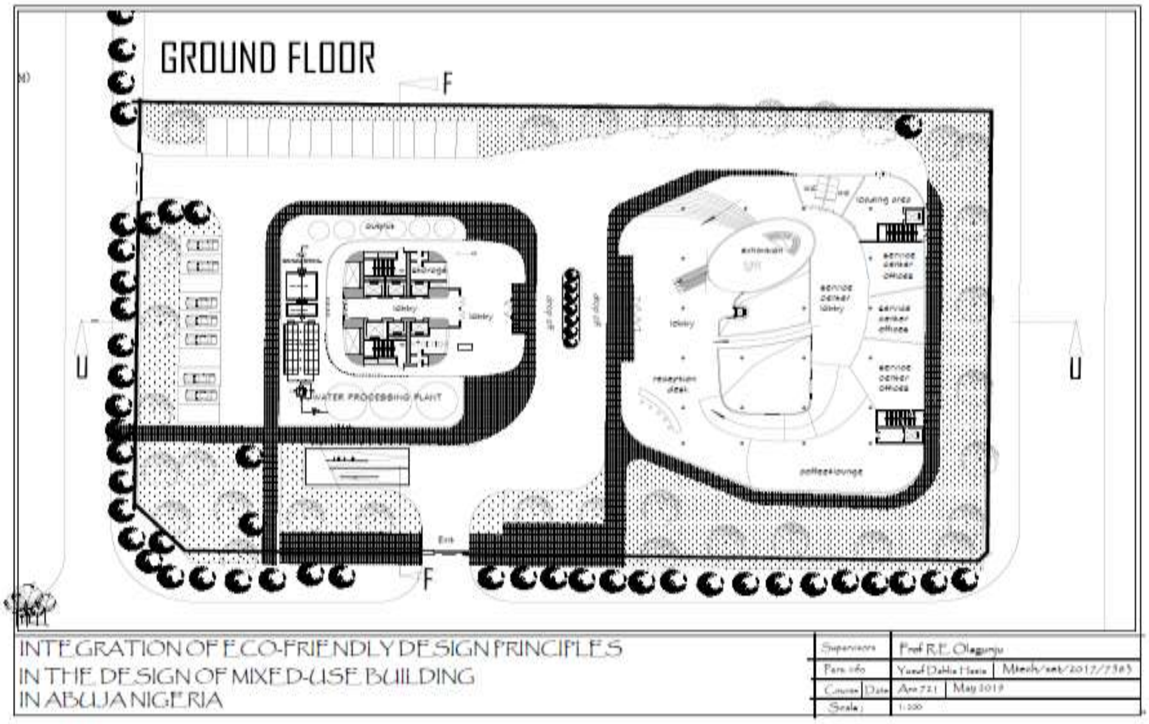
Appendix A: Site plan



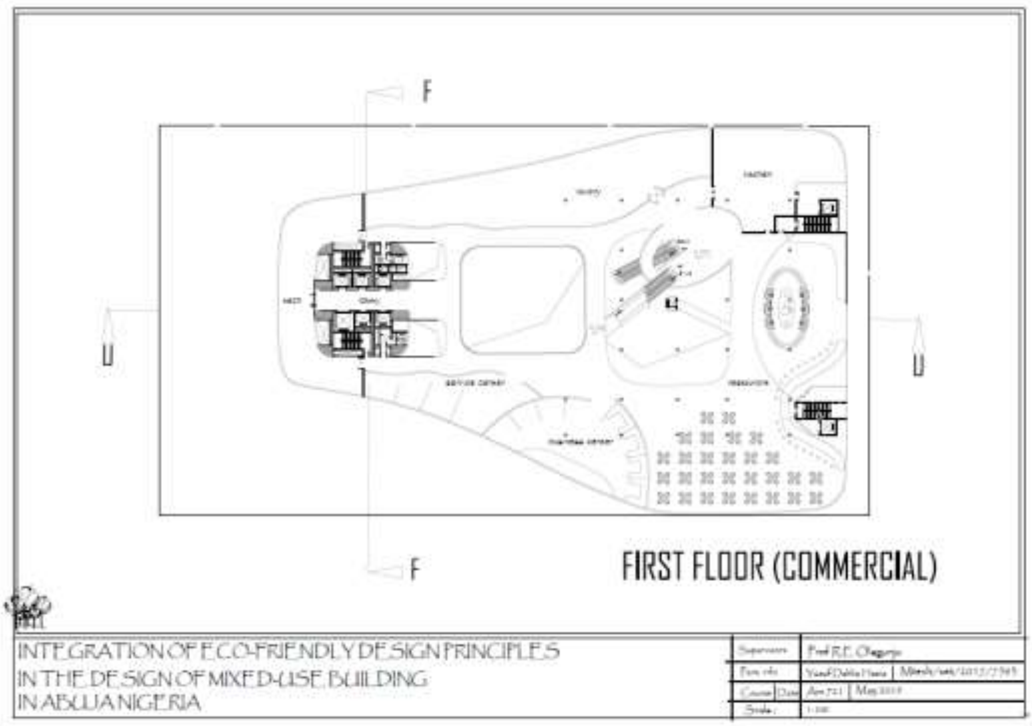
Appendix B: Basement floor



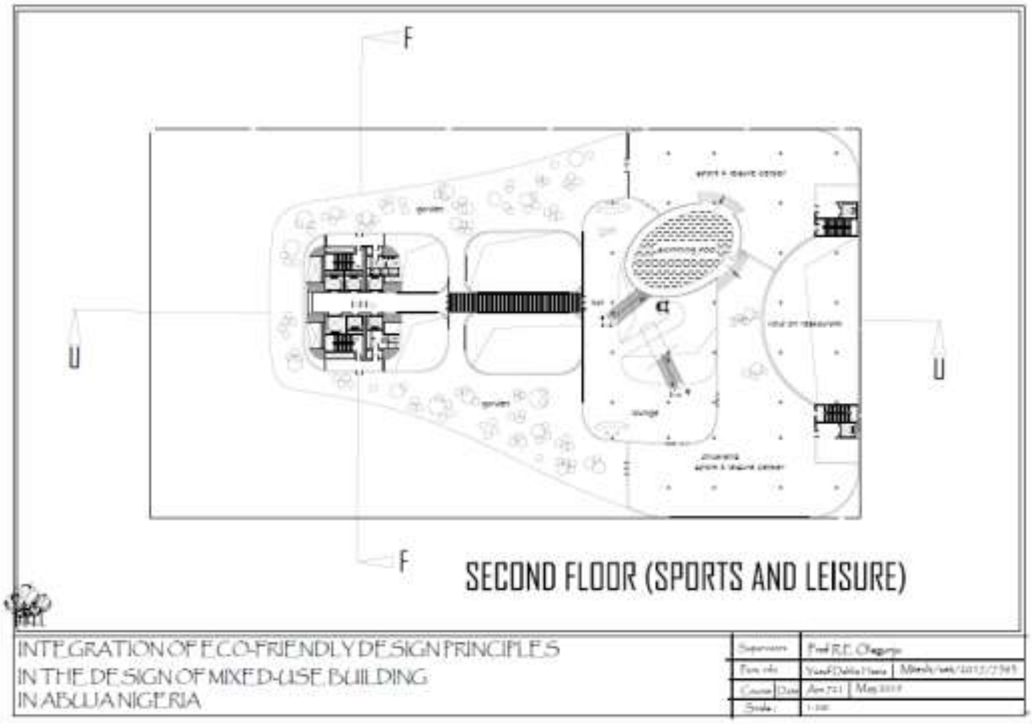
Appendix C: Ground floor



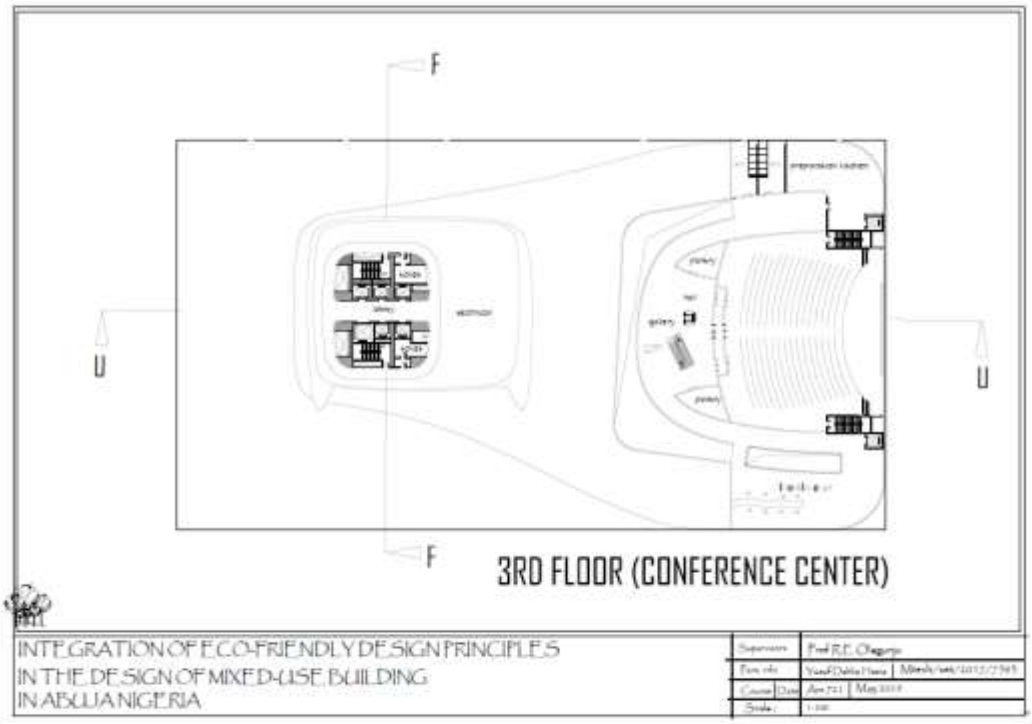
Appendix D: First floor



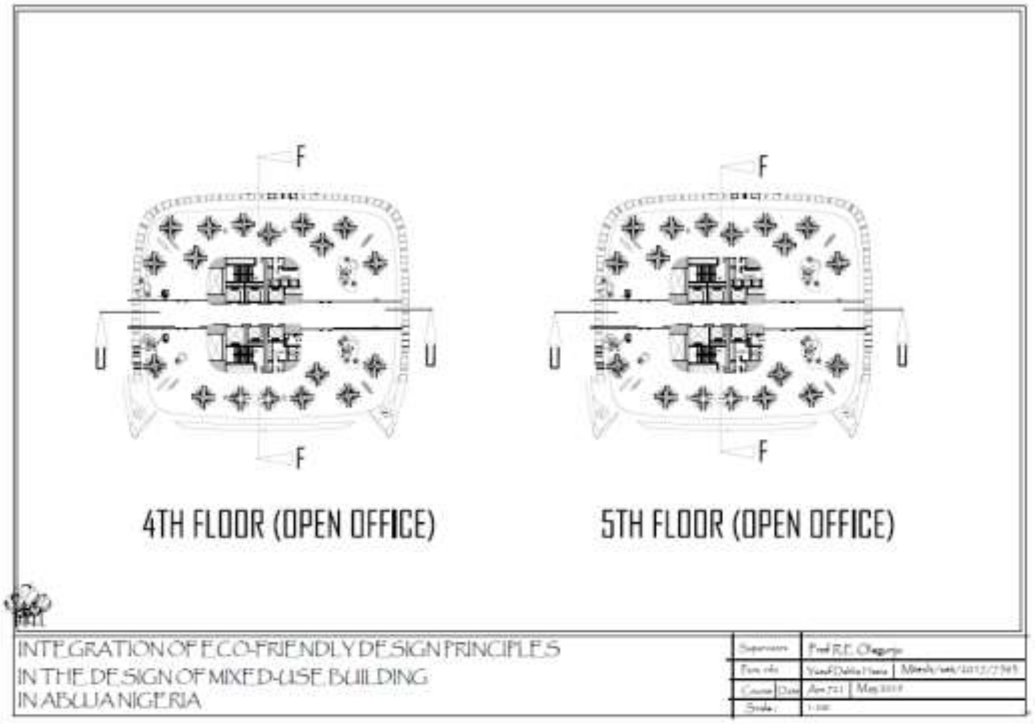
Appendix E: Second floor



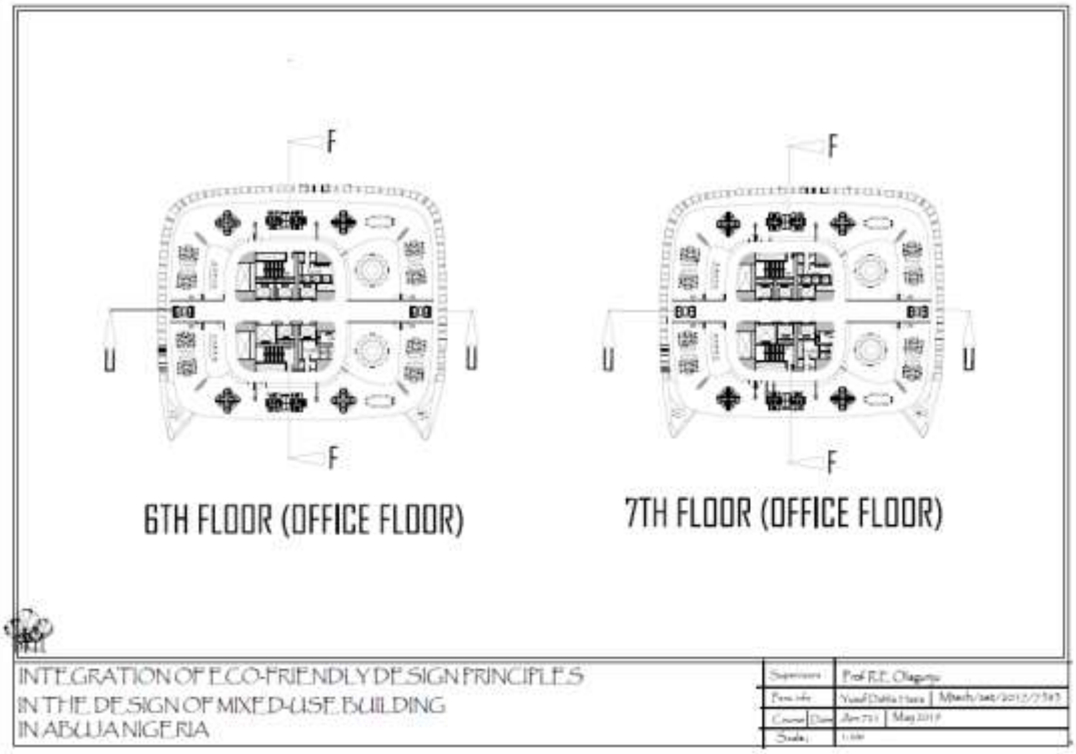
Appendix F: Third floor



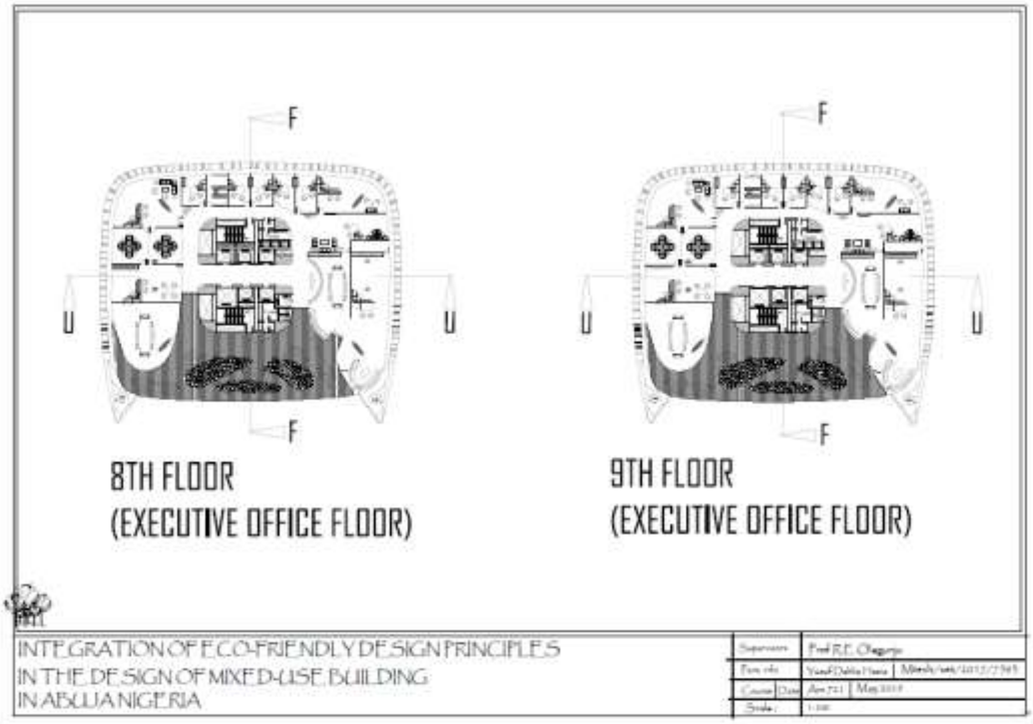
Appendix G: Fourth and Fifth floor



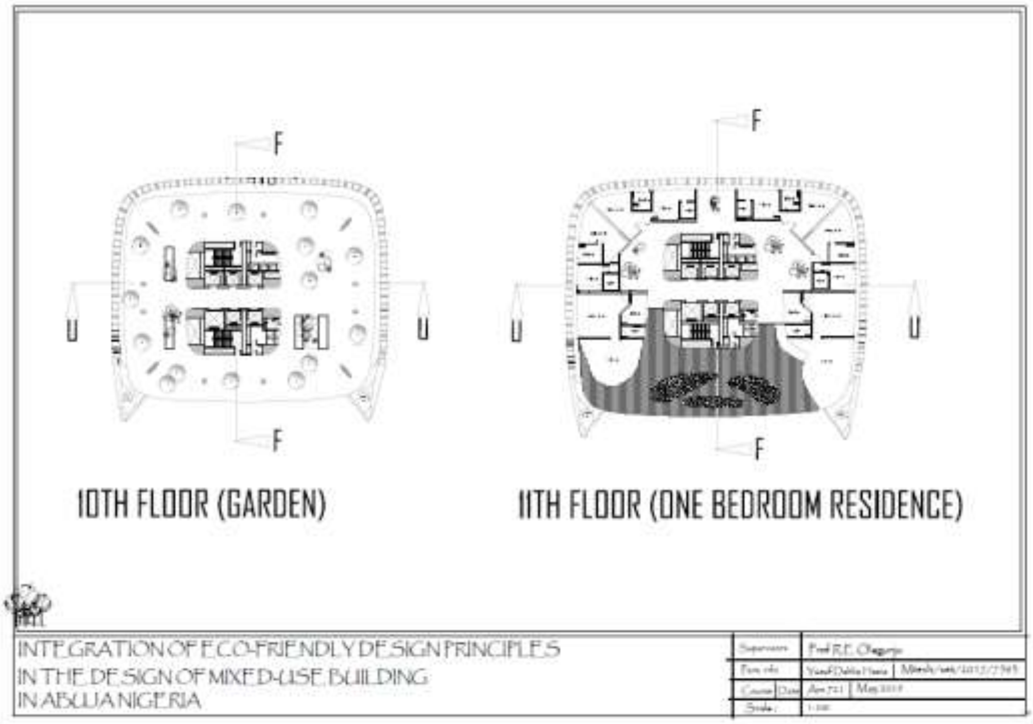
Appendix H: Sixth and Seventh floor



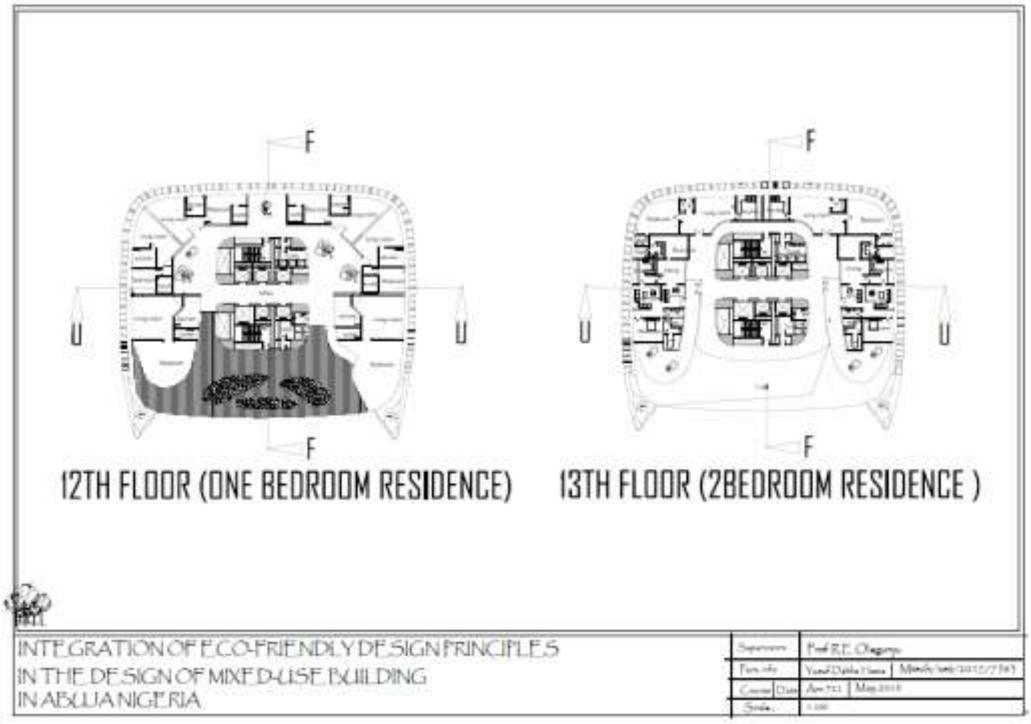
Appendix I: Eight and Ninth floor



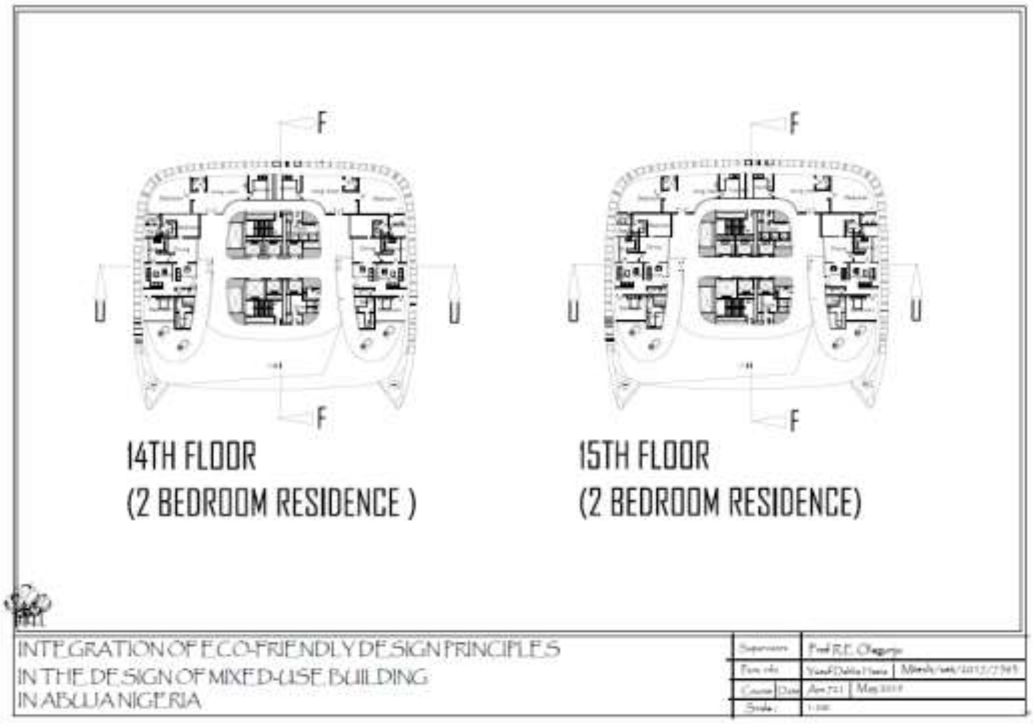
Appendix J: Tenth and Eleventh floor



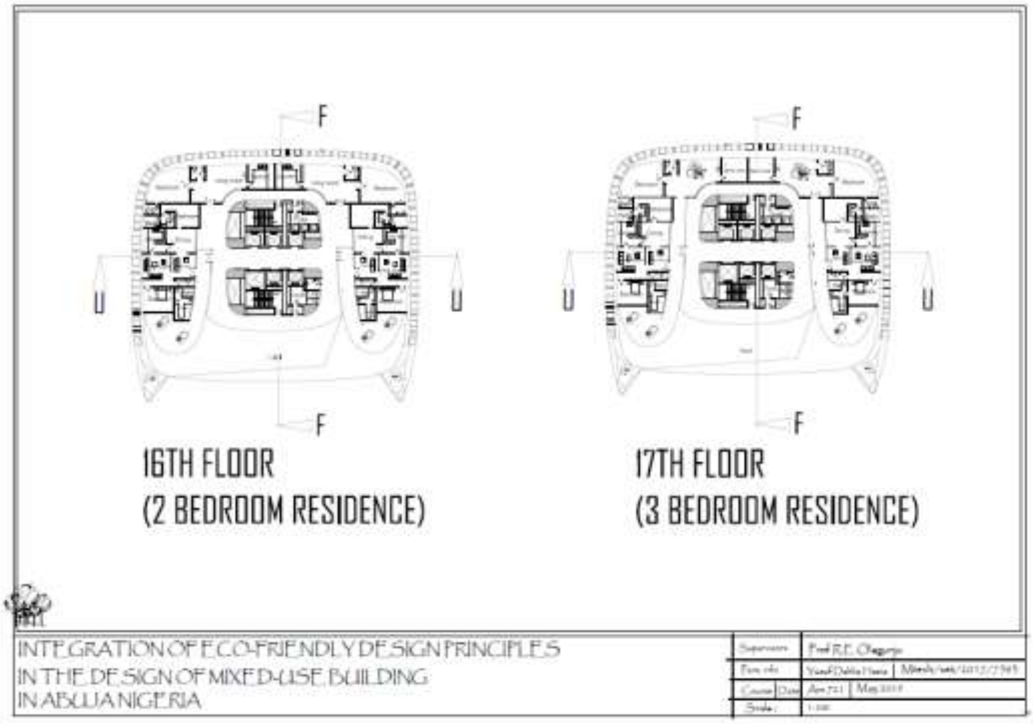
Appendix K: Twelfth and Thirteenth floor



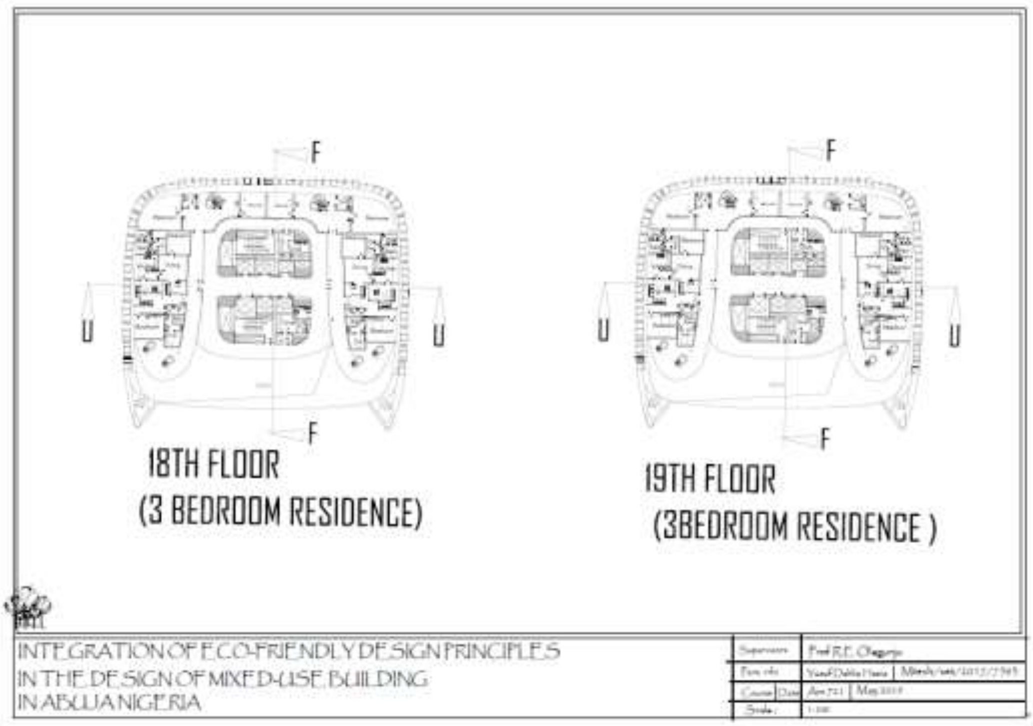
Appendix L: Fourteenth and Fifteenth floor



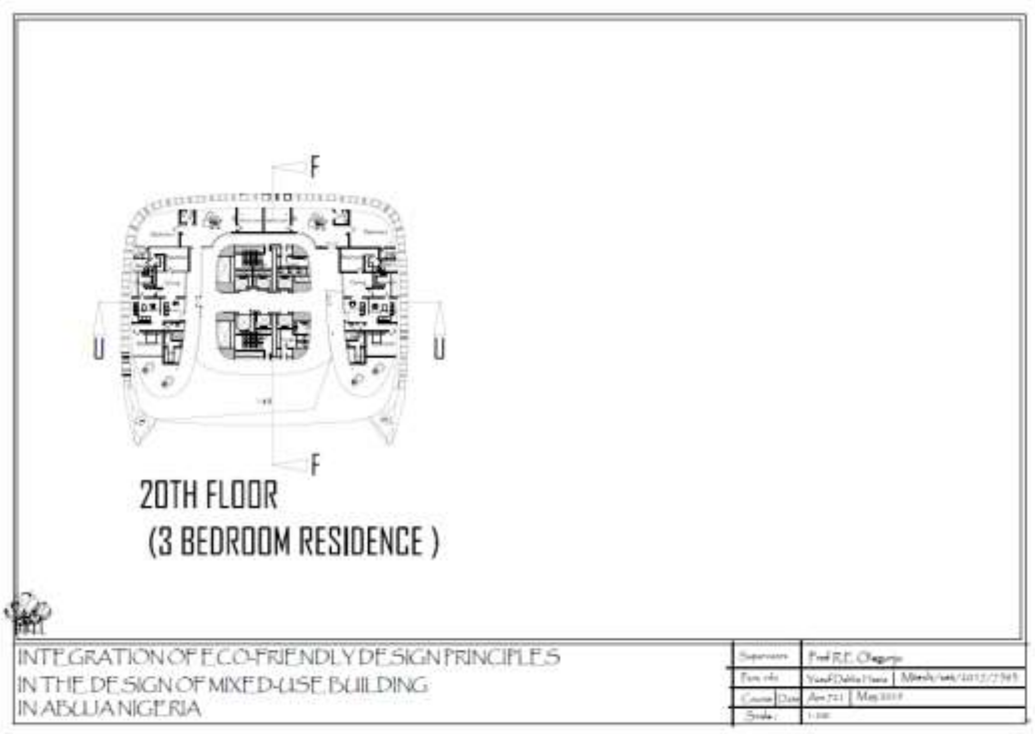
Appendix M: Sixteenth and Seventeen Floor



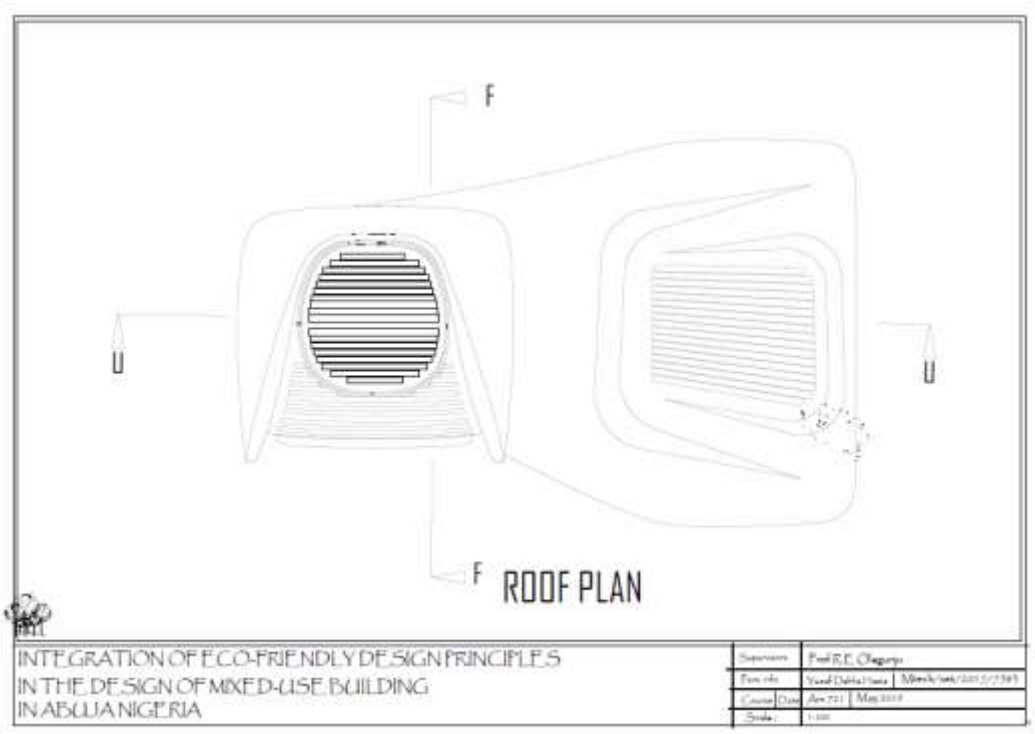
Appendix N: Eighteenth and Nineteenth Floor



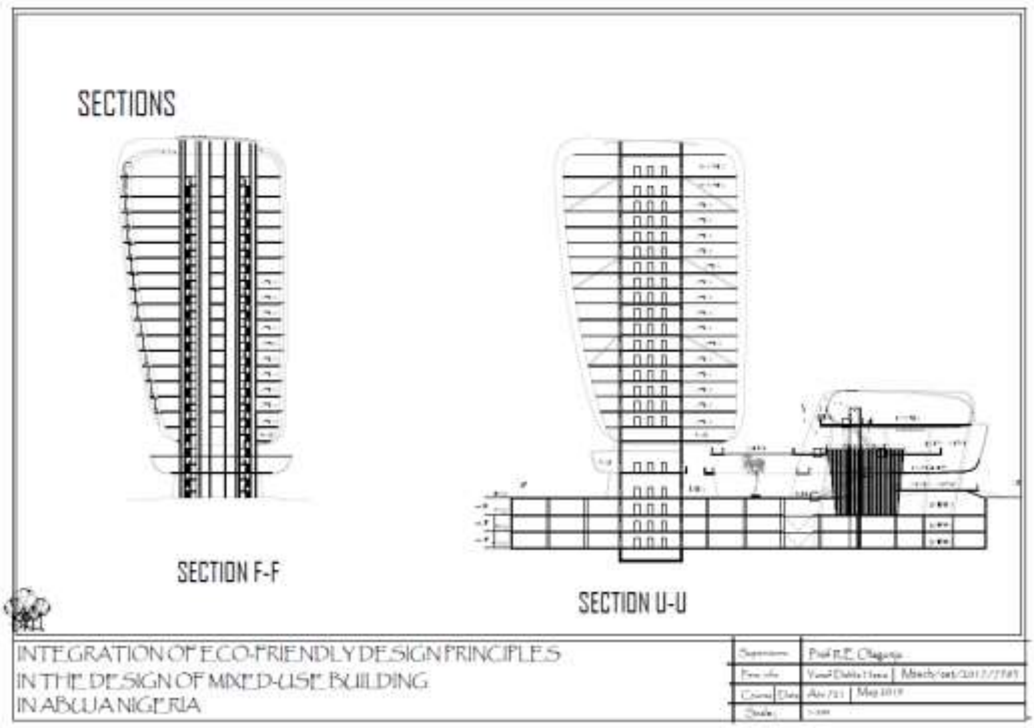
Appendix O: Twentieth Floor



Appendix P: Roof Plan

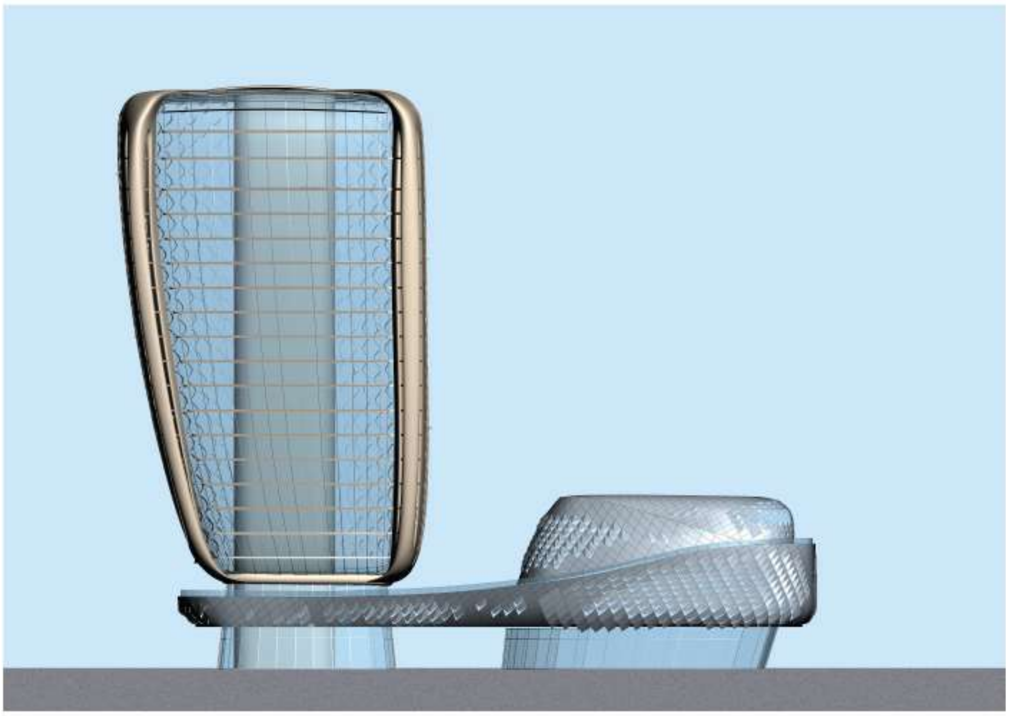


Appendix Q: Sections



Appendix R: Approach Elevation

south elevation



Appendix S: Right Side Elevation

Appendix T: Left Side Elevation

Appendix U: 3-d view

Appendix V: Interior view