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A Sustainable Mixed-Use Vertical Development with emphasis on energy efficiency and minimised carbon emission Ahmadu Bello Way Lagos

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Abstract
The population of Lagos is on regular increase which is estimated to cross 30 million marks by 2030 according to National population commission statistics. This would increase the demand for built environment meeting sustainable Development goal 11 (Sustainable cities) in line with International Union of Architects (Uia) 2050 vision to actualize Architectural projects that are Carbon-free and low energy thus leading to the choice of the Research topic A sustainable mixed-use vertical with emphasis on minimising carbon emission and energy efficiency as a means to having a built environment that contribute positively to climate change. This would be achieved by adopting design strategies, use of energy efficient technologies and Hybrid renewable energy sources which comprises of Hydro water generation using water body close to the site, solar energy generation and biofuel sourced from biodigester installed in the septic tank. The Hybrid energy generation is expected to contribute to not less than 70% of the energy need of the facility in addition to other design means, energy efficient technologies that will enable the project to be low energy thereby emitting less carbon dioxide. The literature review further discussed notable scholarly articles, publications, journals, Architectural research on the research topic revealing information on strategies to low energy and minimising carbon emission in consideration of Leadership in Energy Environment and Design (LEED) designs and materials standards, and recognised sustainable building materials. The research methodology adopted in carrying out this research is case study research methodology and comparative research analysis method because of their proven effectiveness in Architectural Research. the research contain design analysis carried out on case studies, these case studies revealed that Mixed use vertical developments require much energy and adopts nonrenewable energy means to meet their energy needs for optimum functionality, thereby releasing much carbon dioxide into the environment. The carbon dioxide released into the atmosphere results in ozone layer depletion by contributing negatively to climate change and human well-being. These challenges were further taken into consideration in addressing the design challenges and were greatly considered in arriving at a design solution to enhance the optimum function of this project design and ensuring it meets vision 2050 of International Union of Architect of an energy efficient and less carbon emitting building projects. This is also in agreement with SDG 11 goal of sustainable cities and contributing positively to climate in addition to human well-being. The design project thus goes further to improving on the planet as a livable built environment while ensuring that the project design gives high-performance leverage to its users and guaranteed return on investment to investors.
Keywords: climate change, energy efficiency, mixed-use, sustainable architecture

1. Introduction

The Urban Land Institutes Mixed-Use Development (MUD) handbook characterizes mixed use development as one that (1) provides three or more significant revenue-producing uses (such as retail/entertainment, office, residential, hotel, and/or civic/cultural/recreation), (2) fosters integration, density, and compatibility of land uses, and (3) creates a walkable community with uninterrupted pedestrian connections. The city core is often where these kinds of construction projects are located. Residents will be able to continue living close to their places of employment and leisure (Schwanke, 2003). Mixed

use development is of two classifications which are mixed use development vertical and mixed-use development horizontal according to the council on tall buildings and urban habitat (CTBUH, 2008).

The council on tall buildings and urban habitat CTBUH defines mixed use tower or development as a tall building that contains two or more functions, it simply a space that accommodate live work-play in one place (CTBUH, 2008).

Sustainable Architecture is environmentally conscious, energy savings and utilises responsive and renewable materials and system. (Newman, 2001). A mixed-use vertical development that is sustainable is expected to accommodate a community of individuals in different activity spaces which involve live, work and play but have to adopt a renewable means of energy and environmental conscious by not polluting the environment with carbon dioxide thereby contributing positively to climate change by ensuring that design strategies that will enhance energy efficiency and minimise carbon emission are adopted.

1.1 Statement of the problem

Lagos population is on regular increase which is estimated to cross 300 million marks by 2030 according to national population commission statistics. Also, it's been estimated that Lagos state will have to spend billions of dollars to combat climate change impact as a result of carbon emissions regarded as greenhouse gases (GHGs) and its energy utilisation by the year 2050, this design project seeks to adopt measures to help mitigate climate change within the project location and thereby ensuring that the project contribute to enhancing the local climate of Ahmadu Bello way, Lagos with focus on energy efficiency and minimising carbon emission thereby meeting up with International Union of Architects 2050 vision for Architectural projects globally.

I. AIM OF THE STUDY

The Aim of this Study is to design a Green and Sustainable Mixed-Use vertical Development in Ahmadu Bellow Way, Lagos with emphasis on energy efficiency and minimising carbon emission as a means to contributing positively to climate change.

1.2 Objectives of the Study

The objectives of the Study;

i. To determine how to improve on the energy efficiency of a mixed-use Vertical development.
ii. To examine sustainable Architectural elements that aid in minimising carbon emission in a mixed-use vertical development.

1.3 Research Questions

i. How can the energy efficiency of a mixed-use vertical development be enhanced?
ii. What are those sustainable architectural elements that contribute to less emission of carbon di oxide in a mixed-use vertical development?

1.4 Scope of the Study

This study focused on Energy Efficiency and Minimising Carbon Emissions (GHGs) which is part of UN global goal through Sustainable Development Goals and other international environmental organisations like LEED which would also be considered in this Design Project. This Research would go further to adopt proven energy efficiency and various methods on minimising carbon emissions (GHGs) in this Architectural design thereby putting this Research work in line with SDGs goals and LEED criteria for Green and Sustainable Architectural work with emphasis on SDGs goal 11 (sustainable cities and communities). It will adopt Sustainable Architectural feature recognised globally will enhance the quality of life, the economy, sociocultural growth and improve on the users of this facility and on the environment. The energy efficiency mechanism and proven methods on minimising carbon emissions which would promote sustainable cities and communities which is SDGs goal 11 will evoke striking aesthetic that embodies both functionality and progressive design. It's expected to meet the need of its environs and Lagos state with international standard and local content consideration.

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1.5 Significance Of The Study

A reconnaissance enquires backed up with data shown that a lot of potential could be harnessed in Ahmadu Bello Way, Lagos. and also, with the growing dense population of Lagos state giving opportunities for developments of new layout. This Architectural solution will employ Sustainable and Environmental responsive measures that would help in transforming Ahmadu Bello Way, and its environs to a world class modern settlement.

2. Literature Review

2.1 Mixed-Use Development as a Concept

Mixed Use Development combines multiple uses into a single building, often placing more public uses (like retail) at or close to ground level, with more private uses or spaces (like housing or offices) higher up. Mixed-Use development promotes inclusive and resilient neighborhoods by enabling an interactive environment for the public and private sectors through a participative planning process. Development projects may be classified as "mixed-use" if they provide more than one use or purpose within a shared building or development area. Mixed-use projects may include any combination of housing, office, retail, medical, recreational, commercial or industrial components. These projects might vary in scale from a single building occupied by a retail shop on the ground floor with an upstairs apartment to a comprehensive "urban village" development with multiple buildings containing separate but compatible uses such as a retail center, office building and medical clinic located adjacent to a multi-family housing complex. Mixed-use development thrived into the twentieth century majorly at transit centers and intersection (Artscape, 2013).

2.2 Benefits Of Mixed-Use Development Vertical

i) The benefits are so numerous which accounts for good return on its investments and causes it to stand out within its environment.

ii) Mixed use vertical Combines non-similar uses within the same space thereby enabling easy accessibility of verities of activities to its occupants.

iii) It's design generally gives commercial spaces lower floor such as retail outlets, restaurants, other commercial spaces for business in an organised manner thereby enhancing order and proper organisation of functional areas

iv) Due to its proximity of spaces, it enables the distances to be workable thereby enabling its occupants to spend less on transportation and more to those that work and live within the mixed-use facility. Furthermore, as a result of mixing of activities that generate revenue within the same space i.e. self-sufficiency, it has resulted in greater economic viability of the entire facility thereby increasing returns on the investment of the project. (clued from CTBUH, 2008).

Harnessing Ahmadu Bello way as a good location for Mixed Use Vertical Development

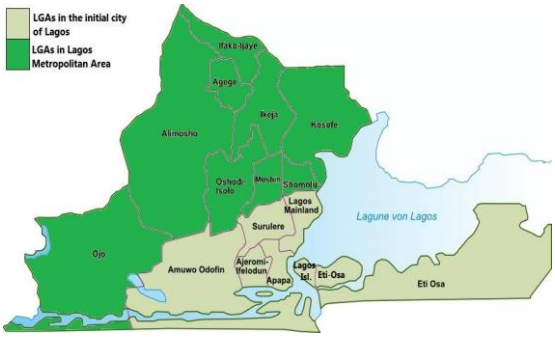


Figure 1 Map of Lagos,
Source: *landsbureau.lagosstate.gov.ng*, *2024*

Ahmadu Bello Way, Lagos

In doing this Research the field survey alongside unstructured interviews and few online information revealed that Ahmadu Bello way is a commercial neighborhood in Victoria Island. it accommodates the affluence and thriving businesses, companies such as: Nigerian Security Printing and Minting PLC, Urban Development Bank of Nigeria PLC, Mansard Insurance PLC, the Infrastructure Bank PLC, Ecobank, Old Mutual Nigeria Life Assurance, Qatar Airways Lagos, Schools in this street include National Open University of Nigeria, Federal palace hotel, Silver Bird Cinema, Eko Atlantic City etc.

Land Use

The land use around the proposed site for the mixed-use vertical development support development of high-rise projects and as such made it a good location to be used for the proposed project. The proposed site is flanked by major buildings such as Eko Atlantic city project, MRS Petro station, Nigerian Navy dockyard, other organisations that will serve as support facility to this proposed project.

Traffic

In general, Ahmadu Bello road is a high traffic zone that suggested for the location of this project in a city block for easy accessibility and as a major criterion for choice of site for mixed use development the site is bounded by roads on three sides. The Chevron Road and MRS Road on the left and right-side help to check traffic within the site location area (field survey, 2024)

Modern Mixed-Use Development Vertical

Nigeria, as a nation is experiencing a transformative shift in its urban landscape. Incessant population growth, urbanisation, and changing lifestyles, have led to a more efficient and effective solution to its urban development. This demand has led to the emergence of Mixed-Use Development in this context high rise as a prominent feature in Nigerian cities.

As the need for urban spaces continue to increase, mix use developments are set to play a good part in ensuring an organised city. Furthermore, it is important that these projects are developed with careful consideration for local contexts, community needs, sustainable practices.

Components found in mixed-use vertical development

Mixed use development is a modern Architectural move to solving urbanisation related issues. It accommodates different facilities in one building. These facilities or activity areas are chosen based on local contents or need, national or regional preferences and to a good extent on the Architect(s) perspectives.

This design project considered many factors in the choice of its different components. These are carefully chosen so as to enable the project to be able to meet its expected aim, environmental needs of its investors and thereby meeting up with its expected end use.

Nigerian factor in Mixed-Use Development

However, the inclusion of culture and institution perspectives is employed in international development application (UN, 2014). Equally, cultural values are found to stimulate the development of a healthier environment and are usually considered as a dimension for sustainable development (Artscape, 2013). Accordingly, as cities grow distance between workplace and residence diminishes (Beckman, 2013) which infers propensity of cultural trait influences developmental process and growth of a city.

Nigerian Architecture in perception of space in mixing of activity spaces in Mixed-Use Vertical development

The phycology of Nigerians affects their taste, priority, choices which is owing to culture, level of exposure and enlightenment. This go a long way in influencing development of which is considered in this design project. However, this research project is not entirely built to retard development but to enhance development and as such would put into considerations the psychology of Nigerians, use of local design strategies and building materials that are sustainable and green alongside with current realities of our modern society, and adopting sustainable high-performance technology for this project.

Mixed use development vertical as the name suggest comprise of different activity spaces all in one building. It's interesting to know that an average Nigerian perceive spaces been mixed as appropriate owing to cultural preferences while some certain spaces are perceived as alien or in appropriate although obtainable in other countries. These and more served as a guide in the choice of spaces to be mixed in a vertical mixed-use development although its worthy to note that these perceived barrier in the heart of average Nigerians were carefully considered and led to a better holistic choice that meets international criteria and standards for a vertical mixed-use development. In consideration of the above, the following spaces were arrived for a vertical mixed-use development

in Ahmadu Bello Way, Lagos which comprises of three main components which are;

1. **Work Area**
   a) Modern partitionable office spaces
   b) Office suite
   c) Studio office
   d) Mini mall
   e) Retail outlets
   f) Daycare
   g) Spa
   h) Multipurpose hall

2. **Live Area Residential Unit**
   a) Three bedrooms apartment
   b) Two bedrooms apartment

3. **Service Apartments**
   a) One-bedroom apartment
   b) Full option self-contained

4. **Play Area**
   a) Local and intercontinental hotel
   b) Cinema
   c) Outdoor recreational area
   d) Support facilities or onsite facilities such as
   i. Hybrid renewable energy center
   ii. Waste recycling center
   iii. Fully automated Multistory car park through hybrid renewable energy sources
   iv. Electric car charging station
   v. Fully automated car wash center through hybrid renewable energy sources
   vi. Facility management office

Climate Change

The recent Global climatic data and variation in climatic conditions, have shown that going by current environmental conditions, if not checkmated can lead to much flooding which is consequences of global warming in addition to other destructive environmental hazards. Lagos is among such areas to experience such environmental menace which is a major reason that this research project will address with design driven solutions. It's been estimated that Lagos state will have to spend billions of dollars to combat climate change impact as a result of carbon emissions regarded as greenhouse gases (GHGs) and its energy utilisation by the year 2050. In the light of contributing to solving this climate challenge and to improve on the terrain of Ahmadu Bello Way and Lago state led to choice of vision 2050 of International Union of Architects as subtopic of this research work in other to achieve low energy and minimise carbon emissions in architectural projects by giving this project a global edge as agent of combating climate change.

Sustainable Architecture as solution to Climate change

Sustainable Architecture is environmentally conscious, energy savings and utilises responsive and renewable materials and system. (Newman, 2001). It goes further to put into considerations the local and global environment. Sustainable building design begins right from the initial pre-design meetings with the client, case studies of similar projects with sustainable features, and definition of initial goals for the performance of the sustainable building throughout the design process (Brunzet al., 2011) The major concerns of the proponents of sustainable architecture are; reduction in global carbon emission and reduction in energy consumed by building occupants, coupled with the fact that Climate change and diminution of natural resources are the major tasks that we have had to confront in the 21st century (UN-Habitat, 2014) Sustainable Architecture means putting environmental factors into consideration, it's Architecture that encourages minimal negative environmental influence of buildings by facilitating the use of sustainable and green designs and Architectural solutions. It goes further to ensure that the ecosystem is not disrupted or endangered by wrong Architectural approach thereby preserving the planet. This Architectural approach encourages reduction in waste and cost of building operation. Sustainable Architecture is anchored on three main pillars of people, planet and profit. Its target is to create buildings that priories human comfort and health, minimise

environmental impact, and ensure long- term financial sustainability. Sustainable architecture seeks to ensure that the planet is preserved from harmful climate change impact that leads to global warming caused by ozone layer depletion. It could be deduced from information gotten from different scholars above that Sustainable Architecture goes further to encourage adoption and considerations of various Architectural natural influences while still embracing human needs and their peculiarities, distinctions and variations. It supports the use of passive design strategies which are based on site climate and are regarded as environmentally friendly.

sustainable Architecture contribution to human well being

Sustainable architecture benefits well-being by improving physical health (air quality, comfort), mental health (connection to nature, stress reduction), and social health (community engagement, sense of ownership) while also promoting planetary health through eco-friendly design, resource efficiency, and climate-conscious planning. Key strategies include incorporating biophilic design and climate-responsive features to create healthier, more comfortable environments that reduce negative environmental impacts.

How Sustainable Architecture Benefits Individual Well-being

Improved Indoor Environment:

Sustainable buildings prioritise fresh air through better ventilation and use non-toxic, low-VOC (volatile organic compound) materials to improve indoor air quality, reducing pollutants like mold and formaldehyde.

Biophilic Design:

Integrating natural elements such as plants, natural textures, and views of nature into the built environment enhances mental restoration, promotes positive mood states, and can reduce stress and anxiety.

Natural Light and Ventilation:

Maximising natural daylight and ventilation reduces reliance on artificial light and improves air quality, positively impacting vision, mood, and overall health.

Comfort and Productivity:

These design strategies lead to more comfortable and stimulating indoor environments, which are linked to increased productivity, concentration, and well-being.

Conceptual Framework of Wellness Centers

A wellness center is a facility designed to promote the overall health and well-being of individuals. These centers usually provide a range of services and facilities including fitness centers, yoga and meditation studios, spas, and nutrition counseling. The goal of a wellness center is to provide a holistic approach to health and wellness, addressing not only physical health but also mental and emotional well-being. Well ness centers exist as stand-alone facility and can also be incorporated into an activity area or facilities such as hospitals, school, corporations, etc. its main aim is to ensure overall well-being and not just treatment of an ailment. İts worthy to note that sustainable architecture encourages human well being by adopting designs that improve physical health, mental health, social health and ensuring environmental health.

Landscape Architecture and Student Well-Being

Landscape architecture involves the planning, design, management, and nurturing of the natural and built environments (IOWA state University). Landscape architecture is an aspect of sustainable architecture that encourages human well being by extension that of students, and is a necessity within campus environment to encourage community and communal living among students as a means to bonding within an environment that is sustainable and nurturing thereby helping them to be relieve of different stress students face. students frequently suffer from mental health challenges such as stress, depression, and anxiety during their studies. It is therefore crucial to offer spaces and landscapes on the university campus that offer mental restoration and promote well-being, given the substantial time spent there.

Nigerian factors in relation to Green and Sustainable Architecture

Its worthy to note that majority of Nigerian Architecture adopts active design approach which requires much energy consumption through nonrenewable sources thereby generating much greenhouse gases (GHGs) including carbon di oxide. These gases have constituted nuisances to human health, the ozone layer leading to ozone layer depletion and global warming that have caused much harm globally and the planet entirely. It's expected that this research will adopt passive means to help regulate and bring to minimum negative impact on the ozone layer thereby ensuring that harmful effect of climate change is brought to a controlled measure thereby ensuring that the earth is more habitable thereby fostering more sustained economic growth and development giving opportunities to modern investment strategies considering local context meeting international standards and preferences while adopting modern technologies that are sustainable to ensure improved high performance results. In this context active design strategies refers to those designs that consumes much energy and produces much carbon di oxide while passive design strategies refer to the ones that incorporate energy efficiency and minimising carbon emission which is a major consideration in carrying out this research work in this case on Vertical mixed-use development. The active design strategies adopted in design of building in Nigeria include;

- Dependency on national electric grid
- Use of generators that uses fossil fuels as alternative power generation
- Little or no consideration on cross ventilation and other passive cooling means
- Little or no softscape with majority of landscape been hardscape

Global criteria adopted in justifying Green and Sustainable standards Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development as adopted by all countries under United Nations members in 2015, planned a 17 world Sustainable Development Goals (SDGs), with its aim on how to ensure there is peace and prosperity for people and the planet as climate change and its related issues are been managed while preserving the ecosystem.

Leadership in Energy and Environmental Design (LEED)

LEED is among the top current green building rating system globally; it's focused on environmental sustainability and preserving earth planet. Its globally recognised because of its proven sustainable researches and affiliations with different organisations and professional individual contributions.

Synergies between LEED and SDGs Adopted in this Study

The Sustainable_Development_Goals (SDGs) is actionable and requires a contributive and collaborative efforts involving the government, organisations, citizens etc. so as to achieve a sustainable environment in the earth planet thereby making peace and prosperity of humans and the environment a reality. In the light of this, the LEED and SDGs collaborative synergies will be adopted as a tool to achieving a modern green and sustainable mixed-use project.

LEED categories can greatly help in realising the SDGs, not only by saving water, increasing energy efficiency, minimising of carbon emissions (GHGs) and significantly reducing harmful air pollutants, etc. but also by promoting Designs and Architectural solutions that will enable these synergies to be a reality through proven Green and sustainable building practices as strategies for achieving the UN SDGs.

LEED for cities and communities' criteria points share similarities with SDGs 11 goal which will be adopted in this Project study considering the following;

i) Provide access to green space, as adopted in this study gardens and green areas to help check pollution, minimise carbon emissions (GHGs).

ii) Ensure Energy efficiency and use of clean and green energy source of energy generation and thereby ensuring that energy is sourced within the building location.

iii) Prepare for weather related risk and seek for means to mitigate climate change in the design of this project.

Energy Efficient and Minimising Carbon Emission strategies

Energy efficiency simply means using less energy to perform the same task- that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. (EESI, 2024). Energy efficient high-rise Mixed-use development building provide a good environment for people to live, work and play effectively without the project and human activities been carried out consuming much energy and possibly using sustainable and green means to generate energy as well as reducing the impact on its environment. The ozone layer depletion is as a result of constant pollution which is as a result of energy generation. It's needful to consider energy conservation methods through a housing lifecycle so as to improve on its sustainability. Energy efficient products and design techniques.

It has been estimated that Lagos state will have to spend billions of dollars to combat climate change impact as a result of carbon emissions (GHGs) by the year 2050, this design project seeks to adopt measures to help mitigate this waste and will require sustainable means to actualise it.

Minimising carbon emission requires that buildings are carbon neutral by ensuring that no more energy over the course of a year than they produce, or import, from renewable energy sources. It should be noted that in attaining energy efficiency in an architectural project carbon emission is minimised, this reveals that there is direct relationship between low energy or energy efficient design and minimising carbon emission. This is further explained in Table 1

Table 1 showing passive design mechanism to energy efficiency and minimise carbon emission

S/N	Passive design that enhances Energy Efficiency	Passive design that leads to reduction in carbon emission
1	Introduction of courtyard	Introduction of courtyard
2	Achieving passive cooling through building orientation.	Proper building orientation reduces energy consumption thereby reducing the need for fossil that leads to carbon emission
3	use of cross ventilation to enable daylight and ventilation.	cross ventilation and daylight is natural means with less dependency on power that generate carbon emission.
4	Use of sustainable local building materials to reduce energy spent in transportation.	Use of sustainable building materials that emit less carbon.
5	Extensive use of vegetation in form of plants, green walls etc. to enhance natural cooling	Use of vegetations that will take in carbon dioxide thereby balancing the ecosystem.
6	Use of prefabricated and recyclable materials to minimise waste of energy and resources.	Use of sustainable and recyclable materials that emit less carbon
7	Use of sustainable materials that need less maintenance which will require less operational energy.	Use of sustainable materials consuming less energy for maintenance resulting in less carbon emission.
8	Use of more than one or hybrid renewable energy sources.	Renewable energy leads to reduction in carbon emissions
9	Use of shading devices that enhance natural cooling	Use of trees and green as shading devices which convert carbon released into the atmosphere into useful purpose

Source; Author's conception

Energy Efficient Strategies recommended using passive design

Hybrid renewable means to energy generation means using more than one renewable energy source as means to generate electricity. In modern day world, it is highly sought after owing to its effectiveness and efficiency, this is in current demand for vertical mixed use or high-rise buildings owing to their much energy need to ensure their optimum performance.

Minimising carbon emission strategies recommended using passive design

Energy efficient and minimising carbon emission strategies recommended using smart technology

Smart technology that are sustainable and emits less carbon emission with low energy are greatly of high importance in order to enable a vertical mixed-use development attain its high performance while greatly meeting the needs of its users alongside ensuring a return on investment to investors will need a sustainable technology support. The following are few sustainable technologies support;

- Fully automated multistory car park
- Electric car charging station

3. Methodology

This study adopted case study research method as its primary source of information due to its proven effectiveness in in solving design problems associated with Architectural Research. This type of study focusses on similar building typologies as guide to arriving at a s design solution of a proposed scheme. It ensures that a guided creative approach to design and its application is embraced in a design. A case study may use a variety of data sources, including observations, interviews, and documents. Case study research aims to produce new ideas or insights as well as a thorough and nuanced grasp of the case subject (Coombs, 2022).

3.1 Research Design

This research project adopted case study research design. Case study research is a type of research in which a researcher uses qualitative research means for the broad purpose of data documentation and analysis for the research topic so as to arrive at appropriate design solution and finally using computer aided simulation approach to enhance and present the design project.

3.2 Study Area

The study area is Ahmadu Bello Way, Lagos and was chosen because of the following reasons:

Ahmadu Bello way is a commercial neighborhood in Victoria Island that accommodates the affluence and thriving businesses. The study proved that there are facilities which are lacking in the neighborhood of which this design project incorporated in the design such as accommodation for students of Nigerian Open university located in Ahmadu Bello way in addition to commercial space that accommodate made in Nigerian goods to improve on the socioeconomic of the location and contribute greatly to Nigerian economy.

i. Nearness to water body that will be used for hydropower generation.
ii. The land use supports the development of mixed-use vertical.
iii. It's located within the city block thereby allowing easy access from different locations
iv. As a means to curb traffic in Ahmadu Bello Way Road

3.3 Population and Sampling

This study is undertaken as a prerequisite to meet the requirement for masters in Architecture in Rivers state university in addition to the main dissertation and as such adopted the academic standard of the school that stipulate not less than five case studies for Master's in Architecture which include local and international case studies.

3.4 Data collection methods

Data collection for this study adopted two sources: primary and secondary sources of data collection. The primary data collection was gathered from observations, case studies carried out at No. 4 Bourdillon Lagos which served as a local case study in addition to visit to the company that designed it; ELALAN Nig Ltd a

company involved in the design and construction of High-rise buildings. also unstructured interviews conducted during the case study visit and within the neighborhood of Ahmadu Bello Way, Lagos, which gave firsthand information on the topic and subtopic. The secondary data were obtained from international case studies, published researches and other literature.

3.5 Research Instruments

The research instruments adopted in this study include the following :

i. Visual observation caried out during case study visits.

ii. Checklists used to asses information for the project design from offline and online sources

iii. Unstructured interview during site visits and telephone interview

iv. Surveys from online sources

3.6 Data Analysis Techniques

The data analysis technique that was adopted in this design project is Comparative research analysis; this type of analysis uses the information provided in the literature reviews, case studies and analyses them to arrive at design solution to meets the design objectives, elaborate results to solving the design challenges and achieving the design goal.

3.7 Limitations of Methodology

İn carrying out this research few limitations where encourtered although alternative measures were adopted so as to gain relevant facts that will aid in achieving the design goal. The limitations inculde inability ro communicate with the facility users appropirately and to capture real life pictures due to security reasons. Alternative measures adopteded include visit to ELALAN Nig Ltd that designed 4 Bourdlion with engaged interactive session using unstructured interviews and checklist, in adddtion to online pictures.

CASE STUDIES

Case Study One: Oasia Mixed-Use High-Rise Building Singapore

DESIGNED BY: WOHA,
Location: 100 Peck Seah Street, Singapore Central Business District
PROJECT YEAR: 2012-2016
Height: 193.3m
Floor Area: 250sqm
NUMBER OF FLOORS: 27
Site Area: 2.5 hectares

Figure 2 Oasia Mixed Use High Rise Building Singapore

Source: www.archdaily.com 2016

A. Building Features

i. The building skeletal system was designed in grid form with exterior gladding to cover it mimicking natural ecosystem.

ii. A good part of the building atrium is communal cultivate green area all through the building.

The building which accommodates 314 rooms of hotel spaces and offices was given the award as best tall buildings award in by the Council on Tall Buildings and Urban Habitat (CTBUH) in 2018

Figure 3 Oasia Mixed Use High Rise Building Singapore,

Source: www.archdaily.com 2016

Other Features

i. 21 different plants were used on the faces, green walls were used on the building exterior
ii. 13 Lifts/elevators
iii. Gardens that were open to the sky were used all through the building to enable natural ventilation without air condition.
iv. Artificial water bodies to enhance passive cooling

Green and Sustainable Features (Energy Efficiency and Carbon Emission strategies)

The building adopted modern sustainable and green features in other to mitigate the energy bills and minimise carbon emissions through the following:

i. Use of frame like features that can allow exterior façade to be embed in it and which can be adjusted as the building continue to function.
ii. About 40 percent of the building's volume consists of communal green space elevated vertically into the skyscraper.
iii. Use of climbing plants, sky gardens among different gardens to minimise carbon emissions (GHGs).
iv. No mechanical ventilation due to various energy efficiency method adopted such as artificial water bodies, different form of gardens, green external facades etc.

B. Appraisal / Deductions

i. Green walls were used on the building exterior
ii. Gardens that were open to the sky were used all through the building to enable natural ventilation without air condition.
iii. Courtyard and Artificial water bodies to enhance passive cooling

C. Intervention / Project Shortcomings

As development continue to spring up within this urban area and on this project, the use of multistory car parking facility is recommended for this facility and an alternative renewable energy source.

Case Study Two: No. 4 Bourdillon, Bourdillon Road, Ikoyi, Lagos

Designed and constructed by: ELALAN NIG Ltd
Location : Lagos Nig
Project year : 2018
Number of floors : 25

Figure 4 No. 4 Bourdillon, Bourdillon Road, Ikoyi, Lagos
Source: www.4bourdillon.com 2019

A. Building Features

mainly residential apartments of 41 units which comprise of 3 bed apartments, 4 bed apartments and 4-bed duplex apartment and 4 bed penthouse apartments

i. tennis court, GYM, leisure, entertainment spots and outdoor children area
ii. children swimming pool and adults swimming pool
iii. multipurpose club room
iv. underground parking and Gate house

Other Features

i. Decorative water features and Gardens for cultivation
ii. Innovative building designs that adopt environmental passive strategies such as natural daylighting and cross ventilation, Gardens for cultivation
iii. Use of pile foundation
iv. Modern Lifts for service and goods
v. Outside parking for visitors

Green and Sustainable Features (Energy Efficiency and Carbon Emission strategises)

This modern mixed-use development vertical adopted few sustainable and green

architecture that enhanced the functionality and aesthetics of this architectural means which include:

i. Gardens and aesthetic pleasing landscaping within the site to minimise carbon emissions.
ii. Ensuring that each residential space with office have a wraparound balcony and Decorative water features to enhance passive cooling
iii. Outdoor and recreational facilities
iv. Innovative building designs that adopt environmental passive strategies such as natural daylighting and cross ventilation thereby ensuring its energy efficient.

Figure 5 No. 4 Bourdillon landscape, Bourdillon Road, Ikoyi, Lagos

Source: www.4bourdillon.com 2019

B. Appraisal / Deductions

The following were adopted from the design:

i. Children swimming pool, adults swimming pool, Gym, Multipurpose club room
ii. Each residential space has wrap-around balconies
iii. Gate house
iv. Use of pile foundation
v. Gardens

Intervention / Project Shortcomings

In line with current architectural sustainable and green practices, a renewable energy source is highly recommended for this facility and also an alternative source of power generation that is effective and efficient, such as solar energy, biofuel powered generator to minimise carbon emission within the environment.

Case Study three: One Central Park, Sydney Australia

Designed and constructed by: Foster+partners

Location : Sydney Austrelia
Project year : 2014
Number of floors : 38

Figure 6 One Central Park, Sydney Australia

Source: www.archdaily.com *2016*

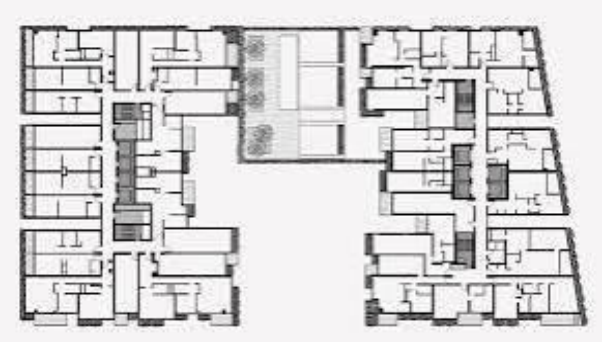


Figure 7 One Central Park floor plan, Sydney Australia

Source: www.archdaily.com *2016*

Building Features

i. Two residential towers
ii. Hotel, Office, Creche
iii. Six level shopping centers at the base
iv. vertical gardens, Gym

Green and Sustainable Features (Energy Efficiency and Carbon Emission strategies)

i. vertical gardens, over 35,000 plants, shrubs, vegetation
ii. minimising carbon emission in choice generator and use of wooden tiles.
iii. Maximising natural light and ventilation throughout.
iv. The tri-generation plant which helps in reducing the rate of carbon emissions to

a good level of about 200 kilotons over its useful life that help in heating and cooling provides heating, cooling.

v. It's a low carbon emitting way of generating electricity. The water recycling treatment function at a good level and generate portable water for the building entire usage. The presence of green roof that also assist in rain water collection and the building form helps in ensuring a nature and sustainable modern building standard is met.

Case Study Four: Capital Spring Tower, Singapore

Designed and constructed by: Big-Bjarke Ingels group and Cra-Carlo Ratti Associate
Project Location: 88 market street Singapore
Project year: 2022
Area: 9.3 hectares
Height: 280m
Number of floors: 51

Figure 8 Capital Spring Tower, Singapore
Source: www.archdaily.com *2024*

Sustainable features (energy efficiency and carbon emission strategies)

i. sky gardens or rooftop garden
ii. integrating open and green spaces throughout the building.

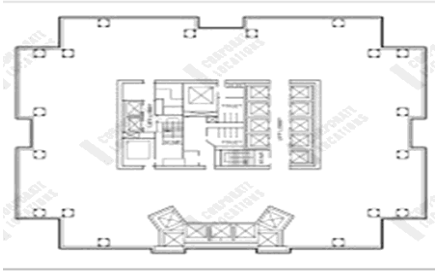


Figure 9 Capital Spring Towe floor plan, Singapore
Source: www.archdaily.com *2024*

Building features

1. premium office space on the 29th floor
2. a serviced residence on the first eight floors which include swimming pool, jacuzzi, exercise track, gym, communal kitchen, residence common room etc.
3. a hawker center
4. restaurants and public spaces
5. sky gardens or rooftop garden
6. the roof is converted to urban garden for cultivation of different species of fruits and vegetables, herbs, flowers for the food center, service residence.

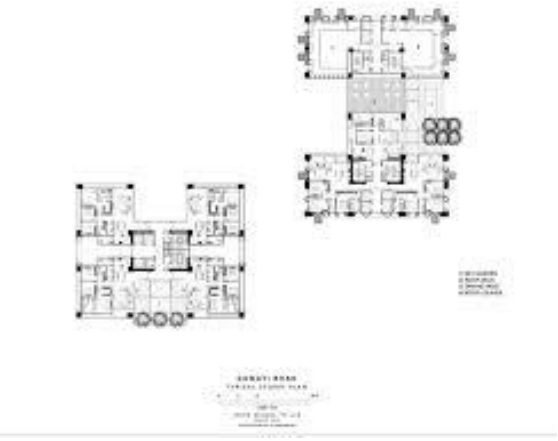
Case Study Five: Sky Green Mixed-Use Development

Designed by WOHA with Feng Chia University as an advisor
Project location- Gongyi road, Taichung City, Taiwan.
Project year- 2014-2019
Gross floor area- 6.1 hectares
Plot area: 4597sqm
Number of floors: 20

Figure 10 Sky Green Mixed-Use Development, Taiwan
Source: www.archdaily.com *2024*

Sustainable features (energy efficiency and carbon emission strategies)

- use of vegetation
- sky gardens at every interval of five (5) floors
- resilient to earthquakes and tycoon emergencies
- green facades serving as passive cooling strategy.



building features

I. restaurant/cafe/coffee room
II. office space
III. conference areas
IV. 8 restroom per floor
V. 10 premium residential apartments.
VI. helipad
VII. multistory parking space for over 225 cars on 18 slit levels

Table 2 showing case study deduction

SN	Case study	Location	Energy Efficiency approach adopted	Minimising Carbon Emission strategies adopted	Shortcomings	Recommendations
1	**Oasia Mixed-Use High-Rise Building**	100 Peck Seah Street, Singapore Central Business District	atrium with cultivate green area all through the building. Gardens that were open to the sky were used all through the building to enable natural ventilation without air condition. Arti use of energy efficient technologies	Several Gardens with greens were cultivated to absorb carbon dioxide. Green façade to absorb carbon dioxide	No renewable means to power generation. Need for multistory car park	the use of multistory car parking facility is recommended for this facility. an alternative renewable energy source.
2	**No. 4 Bourdillon**	Lagos, Nigeria	wraparound balcony to encourage natural daylighting and cross ventilation use of energy efficient technologies	Gardens and aesthetic pleasing landscaping within the site to minimise carbon emissions.	No sustainable means to power generation. Need for additional parking lots	Hybrid means of power generation. Multi story car park that is energy efficient is recommended

3	**One Central Park, Sydney Australia**	Sydney Australia	Maximising natural light and ventilation throughout to reduce consumption of energy. Use of energy efficient technologies	vertical gardens, over 35,000 plants, shrubs, vegetation to absorb carbon dioxide choice generator that emits less carbon dioxide and use of wooden tiles that emits less carbon dioxide.	No renewable source of energy Need for additional parking space	A sustainable means to energy generation is recommended. Energy efficient parking system is recommended that will not require much space
4	**Capitalspring Tower, Singapore**		Use of energy efficient technologies.	integrating open and green spaces throughout the building.	No renewable source of energy	
5	**sky green mixed-use development**		green facades serving as passive cooling strategy. Use of energy efficient technologies	sky gardens at every interval of five (5) floors	No renewable source of energy	

Source; Author's conception

4. Results and Discussion

Comparative Research Analysis using information gained from case studies deduction and literature review

Data analysis was carried out using comparative research analysis method to compare the various case studies carried out in addition to the literature reviews content information so as to incorporate the information gained in achieving a design solution that will enhance optimum performance of a sustainable vertical mixed-use development in Ahmadu bello way, Lagos with emphasis on energy efficiency and minimising carbon emission.

Research Objectives	Data collection method	Analytical techniques
To determine how to improve on the energy efficiency of this design proposal.	Use of hybrid means to generate energy from literature reviewed and suggestions from unstructured interviews conducted Use of courtyard as a passive cooling mechanism from Literature review and case studies	deduction from case study 1 and literature review in line with SDG 11 goal in line with LEED rating. Deduction from literature reviews, unstructured interviews from ELALAN Nig Ltd in line with SDG 11 goal and LEED criteria
To examine sustainable Architectural elements that aid in minimising carbon emission.	Use of locally made materials like bake bricks, stone etc. use of hydro power as a renewable energy source from Literature reviews, case studies and unstructured interviews	Deductions from case studies, literature reviews

Source; Author's conception.

4.1 Results

The comparative analysis carried out in addition to case studies deduction reveals the following:

Energy efficiency

The case studies adopted use of non-renewable means to energy generation. Use of daylight effect were mainly adopted as energy efficient mechanism. Also, energy efficient technologies were adopted in all the case studies.

Minimising carbon emissions

The case studies adopted use of green areas to capture carbon emission thereby ensuring a good carbon cycle. Use of sustainable building materials that emit less carbon.

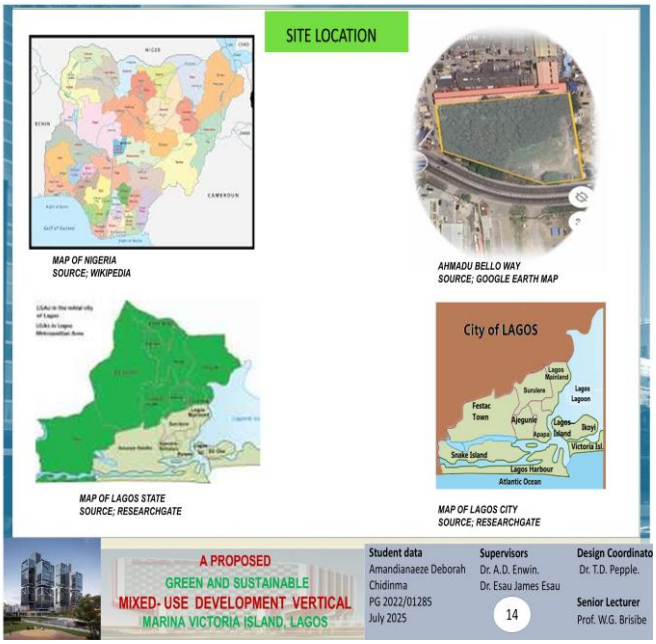
4.2 Discussion

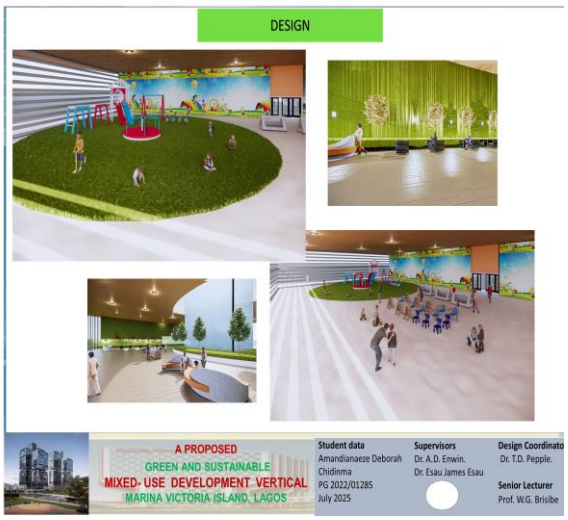
Energy efficiency means adopted

i. Use of hybrid renewable energy sources which comprises of hydropower generation, solar energy and biogas which are recognised renewable energy sources in line with leadership in energy environment and design (LEED)
ii. Use of courtyard as a passive cooling mechanism in addition to sustainable mechanical support clued from Literature review, case studies and unstructured interviews.
iii. the residential tower is placed in a direction that will receive less solar radiation during the day so as to reduce the need for artificial cooling leading to much energy use by the occupants.
iv. use of fins, overhang slab which accommodate service floor as sun shading devices.
v. wind breakers in form of tress,

Sustainable Architectural elements that aid in minimising carbon emission

i. Use of bricks and stones as external cladding as deduced from case studies and literature reviews.
ii. Cultivation of green amenities on the landscape and walls to enhance passive cooling and plants to utilise carbon dioxide released into the atmosphere.





5.Conclusion

Restatement of Purpose

The purpose of this Study is to design a Sustainable Mixed-Use vertical Development in Ahmadu Bellow Way, Lagos with emphasis on energy efficiency and minimising carbon emission as a means to contributing positively to climate change. The various case studies carried out in addition to literature reviews, and information gained during this research work has proved that realising this project is feasible.

5,1 Summary of findings

Data showing various methods to attain energy efficiency and carbon minimising emission strategies

Methods	Energy Efficient	Minimising carbon emission
Passive means	Use of wraparound balcony with advantage for daylight and ventilation.	Planting of vegetation, green facades and sky gardens to trap carbon.
	Harnessing on site means such as building orientation.	Proper building orientation reduces the consumption of energy and carbon dioxide emission
	Use of water bodies to enhance passive cooling.	
	Use of sustainable local building materials to reduce energy spent in transportation.	
	Use of shading devices that enhance natural cooling	
Technological means	Atrium with mechanical support to enhance daylight and ventilation.	Use of sustainable and recyclable materials that emit less carbon
	Use of renewable energy source.	

Source; Author's conception

Implications for Practice

İts worthy to note that from the studies conducted sustaianble architecture contribute positively to the environment and greatly improve on human well being. İts highly recommendable for campus design owing to its stress relieving nature that is of uttermost important in an educational environment such as university environment to aid in improving learning and behaviour of university students.

The following are recommended strategies to achieving a sustainable mixed-use vertical building with emphasis on energy efficiency and minimising carbon emission as explained in the table below.

S/N	Some Nigerian Architecture active design (designs that consumes much energy and produces more carbon	Recommended passive design strategies (designs that seek for energy efficiency and minimises carbon emission)
1	Improper orientation of building	Proper orientation of building
2	not considering sun shading device strategy	Utilising sun shading device strategy to reduce energy consumption
3	Little or no consideration on daylight and ventilation leading to much energy consumption	Adopting design that will utilise daylight effect and ventilation as energy efficacy strategy.
4	Not considering soft landscape and greenery in site arrangement thereby leading to much carbon emission in the environment	Use of soft landscape and greenery to balance ecosystem and reduce carbon emission
5	Not harnessing solar energy	Utilising solar energy as a renewal source of energy supply.
6	Not considering the sustainability of building materials	Adopting sustainable materials as a means to reduce global warming effect.

Source; Author's conception

Attaining a green and sustainable mixed use vertical design currently requires considerations of the macro and microclimate factors with considerations on how to use them and implementing them appropriately in addition to the use of low energy modern technology and less carbon emitting building materials that are sustainable in addition to landscaping and additional green spaces that will facilitate its optimum performance and to meet the needs of its users thereby ensuring return on investments of Investors while greatly enriching its location and environment as beacon of modern day built environment assuring economic and social benefits to the society and globally.

This study is carried out to improve on the sustainability of mixed use vertical development with emphasis on energy and minimising carbon emission, it greatly focused on use of hybrid renewable means to meet the energy need of the project to about 70% and more in addition to design passive strategies such as use of court yard, daylight, accommodating green spaces and landscaping using natice species. İt encourprated energy efficent modern technologies in addition to sustainable building materials that emit less carbon.

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