BIOMIMICRY FOR ENHANCING PASSIVE COOLING IN THE DESIGN OF MILLENNIUM CITY HOTEL, KADUNA.

BY

MABEL EWA

P13EVAT8054

DEPARTMENT OF ARCHITECTURE

AHMADU BELLO UNIVERSITY, ZARIA

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BY

MABEL EWA BSc. Arch.(2014),P13EVAT8054

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ZARIA, NIGERIA.

JUNE, 2018

DECLARATION

I hereby declare that all the work carried out in this thesis titled "Biomimicry for Enhancing Passive Cooling In The Design of Millenium city Hotel, Kaduna." was done by me under the supervision of Dr. Amina Batagarawa and Dr. Steve Oluigbo and to the best of my knowledge, has not been carried out anywhere for the award of a degree. All sources of information have been duly acknowledged by means of references and the responsibility of any mistake is entirely mine.

Mabel Ewa _____ _____

Name of Student Signature Date

CERTIFICATION

This thesis titled "BIOMIMICRY FOR ENHANCING PASSIVE COOLING IN THE DESIGN MILLENIUM CITY HOTEL, KADUNA" by Mabel Ewa, meets the requirements governing the award of Masters of Science (M.sc) in Architecture, Ahmadu Bello University, Zaria.

_____ _____

Dr. Amina Batagarawa Date

Chairman, Supervisory Committee

_____ _____

Dr. S. N. Oluigbo Date

Member, Supervisory Committee

_____ _____

Dr. A.S Salisu Date

Head of Department

_____ _____

Prof. S. Z. Abubakar Date

Dean, school of Postgraduate Studies

DEDICATION

This research is dedicated to Almighty GOD for strength and grace given to me throughout this journey and to my family for their enormous support from the beginning of my undergraduate days till the very end.

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ABSTRACT

The need for sustainable design in the tourism industry arises due to its significant contribution to energy consumption and greenhouse gas emission which has tremendous impact on the environment. Environmental designers look to new approaches like biomimicry to advance a sustainable design future. Biomimicry is the emulation of nature in its many forms, systems and processes to solve the most pressing challenges faced by our world today. The aim of the research is to develop a theoretical solution as well as design solutions for sustainable and energy efficient hotels in hot-dry climate. In understanding the concept of biomimicry in architecture, this thesis reinterprets several environmental designs and case studies from the perspective of human and environmental wholeness.. The cactus plant is known as a self-cooling plant due to its anatomical and physiological features that helps it to survive in hot dry climates. This research looks out to applying the characteristics of a cactus plant to profer solutions to energy efficiency.Three hotels were used as case studies, these includes; Transcorp Hilton Hotel, Abuja; Sheraton Hotel, Abuja and Le Meridien Ibom Hotel, Akwa Ibom. These case studies were analysed with respect to the benefits derived from the application of natural strategies such as the harvesting of renewable energy for power generation, water management and bio-inspired filtration methods and the efficient use of materials in adaptation to changing conditions in the environment to inspire building envelope. The study and selection of these architectural examples showed that the principles of biomimicry were underutilized in the hotels studied compared to foreign cases studied in the literature where they had more promiment biomimicry features in their buildings with the same aim of achieving passive cooling. The research found that incorporating biomimicry approaches helps in resolving the problems associated with passive cooling in hot dry climate and create a viable tourism development in Nigeria. This thesis addresses the importance of biomimicry principles to hotel design

and provides a template by incorporating these principles in various ways for professionals and organizations involved in hotel design in Nigeria.

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1.0 INTRODUCTION

1.1 Background of study

Sustainable development has often been criticized as being ambiguous as an underlying principle for the built environment (Roseland, 2000). All over the country, indeed around the world, architects, engineers, developers and builders are all clamouring to understand how to market their services to reflect a new way of building and a new approach to design with the environment in mind (Russell, 2004). The need for sustainable design in the tourism industry arises due to the reason that tourism organizations are notorious for erecting buildings, such as, airports, hotels and tourist centres, which ruin the beauty and integrity of their surroundings (International Hotel and Restaurant Association (IHRA), 2005).

The present day's urgency in achieving environmental sustainability has promoted renewed interest on gathering inspiration from nature. As a result of 3.8 billion years of "research and development" (evolution), nature provides a set of design blueprints that may be used to guide us to create elegant, sustainable, and innovative designs for human technologies (Benyus 1997). Biomimicry in architecture is a movement for the design and construction of expressive buildings which taps nature's huge reservoir of structures, process optimizations and functional solutions in order to find technical applications of natural principles (Vincent 2009) and it offers as a way to create a more sustainable and even regenerative built environment. The application of biomimicry is wide; by mimicking a variety of elements from nature, the final composition will not only respond to the activities within the building, but also to the surrounding environment (Inas, 2015).

According to Bohdanowicz (2006) the hotel industry constitutes one of the most energy and resource intensive branches of the tourist industry, it uses substantial amount of

energy for providing comfort and services to guests, typically with an alarmingly low level of energy-efficiency which poses a serious environmental threat and this is due to poor environmentally-friendly nature of the architectural concepts used. The energy use varies substantially between different types of hotels and is affected by hotel size, number of rooms, location, climate zone, as well as by the types of services/ activities and amenities provided to guests (European Union, 2004). The energy use in hotels has shown that electricity is the primary source of energy in the hotel industry and the amount of electricity consumed in hotels is thus a good indicator of the overall expenditure in the sector (Shi-Ming & Burnett 2000). Research has shown that in hotels about half of the electrical energy is used for air conditioning purposes (Centre for the Analysis and Dissemination of Demonstrated Energy Technology, 2001).

Hotels in hot-dry climates have the largest energy consumption in cooling and the energy demand for cooling falls within the range of 35% and 50% of total consumption (International Institute for Energy Conservation, 2015). Nigeria solely depends on electricity for energy and the constant power shortage due to inefficient power resources has not met the high energy demand which has prompted most hotels to generate their own power on daily basis which is expensive and emit gasses that deteriorate the quality of the environment (Sunday, 2012). As the hotel industry has grown to become the single largest business sector world-wide, it is necessary to adapt sustainable strategies to provide a environment that is condusive and also meet the need of the users (Bohdanowicz, 2006).

1.2 Problem Statement

The negative impacts of global warming and climate change are enormous. The prevailing global environmental degradation poses serious threat to sustenance of carrying capacity of the ecosystem (Daramola & Ibem, 2010). IHRA (2005) infers that

the nature of planning, construction and running of most hotels and resort facilities contribute to environmental degradation because they run on unsustainable energy sources, generate lots of waste, waste water, and pollute the air which grossly contributes to greenhouse effect. With increasing environmental awareness, it is becoming clear that a shift must be made in how the built environment is created and maintained.

Climate such as the hot-dry climate that is characterized by excessive heat and glaring sun which cause thermal discomfort requires a biomimicry approach to building designs especially to hotel buildings that consume a lot of energy. Hotel buildings use a large amount of energy for its operations; cooling, lighting, heating, cooking etc and the 24 hour time frame operation of the facility per day in order to provide comfort and services to guests (Bohdanowicz, 2006). This high energy demand has not been adequately met since the country faces constant power disruption due to inefficient use of power resources(Alkali, in 'Ahmed, 2012). This increase of energy demanded in buildings has led to a series of chain-consequences such as increases consumption of fossil fuels, increases carbon-di-oxide (CO_2) emissions into the atmosphere, worsening of the greenhouse effect and disruption of climatic conditions; thus affecting environmental and economic sustainability environment (Green Building Elements Facts, 2013). Hence, the highlighted problems thus give rise to the need to address them sustainably, being the basic tool for development which presents options for solving these problems.

1.3 Aim and objectives

The aim of the study is to explore the concept of biomimicry principle in an attempt to enhance passive cooling in hotel design. This will be achieved by the following objectives:

i) To review the concept and principles of biomimicry architecture.

ii) To determine to the extent to which biomimicry principles have been applied in existing hotel designs

iii) To demonstrate through design the application of biomimicry principles in hotel design.

1.4 Research Questions

i) What features of biomimicry design are suitable for achieving comtemporary sustainable architecture?

ii) How successful have principles of biomimicry architecture been in providing solutions to problems such as passive cooling and energy efficiency around the world?

iii) How close do built hotel designs in Nigeria come in realizing biomimicry principles?

1.5 Scope and delimination

The research is limited to the application of biomimicry principles in the design of a five-star hotel, specifically, in a hot-dry climate. It highlights the theoretical framework necessary to achieve a passively cooled hotel design through the assessment of existing principles and the consideration of the study area climate. The facilities to be provided in the proposed mellinnum city hotel were based on studies of existing hotels both within and outside Nigeria. This is essential to the research in order to achieve the standard services provided in a hotel and possible additions to improve existing services. This information were gathered through literature reviews and fieldwork carried out in hotel buildings.

1.6 Justification

Kaduna is a city in north-western Nigeria, an industrial, administrative and centre for trade which has drawn migrants from all over Nigeria, making it one of the country's most ethnically diverse cities (Williams, 2009). With the vision of the former governor of Kaduna state Arc Namadi Sambo who began his project of recreating Kaduna city in a statement said "we are creating new city, new hotels, new shopping mall, new markets, new hospitals and new ways of doing business…." (Jegede, 2009) . The city is to promote leisure, tourism, and commerce, a modern urban centrality for sustainable development where natural beauty and architectural icons must merge together to create an environment that is alive and productive which will attract more and more people and businesses from within and outside the country.

The project is aligned with sustainable development which will positively influence new designs/projects in Kaduna because this green proposal will bring about a movement in architectural style and a review in the decision making of the building sector. There are many approaches towards sustainable production and consumption considering the design profession. Biomimicry has become one of them with the motto of "innovation inspired by nature", which will help in designing sustainable buildings for the purpose of preventing environmental degradation. Therefore this proposal may be regarded as a viable proposal.

2.0 LITERATURE REVIEW

2.1 Biomimicry

Otto Schmitt (1913-1998), an American engineer and inventor, worked on a device that replicated the nerve system in squids. He worked on devices that drew inspiration from nature and further developed the field of biophysics (Norman, 2003). In 1958, Jack E. Steele (1924-2009) coined a similar term called "bionics". He defined it as the science of natural systems or their analogues (Faulid, 2005). (Benyus 1997), promoted biomimicry as an actual field of research in different design disciplines where she defines biomimicry as a systematic way of design that tries to emulate natural organisms' principles and orders.

The word biomimicry is composed of two words, one being bios that means life and the other being mimesis that means to imitate; knowing the meaning of the word makes it easier to understand the concept, but that is a design discipline that seeks sustainable solutions by emulating nature (Biomimicry institute, 2008). Biomimicry is not a style of building, nor is it an identifiable design product but rather, a design process, a way of seeking solutions in which the designer defines a challenge functionally (flexibility, strength under tension, wind resistance, sound protection, cooling, warming, seeks out a local organism or ecosystem that is the champion of that function, and then begins a conversation (Benyus, 2008).

(Benyus, 2002) claims that a biomimicry helps to create products that are sustainable, perform well, save energy, cut material costs, reduce waste, and even define new products. The logic behind this claim is that since natural organisms have faced these challenges for millions of years they have gradually perfected their solutions. Yeang (1995), feels biological knowledge by designers has been the missing variable in past design theory. The emerging field of biomimicry proposes that nature provides

functions, strategies, and characteristics within a set of principles that serve as design blueprints and lay a foundation for all of life to survive and thrive on earth (Benyus, 1997).

Gruber (2011), defined biomimicry architecture as emerging of nature into functional analogies, processes, mechanisms, strategies or information derived from living organisms. According to Hansell (2006**),** biomimicry architecture is one that seeks to extract ideas from nature and applies them on buildings.

The study of biomimicry has identified the core traits of nature's genius and also three ways of thinking/viewing nature.

2.2 Nature Design Principles

Benyus (2007), introduced the concept of biomimicry and defined it as "the conscious emulation of life's genius." She described three tenets of this science: Nature as model, nature as mentor and nature as measure

i. **Nature as Model**: Biomimicry is a science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems, example, a solar cell inspired by a leaf.
ii. **Nature as Mentor:** Biomimicry uses ecological standard to judge the rightness of our innovations. After 3.8 billion years of evolution, nature has learned: what works? What is appropriate? What lasts?
iii. **Nature as Measure:** Biomimicry is a way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it (Benyus, 2007).

The nature's unique characteristics and principles that can be applied and help develop architecture and design is as follows: Nature runs on sunlight, Nature uses only the energy it needs, Nature fits form to function, Nature recycles everything, Nature

rewards cooperation, Nature banks on diversity, Nature demands local expertise, Nature curbs excess from within, Nature taps the power of limits (biomimicry institute, 2008).

2.3 Principles Of Biomimicry Design

According to Benyus (2007) biomimicry design in addition to mimicking specific creatures, can also be the mimicry of general patterns and processes found in nature. These general patterns and processes are referred to as Life's Principles. The principles are

i. Use of natural form
ii. Exploring the application of natural processes
iii. Learning from ecosystem.

2.3.1 Use of natural form

The first level of biomimicry is the mimicking of natural form (Benyus, 2007); architects inspired by the varied patterns of nature apply these inspirations to architectural design. Through the understanding of the organisms' structures and mechanisms of the forms, the control of shapes and structures on biomimicry can therefore be possible. This can be achieved through strategies such as patterns and forms in nature, such as the spiral and fractal, are products of internal laws of growth and of the action of external forces, such as sun, wind, and water. The use of natural forms is adopted from observing living structures: trees, bones, shells, wings, webs, eyes, petals, scales, rocks and microscopic creatures.

These strategies are achieved through technologies such as

- Use of curves: Curves are very strong and can reach optimum structural shapes as parabolic and hyperbolic arches and shells. They may also be sleek and

streamlined to respond to the energy and force of wind and water, or sensual and erotic in suggesting the beauty of living forms.

- Use of fractal geometry: The attribute of self similarity is characteristic of fractals. With Fractal geometry, one can describe natural shapes and rhythms such as snowflakes, leaves, tree branches, mountains, waves and coastlines.

An example is the Beijing Olympic stadium inspired by bird's nest. The stadium was designed by a Swiss architecture firm, Herozog and De Meuron which is not only energy efficient and eco-friendly but also inspired by nature (Adebisi, G. O, Onuwe, J. O & Sani, A. M 2015).The Beijing Olympic stadium (Plate 2.1) draws directly from nature, as elements of the bird nest are exposed as its major aesthetic motif, with little material wasted to disguise the structure. The design of the National Stadium, "bird's nest" collects and process rain water to irrigate the stadium's lawn, to cool down the air-conditioning system, to flush toilets, greening, to be used in fire control purposes (People's daily, 2007).



Plate 2.1: The bird nest stadium. Source: (www.biomimicryinstitute)

The Minister of Municipal Affairs & Agriculture (MMAA) in Qatar (Plate 2.3) is another example of natural form. Aesthetics architects was looking for inspiration to design the (MMAA) in Qatar that would be situated in the hot, dry climate of Qatar, an

area that only receives approximately 3.2 inches of rainfall (Inas, 2015). They decided to investigate the Cactus for ideas on a building solution. Cactus, organism that has adapted to arid, dry climates and so unique in the technology it uses in order to survive. The signature characteristic of a cactus is the "spines" that serve more than just one purpose. The obvious purpose for the spines is for protection, they also serve to channel the rain water down to the base of the plant where it gets collected and stored. But the most important function that the spines serve is to help shade the plant from the intense sun (Mansour, 2010).



Plate 2.2: The cactus plant. Source: (www.biomimicryinstitute)

The architects designed the (MMAA) in Qatar (Plate 2.3) using the technologies from cactus plant (Plate 2.2) to create a unique sustainable solution to a complex problem. The botanic dome at the base of the tower will provide sustainable food source irrigated from Grey and black water treatment. In addition, they incorporate sunshades on the exterior of the building which act like filters with the sunlight that is penetrating the spaces. These shades have ability to automatically fluctuate up and down, depending on the desired interior temperature, to regulate the amount of sunlight and heat that is transferred into the space, This innovative solution allows this building to lower the size

and amount of artificial cooling necessary for the building to operate properly as well as providing a sustainable solution that is aesthetically pleasing (Elshapasy, 2010).

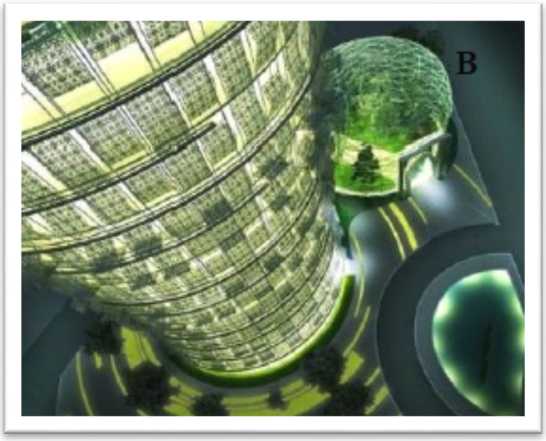


Plate 2.3: The MMAA in Qatar. Source:(www.biomimicryguild)

2.3.2 Exploring the application of natural process

The second level of biomimicry is the mimicking of natural processes and principles, how things are made in nature or what it is able to do (function). Biomimicry is not only about nature imitation but the observation of the general patterns and processes found in nature (Benyus, 2007). The natural processes include

- Use of free energy
- Use of minimal energy and material
- Adaptation and evolution.

2.3.2.1 Use free energy: Collective life can be seen as an unsustainable open system of energy, ultimately dependent on solar energy. Life learnt to harvest energy from the Sun and to transform it for work without creating toxic by-products. The idea is to displace some of our conventional energy with a renewable source (Benyus, 2007). The strategies include maximizing passive design and renewable energy sources and minimization of adverse impacts on the environment through optimized building siting, optimized building design and material selection (Biomimicry Institute 2008). These strategies can be achieved through technologies such as

i. Use of high performance integrated photovoltaic façade systems

ii. Rain screens and stick systems

iii. Double skin façade systems

iv. Shading and Glazing systems

v. Atria and Canopies

vi. Use of high performance low-e glazing, which can result in significant year round energy savings. Window frames, sashes and curtain wall systems should be designed for optimum energy performance including the use of multiple thermal breaks to help reduce energy use.

Vii. Energy Star certified energy efficient appliances, office equipment, lighting and HVAC systems should be used.

2.3.2.2 Use minimal energy and materials: Nature always tries to use energy and materials efficiently, successfully minimizing mass and energy use. Nature recycles everything; the natural skin reacts to changing conditions and influences of air pressure on the surface to perform a process of transpiration in plants. This system is created by a specific arrangement of a basic component, to utilize space and material in an efficient way (Biomimicry Institute 2008).

This is achieved through strategies such as minimizing the use of non-renewable construction materials and other resources, the use of smart materials to control solar radiation transmitting through the building envelope, control of conductive heat transfer through the building envelope, and increased use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible. All of these strategies can be achieved through technologies such as

i. The use of materials that is adaptable to hot humid climate and environmentally responsive such as Thastyron and Polystrene Concrete Facade system with low thermal conductive property, energy efficient and recyclable. Thastyron also costs less to use and maintain than other materials when used for the building envelope design.

ii. The applying of smart materials like Photochromics, Liquid crystals to control solar radiation transmitting through the building envelope and phase change materials to control interior heat generation.

iii. The use of Secondary energy supply systems such as integrated photovoltaics and optimization of lighting system.

iv. Reduction in the amount of materials used and the amount of waste generated through the implementation of a construction waste reduction plan. A policy of "waste equals food" whereby 75% or more of all construction waste is separated for recycling and used as feedstock for some future product rather than being land-filled.

v. Evaluation of all products and systems used for their ability to be recycled when they reach the end of their useful life. Preference should be given to products and systems that facilitate easy, non-energy intensive separation and recycling with minimal contamination by foreign debris.

2.3.2.3 Adaptation and evolution: Nature evolves by responding to its environmental needs and finding solutions that work. The regenerative nature describes processes that restore, renew or revitalize their own sources of energy and materials, holistic frameworks that seek to create systems that are absolutely waste free.

This can be achieved through the following strategies locally attuned and responsive, the use of process oriented regenerative approach, the use of Feedback Loops and

applying the integration of cyclic processes in energy and material consumption, maximizing the use of renewable energy sources and alignment of energy flows with natural tendencies. The strategies can be achieved through technologies such as

i. Environmental responses, Day lighting: the use of Skylights, full-height atrium with glass decks and Sky gardens.
ii. Integrating human processes with natural processes by redesigning our processes to be aligned with natural processes, to protect, reinforce and strengthen them where possible. For example, rather than building seawalls to protect against erosion and flooding, it's far more effective to use natural vegetation to do the same work.
iii. Designing our systems to take advantage of share linkages that would provide mutual benefit and symbiosis between different elements.

An example of this principle can been in the Eastgate tower in Zimbabwe. The architect Mick Pearce, was looking for inspiration to design the Eastgate centre in Zimbabwe where the temperature outside can vary from 3 °C up to 43 °C and where the air condition plays a significant role. Mick Pearce looked at "termites" (Plate 2.4) which have an amazing ability to maintain virtually constant temperature and humidity in their termite mounds in Africa despite outside temperatures that may vary from 35°F to 104°F (3°C to 42°C (Vierra, 2007). The way they construct their mounds to maintain a constant temperature. The insects do this by constantly opening and closing vents throughout the mound to manage convection currents of air - cooler air is drawn in from open lower sections while hot air escapes through chimneys (Benyus, 2008).

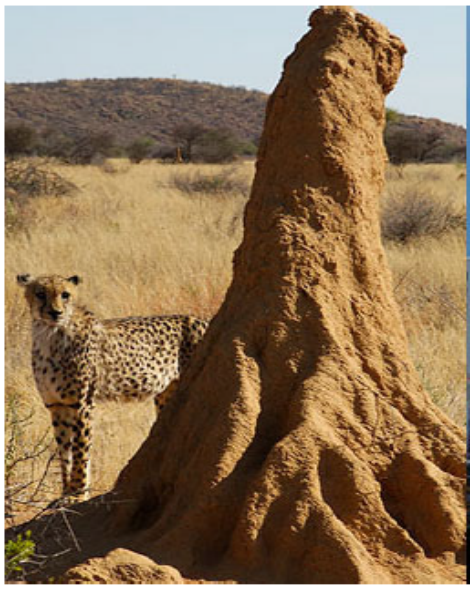


Plate 2.4: The termite mould.Source: (Zari, 2007)

The Eastgate Centre, a mid-rise office complex in Harare, Zimbabwe, uses a form of passive cooling similar to how the termite mound works. It was designed to mimic the heating and cooling systems that termites use in their mounds to Create Sustainable Buildings. The innovative building uses similar behaviour in the design, and air circulation planning it stays cool without air conditioning and uses less than 10% of the energy used in similar sized conventional buildings, hence moving towards a more sustainable building (Mansour, 2010). His solution was to have specially designed hooded windows, variable thickness walls and light coloured paints as a part of a passive-cooling structure to reduce heat absorption. By doing so Eastegate uses 90% less energy for ventilation than conventional building its size and has already saved the building owners over $3.5 million dollars in air conditioning costs **(**Arnarson, 2011).



Plate 2.5: The Eastgate centre Zimbabwe. Source: Zari (2007)

2.3.3 Learning from ecosystem

At the third level is the mimicking of the whole natural ecosystem and the common principles that allow them to successfully function. Benyus points out that, in the near future, buildings will mimic systems in nature with respect to environmental mediation. (Inas, 2015).

2.3.3.1 Enhance the biosphere: Nature uses and builds with life friendly processes and systems. Natural filtration environment filters out and absorbs components that would otherwise pollute the local ecosystem (Biomimicry Guild 2008).

This can be achieved through strategies such as preservation of the existing natural water cycle and design site and building improvements, emphasis on retention of storm water and on-site infiltration and ground water recharge, minimization of unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, extensive use of native vegetation to improve microclimate, local community involvement in construction, maintenance, operations High-level support for the local community (Biomimicry Institute, 2008). These strategies can be achieved through technologies such as

i. Conduction of a thorough site assessment and strategically locate buildings and site improvements so as to preserve key natural hydrological features. Special effort should be made to preserve areas of the site that serve as natural storm water retention and ground water infiltration and recharge systems. Preservation of existing forest and mature vegetation, which plays a vital role in the natural water cycle, by absorbing and disbursing up to 30% of a site's rainwater through evapo-transpiration.

ii. Design and location of 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 ground water recharge or evapo-transpiration. Storm water that leaves the site should be filtered and processed naturally or mechanically to remove trash and debris, oil, grit and suspended solids.

iii. Establishment of a water budget for the building and implementation of a design that minimizes the use of portable water by using low-flow plumbing fixtures and toilets and waterless urinals. Harvesting, processing and recycling rainwater, site storm. Use of on-site treatment systems that enable use of rain water for hand washing, grey water for toilet flushing, rain and storm water for site irrigation, and other uses.

An example is the construction of Earthships (Plate 2.6) integrated with nature. Biomimicry design is not only adapting the design from the nature but also considering how to use nature's effective functions such as heating and cooling system, protecting natural light and ventilation. So the solution is to investigate the natural design

principles for ideas on a building solution to mimicking a specific ecosystem which elements and principles are required for it to function successfully.

The Earthships are designed to integrate with nature based on six natural design principles which are:

i. Constructed with recycled and local materials: Tiers, sand bags, adobe….etc.

ii. Heating and Cooling: From the sun and the earth.

iii. Water Harvesting: Caught on the roof from rain and dew mimicking the Namibian beetle bumpy body.

iv. Renewable Electricity: Photovoltaic / wind power system. This energy is stored in batteries and supplied to electrical automated outlets, including grid-intertie.

v. Sewage: Gray water from bathing, washing dishes is separated from black water from the toilet. The gray water is used and filtered for a second time in interior botanical cells. The flush toilet is the third use of the water, which is contained, treated and used a fourth time in exterior botanical cells.

vi. Food production: Food is grown inside with botanical planters and outside in landscape irrigated with treated gray water (Mansour, 2010).

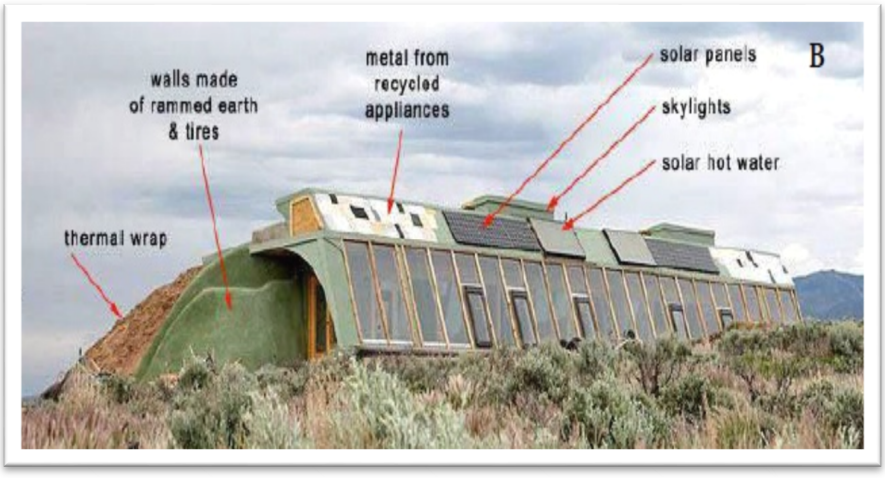


Plate 2.6: The earthship.Source: Roa (2014)

2.4 Design Approaches to Biomimicry

The Biomimicry Institute founded by Janine Benyus created a Design Spiral methodology (Figure 2.1) to help people learn and practice biomimicry. It comprises five or six iterative phases based on the assumption that \after solving one challenge, then evaluating how well it meets life's principles, another challenge often arises, and the design process begins a new" Approaches to biomimicry as a design process typically fall into two categories: design looking to biology and biology influencing design (biomimicry guild, 2007).

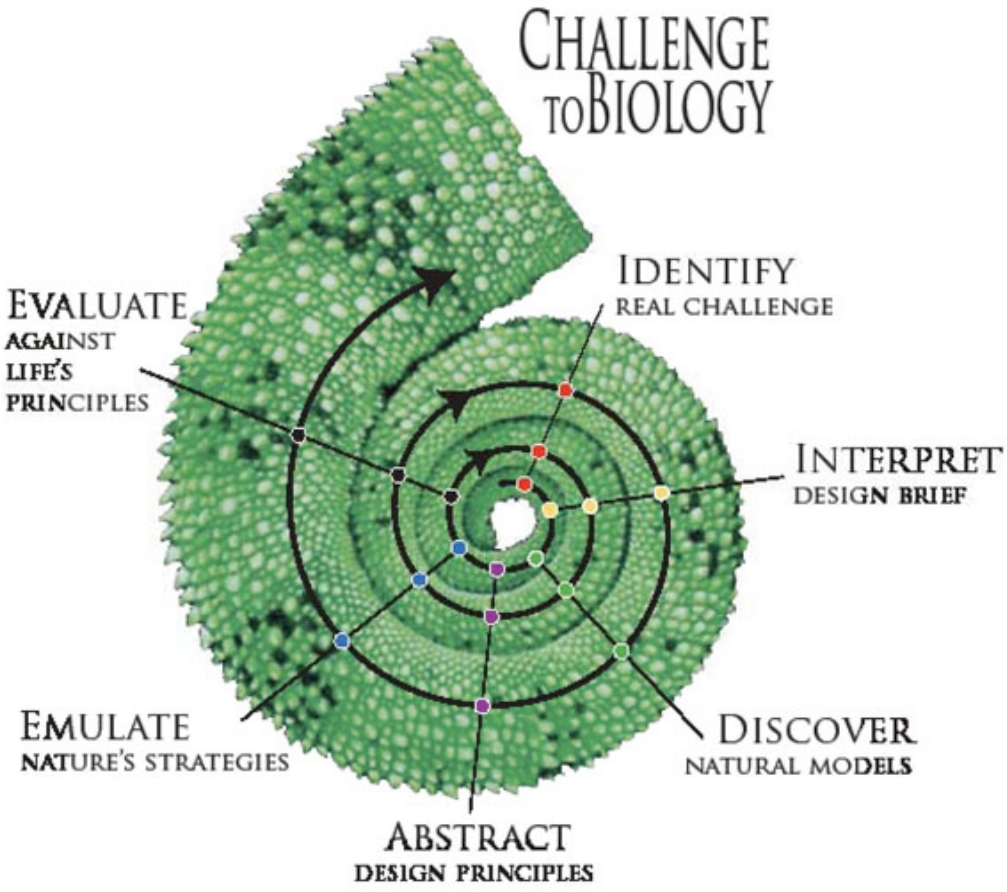


Figure 2.1: Design methodology spiral.Source: (www.biomimicryinstitute)

2.4.1 Identify

Develop a Design Brief of the human need:

- Develop a Design Brief with specifics about the problem to be resolved
- Break down the Design Brief to identify the core of the problems and the design specifications
- Identify the function you want your design to accomplish: What do you want your design to do? (not "what do you want to design?"). Continue to ask why until you get to the bottom of the problem.
- Define the specifics of the problem (Biomimicry guild, 2007).

2.4.2 Interpret

Biologize the question; ask the Design Brief from Nature's perspective:

- Translate the design function into functions carried out in nature. Ask "How does Nature do this function?" "How does Nature NOT do this function?"
- Reframe questions with additional key words.
- Define the Habitat/Location
- Climate conditions (Biomimicry guild, 2007).

2.4.3 Discover

Look for the champions in nature who answer/resolve your challenges

- Find the best Natural Models to answer your questions.
- Consider Literal and Metaphorical
- Find champion adapters by asking "whose survival depends on this?"
- Find organisms that are most challenged by the problem you are trying to solve, but are unfazed by it.
- Look to the extremes of the habitat
- Turn the problem inside out and on its head (Biomimicry guild, 2007).

2.4.4 Abstract

Find the repeating patterns and processes within nature that achieve success

- Select the champions with the most relevant strategies to your particular design challenge.
- Abstract from this list the repeating successes and principles that achieve this success (Biomimicry guild, 2007).

2.4.5 Emulate

Develop ideas and solutions based on the natural models

- Develop concepts and ideas that apply the lessons from your Natural teachers.
- Look into applying these lessons as deep as possible in your designs:

❖ Mimicking Form:

- Find out details of the morphology
- Understand scale effects
- Consider influencing factors on the effectiveness of the form for the organism
- Consider ways in which you might deepen the conversation to also mimic process and/or ecosystem

❖ Mimicking Function:

- find out details of the biological process
- Understand scale effects
- Consider influencing factors on the effectiveness of the process for the organism
- Consider ways in which you might deepen the conversation to also mimic the ecosystem

❖ Mimicking Ecosystem:

- Find out details of the biological process
- Understand scale effects. (Biomimicry guild, 2007).

- Consider influencing factors on the effectiveness of the process for the organism

2.4.6 Evaluate

How do your ideas compare to Life's Principles, the successful principles of nature?

- Evaluate your design solution against Life's Principles
- Develop appropriate questions from Life's Principles and continue to question your solution
- Identify further ways to improve your design and develop new questions to explore.

2.4.7 Identify

Develop and refine design briefs based on lessons learned from evaluation of Life's Principles

Nature works with small feedback loops, constantly learning, adapting and evolving. We can also benefit from this thinking, evolving our designs in repeated steps of observation and development, unearthing new lessons and applying these constantly throughout our own design exploration. (Biomimicry guild, 2007).

2.5 Passive Cooling through Biomimicry

Natural organisms interact with the environment in a successful and sustainable way, without depleting natural resources or polluting the environment. They designed highly efficient biological systems that can adapt themselves to the surrounding environmental conditions in order to overcome different challenges. They develop numerous means of adaptation methods to create thermal comfortable conditions for their bodies (Springuel,2008).

The adaptation methods concern physical characteristics, behavioral reactions or cooling processes: physical characteristics help in reducing heat gain through using small surfaces exposed to sunlight, high density, and high proportion of internal volume

to surface size, and fade colours. Other physical characteristics are to increase thermal insulation such as the presence of spines, hair, waxy and thick external layers (Elghawaby, 2010).

Some plants, such as Mangroves found in south Sinai, avoid direct sunlight by rotating their leaves away from sunlight, while some animals, such as lizards, rest in burrows and shaded areas or move rabidly or rise up their bodies away from heated ground (Biomimicry institute, 2008). The same attitude was mimicked or could be imitated in buildings as active systems. Buildings could rotate, use movable shading devices, windows and controlled wind catch. It could be also transformed into constant features like constructing underground buildings or raise them above the heated ground with high columns (Baumeister, 2009).

The second group of adaptation methods is cooling systems and processes. These methods depend generally on earth deepness, water or natural ventilation to release the internal heat by convention or conduction (Biomimicry institute, 2008). Using the earth deepness in cooling was found especially with animals. In architectural field, some passive cooling systems such as the underground air flow tunnels are created by mimicking this concept (Baumeister, 2009).

2.5.1 **Cactus plant for passive cooling**

Cactus is quite unusual in terms of its adaptation qualities and its appearance. It is adapted to grow in hot and tropical climates and desert areas, where there is very little rainfall. Its anatomical and physiological features help to conserve water and survive in really harsh environmental conditions.

The attributes of a cactus plant include the following

i. Cooling ribs

- Cacti has cooling ribs (Plate 2.7) which provide shade and enhance heat radiation
- The contrast between light and shade of the cooling ribs of the cactus produce rising and falling air currents, improving heat radiation.
- The vertical structure/position of a cactus prevents it from burning in the sun



Plate 2.7: Cooling rib. Source :Biomimicry institute,(2008).

ii. Spines

- Spines and thorns (Figure 2.2) are adapted leaves or buds which serve to protect the cactus from the sun by scattering direct sunlight.
- During night time or rain, the downward pointed spines collect water/dew transport the droplets to the shallow roots in the soil below.
- White spine reflect sunlight away from the plant (all spines provide shade) reducing the potential for damage from excess solar radiation

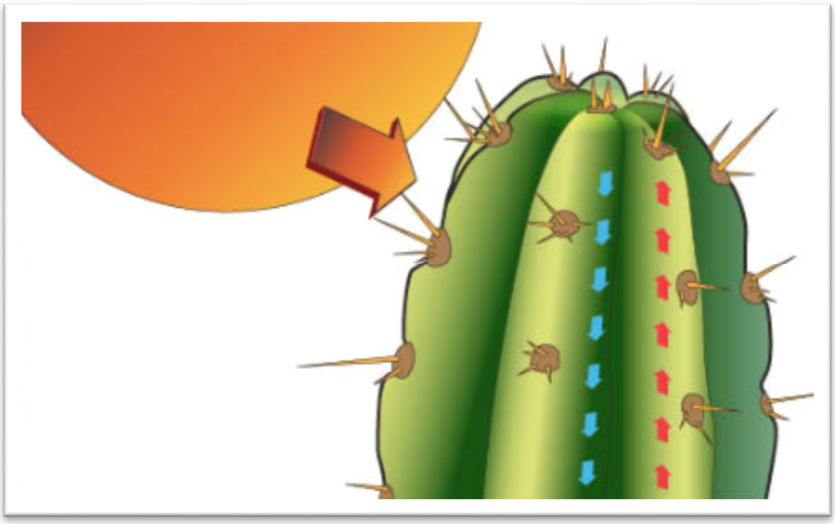


Figure 2.2: The spine. Source :Biomimicry institute,(2008).

iii. Skin

- Cacti have a waxy skin to prevent evaporation of water

iv. Shape

- The shape of cacti (Figure 2.3) helps them to maximize volume of water storage while minimizing surface area for water loss.

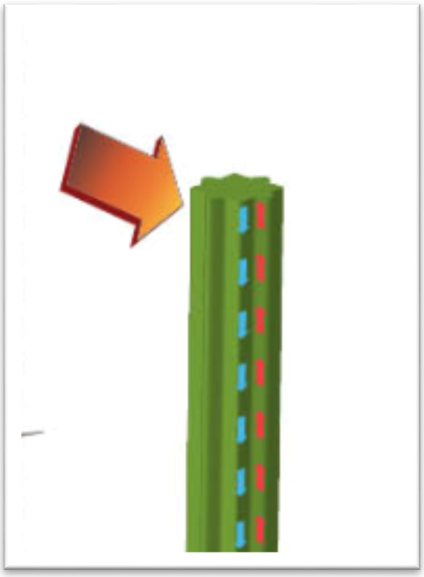


Figure 2.3: The shape. Source :Biomimicry institute,(2008).

2.6 Biomimicry Design Features

The elements of biomimicry design would be discussed in the context of building materials, systems and methods that can be efficiently incorporated in a building to make it sustainable.

2.6.1 Photovoltaic (Solar power)

Solar power is one of the most sustainable technologies that can be employed in a building. This owes especially to the abundant supply of sunlight in many regions of the world. Due to this obvious fact, the discussion provided on photovoltaic will be quite elaborate. Photovoltaic technologies produce electricity directly from sunlight. When sunlight strikes a solar cell, its semiconductor materials absorb a portion of that light, if the energy from the absorbed light strikes electrons in the outer shell of an atom, these electrons are freed from their parent atoms. Free electrons can then travel into a circuit in the form of electricity.

The most common Photovoltaic device available today is made from rigid, crystalline silicon solar cells (although other materials can also be used). About 36 of these cells are typically combined to produce a flat module (see figure 2.4), and about 10 of these modules are mounted to form a Photovoltaic array, which can measure up to several meters on a side. Photovoltaic arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day.

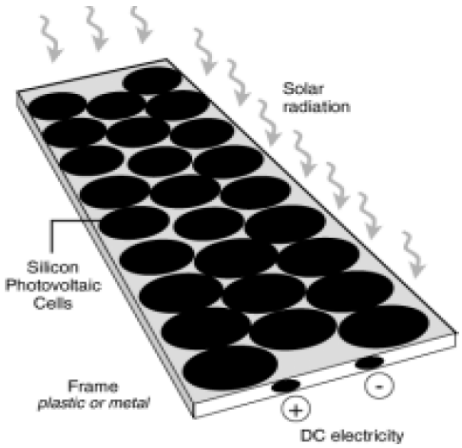


Figure 2.4: Photovoltaic module. Source : National Best Practices Manual for Building High Performance Schools

There is a wide variety of Photovoltaic systems currently disposed on the market suitable for BIPV systems. Most of these can be grouped into two main categories: roofing systems and façade systems.

2.6.2 Grey water use & water efficient fixtures

By collecting rainwater runoff from the roof, grey water can be used to supply many of the water needs of the facility such as landscape irrigation, toilet flushing, the mechanical systems and custodial uses. This minimizes the use of our dwindling potable water resources while decreasing storm water runoff. In addition, by utilizing high efficiency fixtures, watersaving faucets with occupant sensors, and waterless urinals, the overuse of our valuable clean water supply can be minimized. (www.churchville.net, 2008)

2.6.3 Solar hot water systems

Solar hot water is water heated by the use of solar energy. Solar water-heating systems use collectors, generally mounted on a south-facing roof, to heat either water or a nontoxic antifreeze that is circulated from the collector to the water storage tanks. The heated water is then stored in a water tank similar to one used in a conventional gas or

electric water-heating system. The panels may use electricity for pumping the fluid, and have a reservoir or tank for heat storage and subsequent use. Hot water heated by the sun can be used to heat water (e.g. for showering, sanitary purposes and for heating swimming pools) and generate electricity In order to heat water using solar energy, a collector is fastened to the roof of a building, or on a wall facing the sun. In some cases, the collector may be free-standing. The working fluid is either pumped (active system) or driven by natural convection (passive system) through it. The collector could be made of a simple glass topped insulated box with a flat solar absorber made of sheet metal attached to copper pipes and painted black (see fig. 2.5)

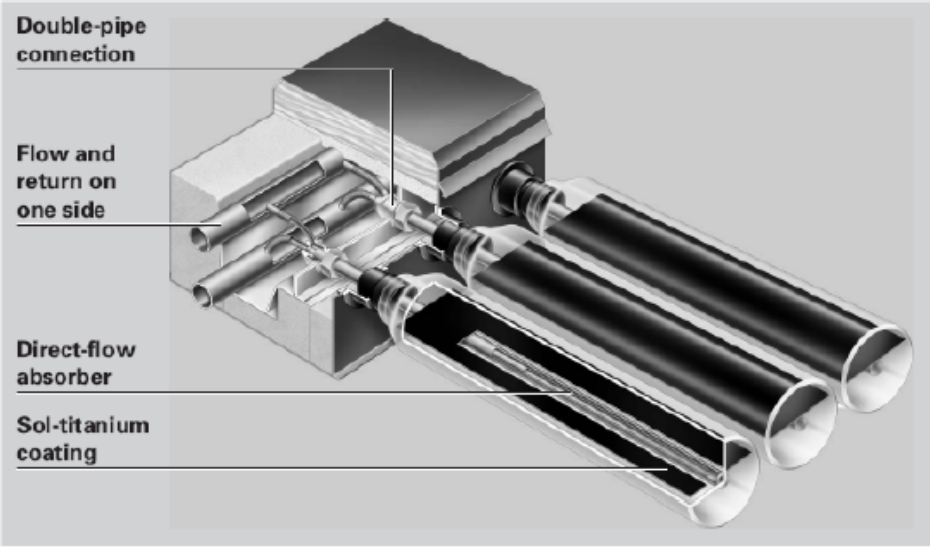


Figure 2.5: vacuum tube collector with sol-titanium coating**.** Source: Veissmann, 2000

In some cases, before the solar energy is absorbed, a parabolic mirror is used to concentrate sunlight on the tube. Some systems are capable of converting light to heat and therefore are not as reliant on outside temperature (Plate 2.8). In sunny, warm locations, where freeze protection is not necessary, a batch type solar hot water heater can be extremely cost effective.



Plate 2.8**:** An installed compact solar hot water system in Australia**.** Source: Solarshop, 2000

2.6.4 Rastra

Rastra is a concrete form system made of light weight material THASTYRON which provides a permanent framework for a grid of reinforced concrete to form load bearing walls and other building components (see plate 2.9) "THASTYRON" (THermo-Accoustic-STYRo-cONcrete) is a lightweight, honeycomb like mixture of small Expanded Polystyrene beads completely covered with a skin of cement and it offers the best properties for a wall material. It has best heat/cold insulation, is resistant against fire, frost and other climate influence and takes plaster, stucco or any other type of wall covering very well. The cavities of the elements are filled with concrete after they have been set up on site, thus a rigid skeleton is formed inside.



Plate 2.9: Rastra elements at a job site. Source: www. rastra.com

2.6.5 Structural Insulated Panels

Structural Insulated Panels (SIPs) are prefabricated insulated structural elements for use in building walls, ceilings, floors, and roofs. They provide superior and uniform insulation compared to more traditional construction methods (stud or "stick frame"), offering energy savings of 12%–14%. When installed properly, SIPs also provide a more airtight dwelling, which makes a house more comfortable and quieter.

The most common types of SIPs use insulation made from expanded polystyrene or polyisocyanurate, a polyurethane derivative.

2.7 Designing a Hotel for Kaduna Millennium City

Mackenzie (2009) defines hotels as establishment held out by the proprietor as offering sleeping accommodation to any person presenting himself who appears able and willing to pay a reasonable sum for the services and facilities provided and who is in a fit state to be received. Clark (2009) opines that it as a commercial establishment that provides lodging, food, and other services to the public.

2.7.1 Types of hotels

Different types of hotels offer different kinds of services to their guests and will be run differently to meet their guests' needs. For example, a luxury hotel may provide more personalised services and facilities that may not appear in a limited-service hotel (Mackenzie, 2009).

2.7.1.1 Airport Hotels

These hotels are designed especially to provide travellers with a place to eat and sleep. They offer a mix of facilities and amenities (Mackenzie, 2009). Therefore they are hotels mainly cater for people en-route (traveling) for business or pleasure (Samuel, 2009). The traditional airport hotels were not as multi-dimensional as their modern counterparts and offered fewer facilities and a limited numbers of guests.

2.7.1.2 All-Suite Hotels

The guests rooms in these hotels are larger than normal hotel rooms, with saperate areas for working, sleeping and relaxing (Mackenzie, 2009). A living area or palour is typically separated from the bedroom, some properties offer a kitchen set-up in the rooms (Samuel, 2009). The amenities and services can vary widely. They can be found in various locations such as urban, suburban, or residential .

2.7.1.3 Boutique Hotels

Boutique hotels differentiate themselves from traditional hotels and motels by providing personalized accommodation and services/facilities (Mackenzie, 2009). They are sometimes known as Design Hotels or Lifestyle Hotels. They are more intimate and perhaps more luxurious.

2.7.1.4 Casino Hotels

They have gambling operations which are the major revenue centres. They also provide live entertainment. A wide variety of luxury amenities, hotel services including fine and casual dining and shopping centres are typically available on site (Mackenzie, 2009).

2.7.1.5 City Centre Hotel

These hotels are located within the heart of a city, the type may vary greatly from business, suites, residential, economy, mid-scale to luxury(Mackenzie, 2009). These are luxury, conventional city hotels characterized by high lot ratio and high rise construction with large functions, accommodation, shops and offices.

2.7.1.6 Conference/Convention Hotels

These hotels can have 2000 rooms or more. In addition to accommodation, they provide extensive meeting and function space for holding conventions. There are banquet areas within and around the hotel complex. Most of them provide an in-house laundry, a business centre, airport shuttle service, and 24-hr room service (Mackenzie, 2009). They are often in close proximity to convention centres and other conventional hotels.

2.7.1.7 Guest Houses

According to Mackenzie (2009), guest houses are similar to bed and breakfast inns. They range from low-budget rooms to luxury apartments. They tend to be like small hotels in bigger cities. Though the facilities are limited, most rooms are air-conditioned with en-suite shower and toilet.

2.7.1.8 Highway Hotels/Motels

They are designed for overnight stays for car travellers with very basic facilities. The rooms usually have direct access to an open parking lot (Mackenzie, 2009). They are often smaller than most hotels. They are located on the outskirts of towns and cities.

2.7.1.9 Historic Conversion Hotels

These properties have historic significance which have been converted into lodging establishments with retention of their historic character (Mackenzie, 2009).

2.7.1.10 Spa Hotels

They are located in resort-type settings or as part of city spa hotels. They provide accommodations, spa treatments, programs and cuisine. Programs offered vary widely. They may include relaxation/stress management, fitness, weight management, grief/life change and pilates/yoga (Mackenzie, 2009). Spas have professional staff that often include dieticians, therapists, masseurs, exercise physiologists, and in some cases, physicians.

2.7.11 Resort Hotels

According to Elliot and Johns a resort provides accommodation, as well as leisure facilities desired by the guests with the features of natural beauty or interest. Also resort hotels and motels usually are located in seaside, lake, or mountain areas, and they cater to tourists and vacationers. Resorts provide all hotel services plus recreational and athletic activities. Ten basic categories of resorts have been defined by Reutes, Penner, & Adams (2001). These hotels are located in picturesque, sometimes remote settings. Guests travel long distance to resorts. Usually, they tend to stay longer (Mackenzie, 2009). Resorts typically provide a comprehensive array of recreational amenities, as well as a variety of food & beverage outlets ranging from informal to fine-dining restaurants. Some of them include Spa Resorts, Ecotourism Resorts, Ski Resorts, and Resort Theme Parks.

2.7.2 Classification of hotel

According to Bundhun (2012), hotel classifications are based on star ratings and hotel ratings are often used to classify hotels according to their quality. Rates were given to hotels according to the customers' perspective on accommodation properties because there was a need to group hotels in a system which would be easy for the customers to understand. Research Department of the Caribbean Tourism Organisation (2002) suggest that the rating system emerged out of efforts by the Automobile and cycling clubs in Europe, who established a rating system such as the British system, Automobile Association (AA) and its American counterpart the (AAA). According to the AA rating system hotels can be classified based on the star ratings, the lowest rating is one star hotel to five star hotel and recently seven star hotel as the highest rating. The most popular system of classification is the star rating system from one - seven star as highlighted in table 2.1 and further discussed in section 2.6.2.1 – 7

Table 2.1a: Physical requirements of hotels of one star to five star classifications.

s/no	Items	1 star	2 star	3 star	4 star	5 star
1	Entrance	The hotel shall have its own independent entrance.	As 1 star	As 2 star plus hotel restaurants shall have their own external as well as internal entrance.	As 3 star	As 4 star Easy access for disable
2	Reception area/ lobby	Seating and appropriate furniture commensurate to hotel capacity. It shall comprise reception desk and porter service.	As 1 star plus minimum area of 40m^2	As 2 star coffee and/ writing tables. Special floor finish.	As 3 star plus minimum floor area of 100m^2	As 4 star plus minimum floor area 150m^2

Table 2.1b: Physical requirements of hotels of one star to five star classifications.

3	Lounge	Area with lounge seating music and/or television services. May also be used for breakfast and reception of guests.	Lounge area or sitting room with music and television services, newsagent/gift desk	As 2 star plus seating at least one-third of hotel bad capacity in combination with reception area with music and television services newsagent/gift desk.	Choice of lounge(s) or sitting room(s) plus service of drinks and refreshments, with music and television services, newsagent/gift desk.	
4	Minimum floor area of lounge	$30m^2$	$40m^2$	$60m^2$	$100m^2$	$150m^2$
5	Public toilet	Toilet facilities are normally required near main lobby, restaurants and bars, banquet halls, conference rooms with nearby cloakrooms, front office- for staff. Separate for each sex normally each shall have a minimum of two water closets with toilet paper, washbasins with hot and cold running water, mirror, soap, towels or hand drier and waste bin. Separate cubicle for the disabled equipped with appropriate fittings. Suitably sited near public areas with interiors screened.				
6	Parking	Free access by car. One parking space for every three guest rooms.	As 1 star	Covered parking spaces reserved for guest and properly lit with 24 hrs. Security. 1 parking space for every 3 guest- rooms special parking lot for coaches.	As 3 star plus exclusive parking or garage to garage to accommodate all hotel guests and casual visitors. 24 hrs. Security plus basic car servicing available.	As 4 star
7	Green area	At least potted plants.	As 1 star	Some garden area with adequate lightening.	Some garden area of terrace with plants.	Green area for guest use such as terrace with plants, roof garden, patio or adjoining gardens.

Table 2.1c: Physical requirements of hotels of one star to five star classifications.						
8	Restaurant	Breakfast room may replace the restaurant	Restaurant or cafeteria where meals are served at lunchtime & evening seating or in immediate proximity to appropriate independent facilities.	Restaurant or coffee shop where meals are served at lunchtime and evening. Seating not less than half of hotel bed capacity. A menu shall offer a wide .selection of dishes	Main first class restaurant and choice of restaurant serving a variety of meals. Private dining or function rooms available. Total seating not less than hotel bed capacity. High quality food and beverage service. Menu shall offer a wide selection of dishes.	Main superior class restaurant and choice of restaurant serving's variety of meals. Private dining or function rooms available. Total seating not less than hotel bed capacity. Snack bar/ coffee shop. Highest standards of cuisine and services.
9	Conference facilities	-	-	At least one small conference room with a seating capacity of at least 30: one banquet hall.	Meeting and conference rooms with appropriate conference facilities at least seating capacity of 30. Multi-purpose function halls/rooms.	Several meeting and conference rooms with appropriate conference facilities at least seating capacity to 50.
10	Sport	-	-	Swimming pool manned by a life guard. Life-guard shall be present on public beaches used by the hotel.	Sauna or swimming pool manned by a life-guard or health club or a combination. Tennis court or other.	Sauna gymnasium health club swimming pool/paddles pool tennis court.

Source: Nigerian tourism development Corporation

2.7.2.1 One- star hotel

Hotels in this classification are likely to be small and independently owned, with a family atmosphere. Services may be provided by the owner and family on an informal basis. There may be a limited range of facilities and meals may be fairly simple. Lunch, for example, may not be served. Some bedrooms may not have en suite bath/shower rooms. Maintenance, cleanliness and comfort should, however, always be of an acceptable standard.

2.7.2.2 Two -star hotel

In this classification hotels will typically be small to medium sized and offer more extensive facilities than at the one star level. Some business hotels come into the two star classification and guests can expect comfortable, well equipped, overnight accommodation, usually with an en-suite bath/shower room. Reception and other staff will aim for a more professional presentation than at the one star level, and offer a wider range of straightforward services, including food and drink.

2.7.2.3 Three- star hotel

At this level, hotels are usually of a size to support higher staffing levels, and a significantly greater quality and range of facilities than at the lower star classifications (see plate 2.10) Reception and the other public rooms will be more spacious and the restaurant will normally also cater for non-residents. All bedrooms will have fully en suite bath and shower rooms and offer a good standard of comfort and equipment, such as a hair dryer, direct dial telephone, toiletries in the bathroom. Some room service can be expected, and some provision for business travellers.



Plate 2.10: Arabian park hotel. Source: (http://www.hoteldesign.com)

2.7.2.4 Four- star hotel

Expectations at this level include a degree of luxury as well as quality in the furnishings, decor and equipment, in every area of the hotel. Bedrooms will also usually offer more space than at the lower star levels, and well designed, coordinated furnishings and decor. The en-suite bathrooms will have both bath and fixed shower. There will be a high enough ratio of staff to guests to provide services like porter age, 24-hour room service, laundry and dry-cleaning. The restaurant will demonstrate a serious approach to its cuisine (See plate 2.11)



Plate 2.11: Four points shetaton, Lagos. Source: www.designarch.com

2.7.2.5 Five- star hotel

These hotels are characterized by spacious and luxurious accommodation throughout the hotel, matching the best international standards (Plate 2.12). Interior design should impress with its quality and attention to detail, comfort and elegance. Furnishings should be immaculate. Services should be formal, well supervised and flawless in attention to guests' needs, without being intrusive. The restaurant will demonstrate a high level of technical skill, producing dishes to the highest international standards. Staff will be knowledgeable, helpful, well versed in all aspects of customer care, combining efficiency with courtesy.



Plate 2.12: Wynn hotel casino resort. Source: www.travelmodule.co.uk

2.7.2.6 Six -star hotel

Some members of the hospitality industry have claimed a six star rating for their operation. One example is the Crown Macau, on Taipa Island in the Chinese territory of Macau (Plate 2.13). Another is the St. Regis Shanghai Hotel in China, The Oriental Bangkok in Thailand. Other examples include the Emirates Palace in Abu Dhabi and the Al Husn Hotel at Shangrila's Shangri-La Barr Al Jissah Resort and Spa Hotel in Oman. The Palazzo Versace, on the Gold Coast in Australia is described by Australian Traveller magazine as meriting "six star" rating though level of rating is not used in Australia.



Plate 2.13: crown macau, Tapia Island China. Source: Crown Macau, 2015

2.7.2.7 Seven -star hotel

Currently, the Burj Al Arab (Plate 2.14) is the only; "seven star" hotel in the world but several "7-Star" hotels are under construction. These include the Laucala Island in Fiji, Morgan Plaza to be finished in Beijing (China) in March 2008, the Flower of the East under construction in Kish, Iran, The Centaurus Complex under construction in Islamabad, Pakistan and the Pentominium, the Grand Chola in Chennai (India), a complex planned for Metro Manila and The Royalties Castle for Davao City in the Philippines.



Plate 2.14: Burj Al Arab. Source: www.travelmodule.co.uk

2.8 Hotel and Energy Use

The hotel industry is one of the leading growth sectors of the economy and constitutes one of the most energy and resources intensive branches of the tourist industry, therefore, has created an increasing amount of stress on the environment according to (Bohdanowicz, 2006). He further claims that services hotel offered rarely incorporate resource efficiency or conservation leading to a significant used of energy and water leading to global warming and climate change (Bohdanowicz, 2006). Furthermore, Ampatzi (2009) also claims that the energy efficiency of most hotel facilities are frequently low, and the resulting environmental impacts are typically greater than those caused by the excessive consumption of local/imported resources (e.g., water, food, electricity and fuels) as well as by emissions released to air, water and soil.

Heating, air conditioning, ventilation and cooling systems typically account for a major and frequently the largest portion of the energy consumed in a hotel (CADDET, 1997). About half the electrical energy is used for space conditioning purposes. Depending on the category of the establishment, lighting may amount up to 12-20%, and in some

cases up to 40% of the total energy consumption (EU, 1994). The demand for domestic hot water varies appreaciably with hotel category (90-150 litres per guest per day) EU (1994). Supplying DHW typically accounts for up to 15% of the total energy demand. For a medium category hotel with an average annual occupancy rate of 70%, this translates to an average annual consumption of 1500 to 2300kwh/room (EU, 1994).

2.9 Design Considerations for Hotel Design

According to Automobile Association (AA), (2011) the following are to be considered in the design of hotels

2.9.1 Building location:

- The building should be located to offer the best possible visibility from main roads or streets.
- Public entrances to the property should be conveniently located for approach by vehicular traffic.
- Separate service entrances to the main building are required.

2.9.2 Approach to the building

- The approach to the building entrance should be clearly defined.
- The surfaces should be firm and even with a finish which is slip resistant in all weather condition.
- The width of the paths should be appropriate to meet the needs of the users. A recommended clear width of 1800mm will allow two wheelchair users to pass each other on path, however where obstacles are unavoidable and 1800,, width cannot be provided, a clear width of at least 1200mm should be provided throughout the path.

- Any kerbs in the route should have appropriate drop kerbs to allow access to the wheelchair.
- There should be a landing of at least 11800mm x 1800mm immediately next to the door.

2.9.3 Building exterior

- The building must have finishes and detailing that presents a cohesive architectural style or regional architectural or historic styling.
- Unique architectural concept or finishes is required.
- Pitched roof should have varying planes to eliminate the appearance of excessively large areas.
- Flat roofs should have raised parapets to screen rooftop equipments or structures that are not intended to be part of the elevation

2.9.4 Landscaping

- The entire site should be attractively landscaped, where conditions allow, with ground cover, lawns, shrubs, and trees.
- Landscaping should include abundant specimen quality trees and shrubs.
- The materials to be used should require minimal maintenance, such as low-growing or dwarf plants, rather than plants requiring frequent punning.
- The style should be consistent with architectural style, of good quality, and up-to-date.

2.9.5 Parking lot/ driveways

- Parking spaces and driving lanes are to be clearly marked and adequately illuminated.
- Guest parking should be as close as possible to room locations.

- Adequate additional parking and loading space for delivery and service vehicles is required.
- Parking areas should have large - scale, in-ground landscaping.
- Landscaping should cover 15% of the paved area creating breaks with landscape islands or other features.

2.9.6 Trash dumpster and service areas

Dumpsters, grease traps, and service areas should be screened from view. A reinforced concrete entry is recommended to support heavy trash trucks.

2.9.7 Fire safety

- All escape routes should be clearly indicated, not obstructed and available for use at all times.
- The external areas at or near exists should not be obstructed.
- Designate routes should be at least 1200mm wide, to ensure to ensure a wheel chair user and an able bodied person are able to pass each other along the route.
- The route should be free of steps or sudden changes in level.
- Two independent sources of water at specified pressure for firefighting are provided. There exists on the one hand, water hydrants linked with the mains supply and on the other hand, a high level storage tank.

3.0 RESEARCH METHODOLOGY

The purpose of this chapter is to introduce the research strategy and the empirical techniques applied in order to explore the principles of biomimicry design in hotels. In this research, case studies were conducted using qualitative approach to examine the reflection of biomimicry design principles in the design of hotel in an attempt to enhance passive cooling.

3.1 Case Studies

A case study may refer to both research method and unit of analysis, which involves the study of examples as case of being researched (Oluigbo, 2010). Case study in architecture begins with a documentation of the physical characteristics of the case (Oluigbo, 2010). Case studies allow one to present data collected from multiple methods (i.e., surveys, interviews, document review, and observation) to provide a comprehensive record of the structures under consideration.

The assessment will be conducted through visual surveys, observation, and a checklist on the application of biomimicry design principles under study. As earlier outlined these principles are natural form, exploring the application of natural processes and learning from ecosystem. The cases studied were

- Le meridian Ibom hotel, Akwa Ibom
- Sheraton hotel, Abuja
- Transcorp Hilton hotel, Abuja

3.2 Criteria for Selecting Case Study

Case study selection is comparable to sampling in a quantitative research and that those cases are usually purposively selected (Veal, 2006 in Oluigbo, 2010). This suggested that cases are identified for study due to their inherent qualities which were in consonance with the phenomenon under investigation (Oluigbo, 2010).

The case studies selected for this study would be sampled purposely on two bases (as seen in Table 3.1).

i. As tourism facility with adequate coverage in scope of facilities required to operate as a standard hotel facility.

ii. As a facility that possesses some Biomimicry design feature.

Table 3.1: Case study selection criteria

Case studies	Scope of facility	Biomimicry design features
Le meridian Ibom hotel, Akwa Ibom	Recreational facility, restaurants, guest rooms, golf club house, shops, conference room, outdoor facilities.	Sky, garden, Retention of plants, recyclable building material, photo chromic, minimal cover of site with impervious ground cover, onsite treatment plant.
Sheraton hotel, Abuja	Casino, conference hall, event facilities, conference hall, restaurants, shops.	Recyclable building material, photo chromic, trees to control micro climate.
Transcorp Hilton hotel, Abuja.	Night club, casino, fitness and gymnasium, conference centre, restaurants, shops, guest room.	Retention of plants, recyclable building material, photo chromic, minimal cover of site with impervious ground cover, onsite treatment plant.

Source: Field study, 2016

3.3 Data Collection

Case studies in architecture begin with a documentation of the physical characteristics of the case, and for theoretical research they may require the use of general methods of data collection (Oluigbo, 2010). Theory could be absent from studies which focus on describing the case and its issues. The use of multiple sources of data in order to capture the complexity of cases is one of the defining characteristic of case study methodology (Yin, 2004; Veal, 2006; Johansson, 2010 in Oluigbo, 2010).

3.3.1 Methods of data collection

For the purpose of this study, the method of data collection will be; visual survey and checklist of the level of application of biomimicry design principles on the cases studied.

3.3.1.1 Visual survey

This is a method of data collection in which the eyes is used to study and observe. This survey must be guided by literature review guidelines. It can be documented through photographs, sketches, notes, written reports, etc.

3.3.2 Instruments for data collection

Writing a research report is incomplete without describing the instruments and how they were validated. There are many different types of instruments which can used to collect data from a case study. The case studies for theoretical research in Architecture may require the use of general methods for data collection (Oluigbo, 2010). The use of multiple sources of data in order to capture the complexity of cases is one of the defining characteristic of case study methodology (Yin, 2004; Veal, 2006; Johansson, 2010 in Oluigbo, 2010). For the purpose of this study, the instruments that were used for the collection and documentation of data were Photographs, sketches, and notes.

3.3.2.1 Photographs

Photographs were taken of relevant case studies to ascertain the features of bio mimicry in architecture they possess as well as the extent, to which they were applied, that is to say, if their extent of application was strong, weak or non-existent.

3.3.2.2 Sketches

Sketches were made of some parts of the selected case studies. These sketches showed the spatial organization of some of the case studies.

3.3.2.3 Notes

These notes where in form of field forms outlining the variables of bio mimicry in architecture as it relates to hotels and some other public building types.

3.4 Variables of Study

The case studies would be assessed using the following variables:

3.4.1 Principle 1: use of natural form

Here the variables used are extracted from the principles of natural form architecture.

i. Building form (form and flow) exterior:

a) Symbolism

b) Geometry.

ii. Building's Relationship to site

3.4.2 Principle 2: Application of natural processes

3.4.2.1 Use of free energy

Variable

- **Energy/power sources:** This entails the use of renewable energy sources.
    i. Use of high performance integrated photovoltaic façade systems
    ii. .Building integrated wind turbines, wind tunnels and shafts.

3.4.2.2 Use minimal energy and materials: This principle encourages the minimal use of non-renewable construction materials and other resources that are not recyclable. (governor's green government council, 2007). There are three variables under the use of minimal energy and materials which include adaptability and energy saving property of building materials to the environment, use of recyclable and biodegradable building materials and smart materials.

Variables

- **Adaptability and energy saving property of building materials to the environment**
    - **i.** Use of low thermal conductive building envelope materials such as Rasta Thastyron panels
    - **ii.** Use of double or triple pane low e-glazing.
    - **iii.** Use of high performance low e-glazing to minimize energy consumption.
    - **iv.** Use of sensors, controls and design circuits can be incorporated so that lighting fittings can be turned off independently when day lighting is sufficient.
    - **v.** Use of solar water heating
- **Use of building materials that are recyclable and biodegradable**
    - **i.** Use of recycled or recyclable thermally efficient composite roof panels.
    - **ii.** The use of bio based materials and finishes such as various types of sheathing and insulating agriboards, these biodegradable materials do not contaminate the air or water with gases or hydro soluble substances.
    - **iii.** Use of recycled building materials such as Thastyron Rastra panels, the essence is to reduce waste pile up in landfills.
- **Application of Smart Materials**
    - i. Control of conductive heat transfer through the building envelope.
    - ii. Control of interior heat generation using phase change materials.
    - iii. The use of Secondary energy supply systems and optimization of lighting system

3.4.2.3 Adapt and evolve: Nature evolves by responding to its environmental needs and finding solutions that work.

Variables:

- **Locally attuned and responsive:**
    i. The use of courtyards to create a pleasant and comfortable environment for its occupants.
    ii. Enhancing natural ventilation via stack effect using operable windows and provision of fresh air via sky gardens.
- **Resourceful and opportunistic:**
    i. The use of trees to control micro climate and applying natural vegetation to control soil erosion.
    ii. Applying the integration of Cyclic processes in energy and material consumption, creating sustainable systems.
    iii. Applying the use of photovoltaic façade systems and integrated wind turbines to maximize the available local renewable energy source

3.4.3 Principle 3: learning from the ecosystem

3.4.3.1 Enhance the biosphere

There are three variables in other to enhance the biosphere which include water harvesting, channelling and filtration technique, natural hydrological systems, and methods of water conservation.

Variables

- **Water harvesting, channeling and filtration technique**

  Harvesting, processing and recycling rainwater, site storm water, and building gray water and identification of appropriate uses within the building and site.
- **Natural hydrological systems**
    i. Minimal alteration of natural water cycle through building improvements that closely emulate the site's natural "pre-development" hydrological systems.

ii. Use of on-site treatment plants to enable recycles of grey water.

iii. Use of pervious ground cover to support on-site water retention and recharge.

- **Methods of water conservation**

i. Use of on-site treatment systems that enable use of rain water for hand washing, greywater for toilet flushing, rain and storm water for site irrigation, cooling tower make-up and other uses.

ii. Design and location of buildings and site improvements to optimize use of low-impact storm water technologies such as bio-filtration ponds, 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 ground water recharge or evapo-transpiration.

3.5 Data Analysis and Presentation

Analysis of data collected on the visual survey and observation is based on the descriptive accounts as observed, and noted via the instruments of data collection (Veal, 2006). The data obtained during the field survey is presented through sketches, notes and photograph translating the study into more themes. The field survey addressed listed variables. The checklist is analysed and the data presented in a tabular form. The checklist of the variables analysed was developed so that the studied data can easily be extracted. The data analysed during the survey was tabulated with each variable. The table highlights the principles which were used to define the design concept and the way the biomimicry concepts were considered in all the cases

4.0 CASE STUDY FINDINGS AND RESULTS

The aim of this case study is to find out the extent to which biomimicry principles has been applied in the design of hotels in other to evaluate the biomimicry potential of existing hotels. The data retrieved from the cases studied are described and a checklist is employed to access and record if the said principle was applied.

4.1 Case Study One: Transcorp Hilton Hotel, Abuja



Plate 4.1: perspective view of Transcorp Hilton hotel, Abuja. Source: Field study, 2016

4.1.1 Background

Transcorp Hilton hotel (a five star hotel) is located in the heart of Nigeria's Federal capital precisely the Wuse district (Plate 4.1). The name Transcorp Hilton was derived from the abbreviation of the name of the owning company translational corporation and Hilton Corporation that is running the hotel on management contract. The hotel was a joint venture between National Insurance Corporation of Nigeria (NICON) hotels Ltd and NOGA hotels int. Ltd and Hilton international as Management Company.

The construction of the building started on March 1982, and was completed and commissioned by then president (IBB) and commander- in- chief of the Armed forces of Nigeria, ably represented then by Admiral Patrick Koshoni on August 15, 1987.

Transcorp hotel provides various indoors and outdoors facilities which include 695 rooms, 4 restaurants, 3 bars, nightclub, casino, 24 meeting rooms, large congress hall, 3 outdoor floodlit tennis court, 3 squash courts, business centres, coffee & pastry`shop, fitness centre, national & international communication facilities, outdoor swimming pool.

4.1.2 Building relationship to site

The structure and other supporting facilities are planned in such a way that it blends with the natural topographic formations (as seen in plate 4.2). The landscape of the hotel environment creates this feeling of being at home with nature which also gives a warm reception to guests and takes them from the entrance gate through the congress hall to the porte-cochere. The hotel has large site area well landscaped with the green areas and hedges, paved parking area and a number of large tress which improve the microclimate within the building (See plate 4.3)



Plate 4.2: Building following the topography of the site. Source: Field study, 2016



Plate 4.3: Trees to control microclimate. Source: Field study, 2016

4.1.3 Building form

The hotel replicated and conserved a Y- shaped conceptual form both on plan and the facades. The use of architectural elements such as; large slanting buttresses spanning from ground floor to second floor and a rhythmic succession of horizontal and vertical shading devices that gives the structure an elegant look (See plate 4.4)



Plate 4.4: Slanting buttrees. Source: Field study, 2016

4.1.4 Reusability of building materials

The structure composition is a combination of concrete and steel frames, the horizontal and vertical members are of reinforced concrete. The fenestrations are mainly of steel and glasses shaded with horizontal and vertical reinforce concrete (See plate 4.5) and the outdoor relaxation area has thatch roofing system (See plate 4.6) The wall finishes are more of allucobond with some part having pre-cast concrete panels.



Plate 4.5: horizontal and vertical reinforced concrete for shading the window. Source: Field study, 2016



Plate 4.6: Use of thatched roof system for the swimming pool area. Source: Field study, 2016.

4.1.5 Energy and energy sources

The facility runs on a standby diesel engine power generator as the source of the electric power. Power from the national grid is seen to be unreliable following the epileptic nature of supply. There is no renewable source of energy seen in any manifestation.

4.1.6 Water sources and management strategies

The main source of water here is an onsite bored hole, from which water is pumped to the reservoir (as seen in plate 4.8) and water ia also being supplied from water board. An onsite water treatment plant (See plate 4.7) exist which is used to treat water collected from the building, for use in various facilities of the hotel.



Plate 4.7: Water treatment plant. Source: Field study, 2016



Plate 4.8: Reservior. Source: Field study, 2016

4.1.7 Case Study Critique

Merits:

i. The hotel site is properly landscaped with guest relaxation and recreational facilities and extensive parking spaces properly zoned.

ii. The Architectural statement of the hotel is direct; the form has been handled to give the building its own special character and appeal.

iii. The combination of steel frames with concrete gives the building a strong and impressive character.

iv. The interior is lavishly furnished to the highest taste and is indeed welcoming and classy.

v. The hotel scale justifies the choice of form in keeping with the 12 storey height limit of Abuja.

vi. Disabled guests were considered by providing prominent ramps and specially designed rooms for them.

vii. The guest rooms are tastefully furnished.

Demerits:

i. The site of the hotel is too brisk and inhumane for the casual guest and does not allow for people on vacation and tourists to enjoy their stay.

ii. The hotel rooms have no balcony, thus making it impossible for the guest to have a semi-physical contact with the immediate landscape and environment.

iii. There is no direct link between the administration and the service areas. There is no direct link between the service areas and the public areas without going through the kitchen.

iv. The fire escapes in the guest room wings are not adequate.

v. The hotel depends so much on mechanical system of lighting and ventilation (it is too synthetic), therefore its green building rating is not commendable.

Table 4.1 Assessment of Application of Biomimicry Principle One at Transcorp Hilton Abuja hotel

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORM						
Variables	**Features**	**Level of reflection**				**Justification**
		Abs	Low	med	Hi	
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	0				No natural form was mimicked
	Geometry adopted to achieve the form	0				
Building's Relationship to site	Use of materials indigenous to site	0				

Source: Field study, 2016

Table 4.2 Assessment of Application of Biomimicry Principle Two at Transcorp Hilton Abuja hotel. Source: Field Study, 2016.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION OF NATURAL PROCESSES						
Variables Features		**Level of reflection**				**Justification**
		Abs	Low	Med	High	
Energy/power source	Integrated photovoltaic façade systems	0				Nil
	Building integrated wind turbines, wind tunnels and shafts.	0				Nil
Energy conservation	Automated operable windows	0				Nil
	Solar water heating, Use of sensors, controls and design circuits.	0				Nil
	low e-glazing or double pane glazing	0				Nil
Re-usability of Building materials	Use of recyclable or reusable building materials,			2		Steel, concete, thatch roof.
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation e.g. phase change materials	0				Nil
	Secondary energy supply systems and optimization of lighting system	0				Nil
Environmental Response to design features	Day lighting, the use of Skylights.	0				Nil
	Natural ventilation via stack effect.	0				Nil

Table 4.3 Assessment of Application of Biomimicry Principle Three at Transcorp Hilton Abuja hotel. Source: Field study, 2016.

BIOMIMICRY PRINCIPLE 3: LEARNING FROM ECOSYSTEM						
Variables		**Level of reflection**				**Justification**
Features		Abs	Low	Med	Hi	
Source of water	Source of water is a bore hole drilled on site.				3	Bore hole drilled on site
	Effort at harvesting, processing and recycling rainwater.		1			
	Use of on-site storm water treatment and ground water recharge		1			
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.			2		most of the native plants such as oil palm were retained
	Construction of structures to follow the topography of the site				3	Minimal cut and fill of the site.
Regenerative site, design	The use of trees to control micro climate				3	Presence of trees in the site
	Use natural vegetation to control soil erosion			2		The trees are planted in a well aligned pattern
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.				3	More than 80% of total site area is pervious to rain water.
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling			2		use of water management and waste recycling
Water conservation Methods	On-site treatment plants				3	There is an on-site water treatment plant for the recycle of grey water.

4.2 Case study Two: Sheraton Hotel, Abuja.



Plate 4.9: Approach of Sheraton hotel, Abuja. Source: Field study, 2016

4.2.1 Background

Abuja Sheraton Hotel is conveniently located in the heart of the Federal Capital of Nigeria (Plate 4.9); the hotel is only 40 kilometres from the Nnamdi Azikiwe International Airport and is nestled within the many tourist sights and sounds of Abuja. The Hotel was designed by Skidmore, Owings & Merrill Architects, Chicago. The building exterior is just a prelude to the spectacular space inside, 14 stories high; day lighted by an open atrium enclosed by the projecting balconies creates an exciting dramatic effect. The focal point for this splendours space is the enclosed garden standing close to a pool of quiet water, trees, shrubs, flowers and the patterned paving of the floor. People are always there getting a feel of the social space.

4.2.2 Building relationship to site

The integration of the hotel design into the natural landscape has a naturalistic aesthetic appeal to most visitors. The site area well landscaped with the green areas and hedges (as seen in plate 4.10) paved parking area and a number of large tress which improve the microclimate within the building (See plate 4.11)



Plate 4.10: Integrating Sheraton hotel into natural landscape. Source: Field study, 2016



Plate 4.11: Tress for controlling microclimate. Source: Field study, 2016

The building was designed in three segments but linked together making the hotel spatially one structure which has a spacious and centralised enrance porch (See fig 4.1). The network of pathways within the hotel facility is well zoned preventing conflict between human and vehicular traffic. The drive way to the hotel leads directly to the customer's parking. Behind the hotel features the hotel's recreational facilities which include the lawn tennis courts, swimming pool, and Casino etc. The ground floor houses the reception, bar, restaurants, shops, travel agency, art gallery, conference rooms, casino, while the first floor houses the hotel offices, meeting rooms, more shops.

The rooms are located on all the floors of the hotel's two arms. it has 216 rooms available to visitors for lodging and accommodation of which there are 26 classic single Rooms, 142 Superior double Rooms, 36 Deluxe Rooms, 9 Executive Suites, 2 Diplomatic Suites and 1 Presidential Suite.



Figure 4.1: Site plan and hotel layout. Source: Field study, 2016

4.2.3 Building form

The rectangular floor plans are linked together by open courtyards (See plate 4.13) which promotes natural ventilation and lighting into the hotel spaces. The building has a structural grid framework of columns and beams, demarcating spaces and floors



Plate 4.12: Courtyard showing the garden. Source: Field study, 2016

4.2.4 Reuseability of building material

The structure is made of concrete structural insulated panels (See plate 4.14) make up the sunshade panels on the reinforced concrete structural frame. The fenestrations are of glass and steel (See plate 4.15) while the swimming pool has a surrounding sit out that is roofed with grey tiles roofing sheets (See plate 4.16) laid on steel purlines.



Plate 4.13: Concrete insulated panels Source: Field study, 2016



Plate 4.14: Glass and steel material. Source: Field study, 2016

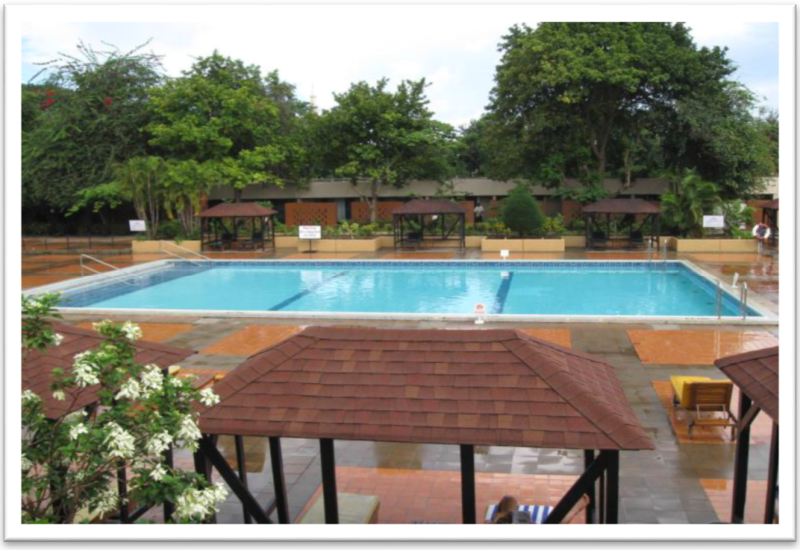


Plate 4.15**:** Swimming pool area in Sheraton hotel, Abuja. Source: Field study, 2016

4.2.5 Energy and energy sources

Sheraton hotel runs on dual dependency partly on the power supply from the national electric grid and almost totally on the diesel engine power plant installed on site. There is no use of renewable source of energy.

4.2.6 Water source and management strategies

The main source of water to the facility is an onsite bored hole from where water is pumped reservoirs. This is distributed to the building and facilities around the hotel as the main source of water, to meet the demand for water. Also there is no rainwater harvesting, and management strategy present.

4.2.7 Case Study Critique

Merits:

i. The form of the hotel is so interesting that it charms many guests to the hotel. It allows for cross.

ii. The rooms all have balconies which allow the guests to get in touch with the natural environment.

iii. ventilation and natural lighting. What is splendid about the architecture of this hotel is the spatial transition from the lobby to the Courtyard.

iv. The landscaping of the courtyard has a touch of traditional effects with use of indigenous building materials like thatches. The north facing guest rooms are also ideal in order to keep out the intense tropical heat of the area.

Demerit:

i. The atrium is not enclosed, hence, the spaces immediately around and in the courtyard are affected by weather factors.

Table 4.4 Assessment of Application of Biomimicry Principle One at Sheraton hotel Abuja

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORM

Variables	**Features**	**Level of reflection**				**Justification**
		Abs	Low	Med	Hi	
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	0				No natural form/organism is mimicked
	Geometry adopted to achieve the form	0				
Building's Relationship to site	Use of materials indigenous to site	0				

Source: Field Survey, 2016.

Table 4.5 Assessment of Application of Biomimicry Principle two at Sheraton hotel Abuja

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION OF NATURAL PROCESSES						
Variables	**Features**	**Level of reflection**				**Justification**
		Abs	Low	Med	High	
Energy/power source	Integrated photovoltaic façade systems	0				Nil
	Building integrated wind turbines, wind tunnels and shafts.	0				Nil
Energy conservation	Automated operable windows	0				Nil
	Solar water heating, Use of sensors, controls and design circuits.	0				Nil
	low e-glazing or double pane glazing	0				Nil
Re-usability of Building materials	Use of recyclable or reusable building materials,				3	use of concrete, steel and aluminium
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation e.g. phase change materials			2		High performance insulated concrete panels on the building envelope
	Secondary energy supply systems and optimization of lighting system	0				Nil
Environmental Response to design features	Day lighting, the use of Skylights.				3	Use of courtyard system and garden

Source: Field Survey, 2016.

Table 4.6 Assessment of Application of Biomimicry Principle Three at Sheraton Abuja hotel

BIOMIMICRY PRINCIPLE 3: LEARNING FROM ECOSYSTEM						
Variables	**Features**	**Level of reflection**				**Justification**
		Abs	Low	Med	Hi	
Source of water	Source of water is a bore hole drilled on site.				3	Bore hole is drilled on site
	Effort at harvesting, processing and recycling rainwater.	0				Nil
	Use of on-site storm water treatment and ground water recharge	0				Nil
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.			2		Most of the native plants such as oil palm were retained
	Construction of structures to follow the topography of the site				3	Minimal cut and fill of the site.
Regenerative site, design	The use of trees to control micro climate				3	Presence of trees in the site
	Use natural vegetation to control soil erosion		1			Nil
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.				3	More than 90% of total site area is pervious to rain water.
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	0				Nil
Water conservation Methods	On-site treatment plants	0				Nil

Source: Field Survey, 2016.

4.3 Case Study Three: Le Meridian Ibom Hotel, Akwa Ibom



Plate 4.16: Entrance porch of le meridian Ibom hotel. Source: Field study, 2016

4.3.1 Background

Le‟ Meridian Ibom Hotel and Golf Resort is rated as a four star resort hotel (see plate 4.16). The hotel was opened in December 2007, following the Golf Course opening in March same year by Colin Montgomerie, Retief Goosen and Nancy Lopez and is now a premier location for top golf professional tournaments in Nigeria. Le‟ Meridien Ibom Hotel is situated on a hilltop ridge, with spectacular views over the surrounding rainforest stretching to the mountains of Cameroon. The hotel and Golf resort is located along Nwaniba road, Uruan, Uyo, Akwa Ibom state, Nigeria. The main facility is a storey building hotel with 163 Rooms and 26 suites. The resort is about 45 minutes‟ drive from Umuahia, 90 kilometers from the Calabar Airport and 160 kilometers from the Port Harcourt Airport, It is owned by the Akwa Ibom state government but presently managed by the Le Meridian Group, known also as Starwood Hotels.

4.3.2 Building relationship to site

The resort is nestled on a hilltop amidst a palm- tree forest, with efforts directed towards its incorporation to the rain forest landscape in an ecologically friendly manner. Because of the location of the resort, there is deliberate incorporation of the facility into the surrounding natural landscape greenery. The facility consists of a large built up area, spreading horizontally in various directions and a single storey vertically (See Fig 4.2). Le‟ Meridien has one hundred hectares of tropical garden, a fitness and health club, outdoor children‟s and adult pools, two Jacuzzis, four standard tennis courts and one hundred and one squash facilities. The garden also adds to the relaxing atmosphere of the complex with a Gazebo overlooking the palm tree forest.

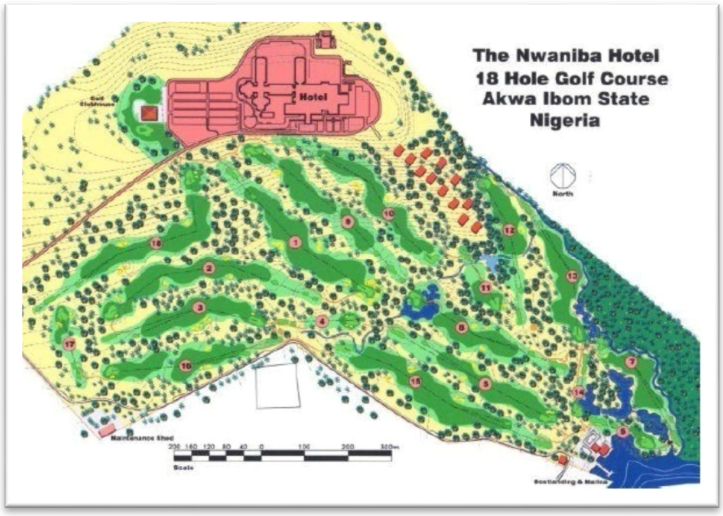


Figure 4.2: Overall site planning and landscaping of le meridien hotel. Source: http://le meridian hotels.com/photo_gallery.htm

4.3.3 Building form

Le‟ Meridien Ibom Hotel and Golf Resort is a magnificent concrete structure amidst hilltop of a tropical rain forest. The structure is zoned into several areas integrated in the same entity. The building has terraced rooms and suites some overlooking the natural greenery, while others the landscaped courtyard (as seen in plate 4.17 below). Within the building, several areas (Accommodation, conference, fitness, bar, dining/ restaurant,

are interconnected making up the large edifice both in form and structure. The resort is known mostly for the services provided. Also no significant local expression can be attributed to the building in form or in structure but for the acclaimed services.



Plate 4.17: court yard of le meridian Ibom hotel. Source: Field study,2016

4.3.4 Resusability of building materials

The building materials used in the Le‟ Meridien consists dominantly of concrete, steel and glass for the main building. Wood is used mostly in the roof construction, and as interior décor. Outdoor gazebos (see plate 4.18) exist which are of local building materials (Bamboo and thatch roof). Also the dominant roofing material is corrugated Aluminum finished sand blast (see plate 4.19 below).



Plate 4.18: Bush bar of le meridian Ibom hotel. Source: Field study,2016



Plate 4.19: Corrugated aluminium sand blast. Source: Field study,2016

The landscaping consists of a mixture of soft and hardscape. The soft-scape consists of green lawns, hedges, shrubs and trees of both local and foreign origin. While the hard-scape consist of asphaltic roads, tiled concrete walkways and interlocking stones, as can be seen in the plate below;



Plate 4.20: Landscaping element of le meridian Ibom hotel. Source: Field study,2016

4.3.5 Energy and energy sources

The main source of electric power to the resort is a heavy duty diesel engine power generator. Power from the national grid is sometimes utilized but this is not depended on as it is usually unstable. Plate 4.21 below shows a view of the heavy duty power generator with its exhaust emitting gaseous substances into the atmosphere.



Plate 4.21: Generator house of le meridian Ibom hotel. Source: Field study,2016

4.3.6 Water sources and management strategies

The main source of water here is an onsite bored hole, from which water is pumped to the reservoir. An onsite water treatment plant exist which is used to treat water collected from the building, for use in various facilities of the resort hotel, except portable water. There is also rain water collection scheme for watering flowers. The image below (Plate 4.22) shows the onsite water treatment plant used for treating waste water, to be reused in the facility.



Plate 4.22: water treatment plant of le meridian Ibom hotel. Source: Field study, 2016.

4.3.7 Case Study Critique

Merits

i. There is a conscious incoperation of the facility into the surrounding natural landscape greeny.

ii. The building has tarrraced rooms over looking the natural greeny and water body bringing the guest closer to nature.

iii. The hotel site is properly landscaped. Low level shrubs and grasses were used to defined the vehicular and pesdestrian movement.

iv. Guest relaxation area is over looking the virgin palm tree forest which creates a relaxing atmosphere and soothing feeling to the guest.

v. The court yards are properly landscaped with trees and low level shrubs which provides adequate cross ventilation and natural lighting through out the facilty.

Demerit

i. There is no direct link between the administration and the service areas. There is no direct link between the service areas and the public areas without going through the kitchen.

Table 4.7 Assessment of Application of Biomimicry Principle One at le meridian Ibom hotel

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORM						
Variables	**Features**	**Level of reflection**				**Justification**
		Abs	low	Med	Hi	
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	0				Nil
	Geometry adopted to achieve the form	0				Nil
Building's Relationship to site	Use of materials indigenous to site	0				Nil

Source: Field Survey,2016

Table 4.8a Assessment of Application of Biomimicry Principle Two le meridian Ibom hotel

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION OF NATURAL PROCESSES						
Variables	**Features**	Level of reflection				Justification
		Abs	Low	Med	High	
Energy/power source	Integrated photovoltaic façade systems	0				Nil
	Building integrated wind turbines, wind tunnels and shafts.	0				Nil

Table 4.8b: Assessment of Application of Biomimicry Principle Two le meridian Ibom hotel

Energy conservation	Automated operable windows	0			Nil
	Solar water heating, Use of sensors, controls and design circuits.	0			Nil
	low e-glazing or double pane glazing	0			Nil
Re-usability of Building materials	Use of recyclable or reusable building materials,		2		use of concrete, steel and aluminium, wood
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation e.g. phase change materials	0			Nil
	Secondary energy supply systems and optimization of lighting system	0			Nil
Environmental Response to design features	Day lighting, the use of Skylights.			3	Use of courtyard system and graden
	Natural ventilation via stack effect.			3	The use operable windows and provision of fresh air via sky gardens.

Source: Field Survey,2016.

Table 4.9 Assessment of Application of Biomimicry Principle Three le meridian Ibom hotel

BIOMIMICRY PRINCIPLE 3: LEARNING FROM ECOSYSTEM						
Variables	**Features**	**Level of reflection**				**Justification**
		Abs	Low	Med	Hi	
Source of water	Source of water is a bore hole drilled on site.				3	Borehole is drilled on the site
	Effort at harvesting, processing and recycling rainwater.	0				Nil
	Use of on-site storm water treatment and ground water recharge			2		Nil
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.				3	Most of the native plants such as oil palm were retained
	Construction of structures to follow the topography of the site				3	Minimal cut and fill of the site.
Regenerative site, design	The use of trees to control micro climate				3	Presence of trees in the site
	Use natural vegetation to control soil erosion		1			Nil
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.			2		More than 90% of total site area is pervious to rain water.
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	0				Nil
Water conservation Methods	On-site treatment plants				3	There is an on-site water treatment plant for the recycling

Source: Field Survey,2016.

4.4 Data Analysis

As a result of the analysis of data gathered from the various cases studied based on the extent of reflection of biomimicry principles, a degree of variation on the levels of reflection exists among the cases studied

Table 4.10: Summary of case study

PRINCIPLES	CASE STUDY 1: Transcorp Hilton hotel, Abuja	CASE STUDY 2: Sheraton hotel, Abuja	CASE STUDY 3: Le meridian Ibom hotel, Akwa Ibom	Total
USE OF NATURAL FORM	0	0	0	0
NATURAL PROCESSES	4	11	8	23
ECO SYSTEM	25	15	20	50

4.5 Biomimicry Analysis

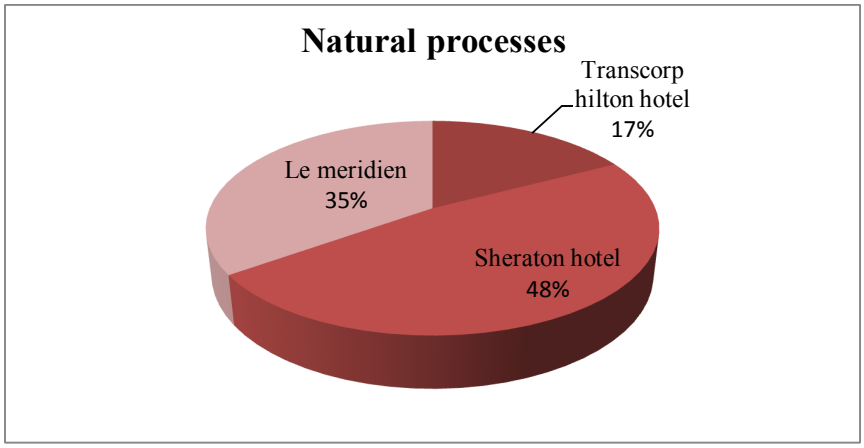


Figure 4.3: Natural processes analysis. Source: Data analysis, 2017.

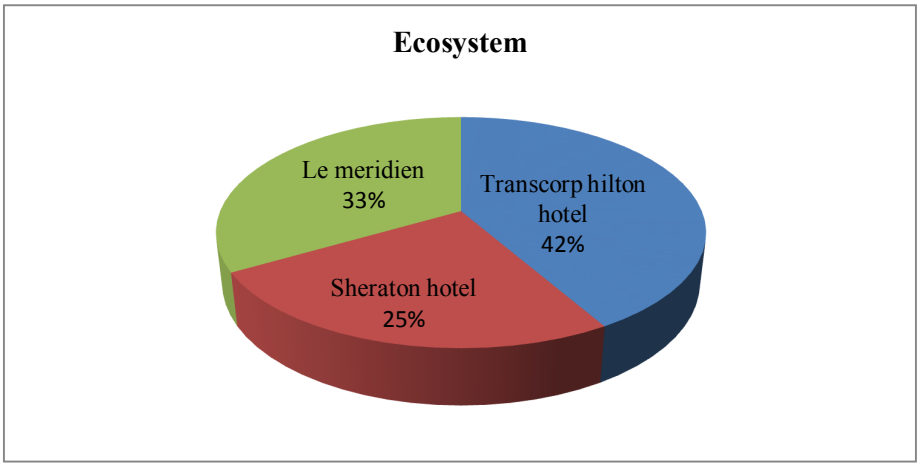


Figure 4.4: Ecosystem analysis. Source: Data analysis, 2017.

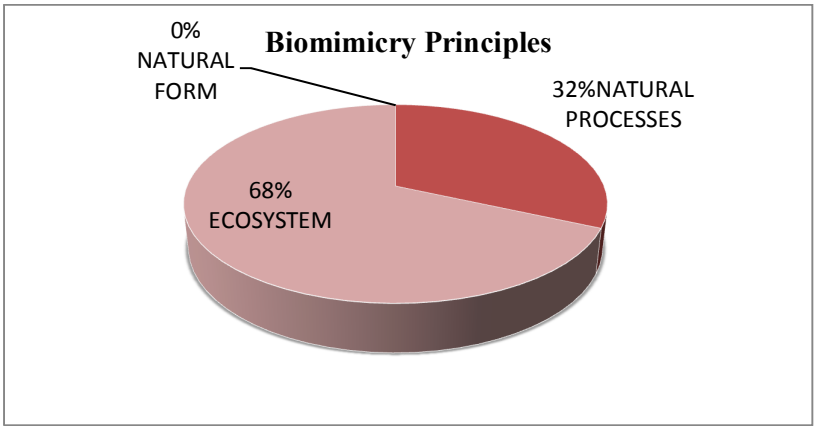


Figure 4.5: Biomimicry analysis. Source: Data analysis, 2017.

4.6 Discussion of Findings

Based on the principle of natural form, transcorp Hilton hotel, Sheraton hotel and le meridien hotel scored 0% due to the fact that none of the cases mimicked any organism. Further more, in the biomimicry principle of exploring the application of natural processes, Sheraton hotel scored highest of up to 48% reflection of natural processes, followed by le meridien hotel with 35% and then transcorp Hilton hotel scores 17%. This shows that sheraton hotel utilizes recyclable building materials,phase change material, daylighting and natural stack effect in the design.

Under the principle of learning from ecosystem, transcorp Hilton has the highest score of up to 42% embedded in the design of the hotel, followed by le meridien with 33%. While Sheraton hotel scored 25%.

From the analysis, it shows that the principle of learning from ecosystem reflected more in the three cases studied about 68%, followed by the application of natural processes with 32%.while the use of natural form was not reflected in all three cases.

4.6.1 Findings from research question one

What features of biomimicry design principles are suitable for achieving comtemporary suatainable design?

In order to address this question, rigorous and in-depth study and research into biomimicry architectural design and principles have been carried out presenting the three biomimicry principles in which each principle are futher sub-divided into various strategies and ways they can be achieved architecturally. The features of biomimicry principles can be seen in table 4.11 below.

Table: 4.11a:Principle of biomimicry architecture and features

PRINCIPLES OF BIOMIMICRY DESIGN	FEATURES
1. **Use of natural form**	• Building form • Building relationship to site
2. **Application of natural processes** • **Use of free energy** • **Use of minimal energy and material** • **Adaptation and evolution.**	• Energy conservation • Re-usability of building materials • Application of smart materials • Environmental response to design features • Energy/power source

Table: 4.11b:Principle of biomimicry architecture and features	
3. **Learning from eco – system** • **Enhance the biosphere**	• Regenerative site design • Minimal alteration of natural hydrological systems • Working with site topography and native elements • Source of water

The goal of biomimicry architecture is to present a suitable solution to the current sustainability predicament without affecting the environment negatively. Hence, it can be seen that the incoperation of biomimicry design features in today's comtempoary designs has great potential to pave way in the production of ecological sustainable designs, zero waste system and a overall regenerative built environment. Thereby not only positively affecting human life as a whole but also working with nature instead of against it.

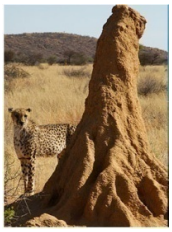
4.6.2 Findings from research question two

How successful have principles of biomimicry architecture been in providing solutions to problems such as passive cooling and energy efficiency around the world?

With today's effort to advance sustainability in built environments, biomimicry is a successful ecological approach for energy efficient buildings. It is a solution based approach which has successfully resolved many environmental issues through architectural inventions in built environment. Table 4.12 below shows examples of projects that represents the recent ways designers have integrated biomimicry in architecture to show the potential impact biomimicry have as a sustainable design practice. These examples have been taken into account with respect to the building

typology, the inspiration from nature considered, their application in design and how the problems got resolved through its application as a design solution.

Table: 4.12: Examples of projects which integrated biomimicry principles

Name of the building	Inspiration	Application in design	Problem solved	Sustainability achieved
East gate center harare 	Termite mould 	The center opens and draws more air to help fans and is pushed up through ducts.	Temperature regulated throughout the year with no need for HVAC systems.	• Energy reduction in HVAC-100% • Allows natural ventilation.
Sinosteel international plaza 	Bee hive 	The windows are designed in five different sizes of hexagon placed in an energy-efficient configuration	-Minimum possible energy used in the form of conservational energy -The skin removes the need for internal structures	• Energy efficiency achieved -75%
Ministry of municipal and agriculture 	Cactus plant 	Sun shades on the windows can be opened or closed to suit the prevailing temperature.	Controls the amount of sunlight entering the building, keeping it cool and flooding room with natural light.	• Temperature regulated • Absorption and loss of heat controlled.
Beijing national stadium 	Bird's nest 	Contains ETFE panels that insulates by stuffing small pieces of materials in the twigs Panels allows sunlight filteration	Facade allow for natural ventilation Panels reduce the dead load supported by the roof	• Cost reduction by 60%, durable and recyclable

From the above examples, it can be concluded that there have been some successful implantation of biomimicry principles in architecture resulting to efficiency in structures, zero waste system, control of thermal environment and energy production.

4.6.3 Findings from research question three

How close do built hotel designs in Nigeria come in realizing biomimicry principles?

The data presentation chapter of this thesis report has given in-depth analysis of data collected from case studies in a bid to address this question. It gave a vivid description of the levels of reflection of biomimicry architecture principles both qualitatively and graphically. The study revealed that features of biomimicry architecture has been applied in small patches amounting to an overall below average reflection of the principles bearing in mind that the goal of biomimicry architecture is an excellent remark which is to harmonize with nature to achieve designs pleasing to the eyes, high – energy efficiency and minimum impact to the natural environment.

In conclusion, knowingly or unknowingly certain biomimicry attributes had been adopted in some aspects of the building design to achieve sustainability in the building.

5.0 SITE SELECTION AND PRELIMARIES

This chapter extensively discussed manifold issues relating to the following: The site, Schedule of accommodation and development of design brief suggesting functional spaces per each unit of the proposed city hotel.

5.1 Site Location

The proposed city hotel is to be located in millennium city, Kaduna state of Nigeria (Plate 5.2). Its coordinates are 10°31'12"N and 7°26'24"E with a total area of 46053km^2. Kaduna state is found in the Northwest of Nigeria and it is characterised with hot-dry climate. It shares common boundaries with Niger state to the west, Zamfara, Katsina, Kano states to the north, Bauchi, Plateau states to the east, FCT Abuja, and Nassarawa state to the south. The site is identified with CO1 as seen in (Plate 5.1)

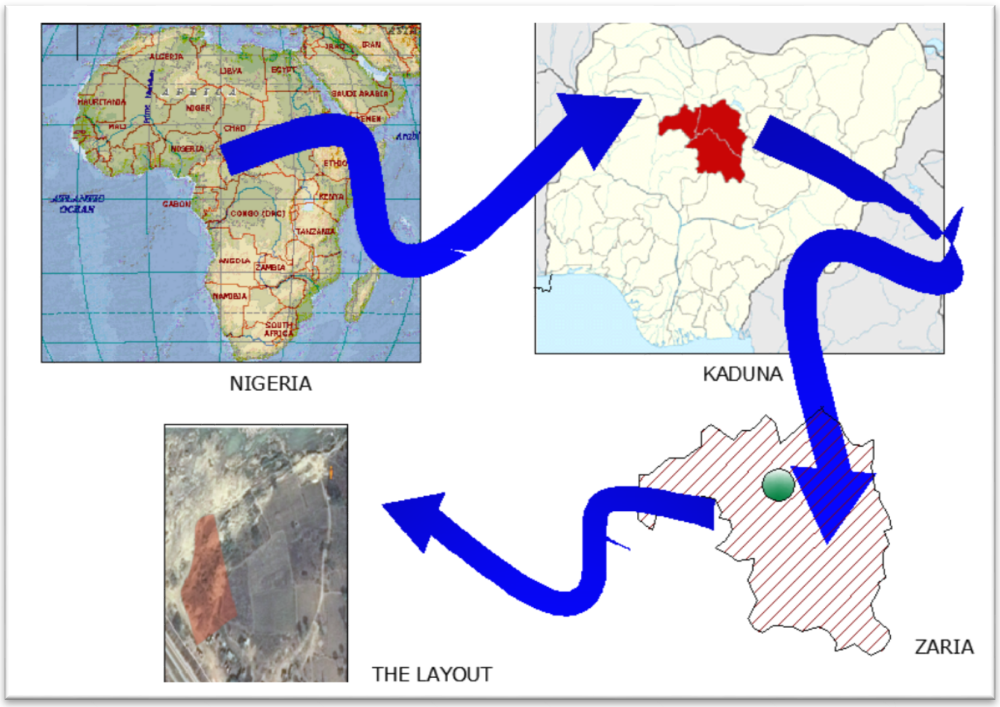


Figure 5.1: Site location. Source: Preliminary Analysis, 2017.

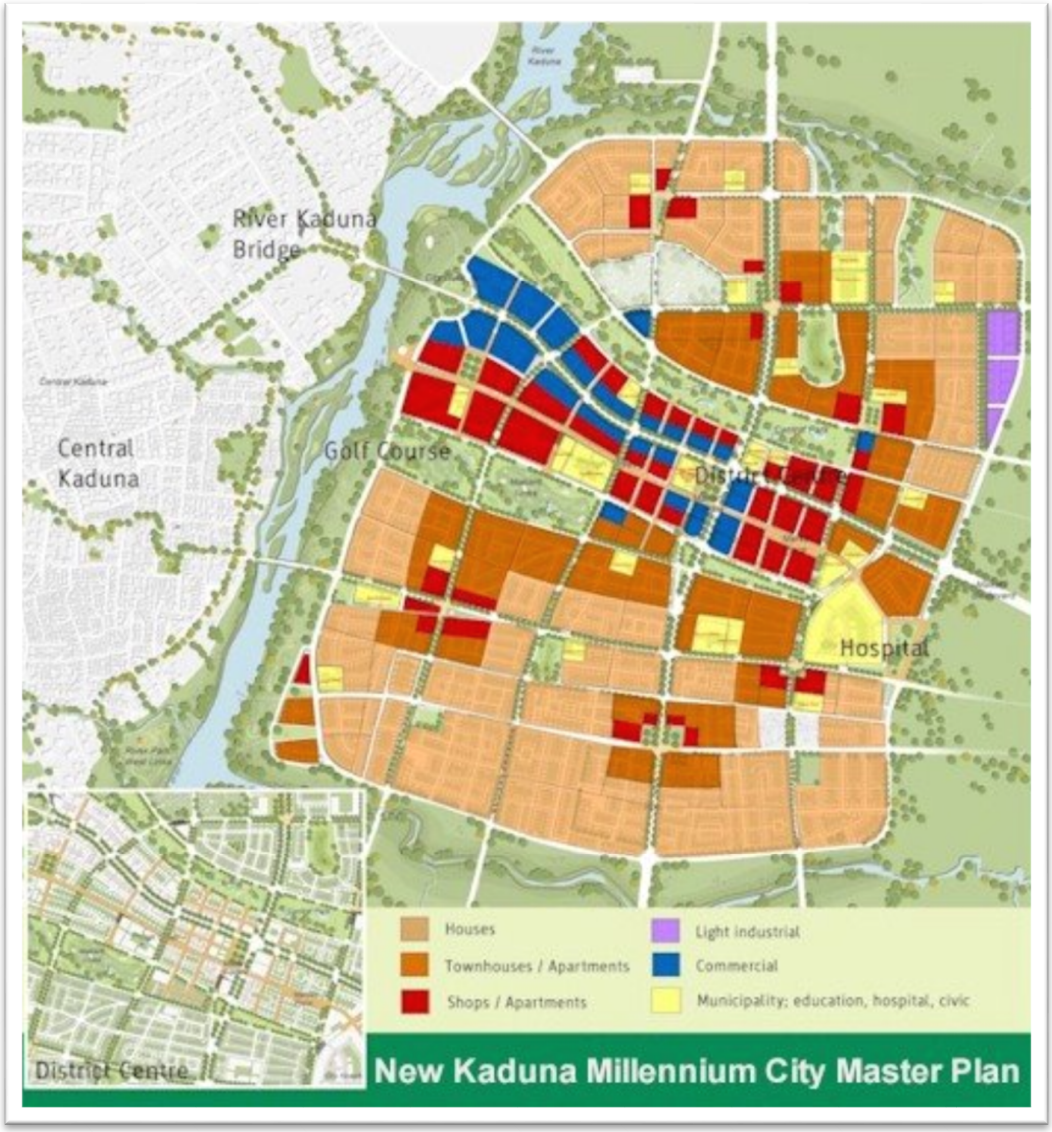


Figure 5.2: Land Use Plan. Source: Preliminary Analysis, 2017.

5.2 Site Selection Criteria

Selection of the most suitable site is important to the development of hotel establishments. Two different sites with suitable conditions at Millennium city were considered. The most suitable site was selected for the development of the proposed city hotel based on the following criteria:

i. Accessibility

ii. Availability of services and utilities

iii. Land use

iv. Expansion potential

5.2.1 Accessibility

The ease of access to the site is considered very important when locating a hotel and should allow for greater vehicular and pedestrian access to and from the city. It is desirable to locate the site close to the city major roads and airport for accessibility by guests.

5.2.2 Availability of services and utility

Sites for development needs good services around it, therefore, availability of services is a perquisite in selecting a site for the development of hotel. Services like electricity or power lines, water supply mains, drainage systems, constructed roads, telephone line, telecommunication networks and other services attract investors and save cost of development.

5.2.3 Land use

Developing a hotel on a site lay-out that complies with the urban development authority land use is important for the success of the establishment. Land use compliance is considered as one of the most important criteria in developing a hotel.

5.2.4 Expansion potential

The site to be selected for the hotel development should allow for future expansion. Over time, new hotel policies and the need to expand the existing hotel facilities may require additional land; therefore it is desirable to select a site with large area of land that will allow for a flexible design and any possible future expansion of the hotel facilities.

5.3 Proposed Site

The site is situated at the new commercial lay-out. It has an irregular shape and relatively flat with large site area (see plate 5.3) It allows for great vehicular and pedestrian access because of the well connected road networks constructed recently and it is linked by tarred road to popular Isa- Kaita road that allow access from other major roads in and out of the city. The site has good view of green areas and water body (Kaduna River)

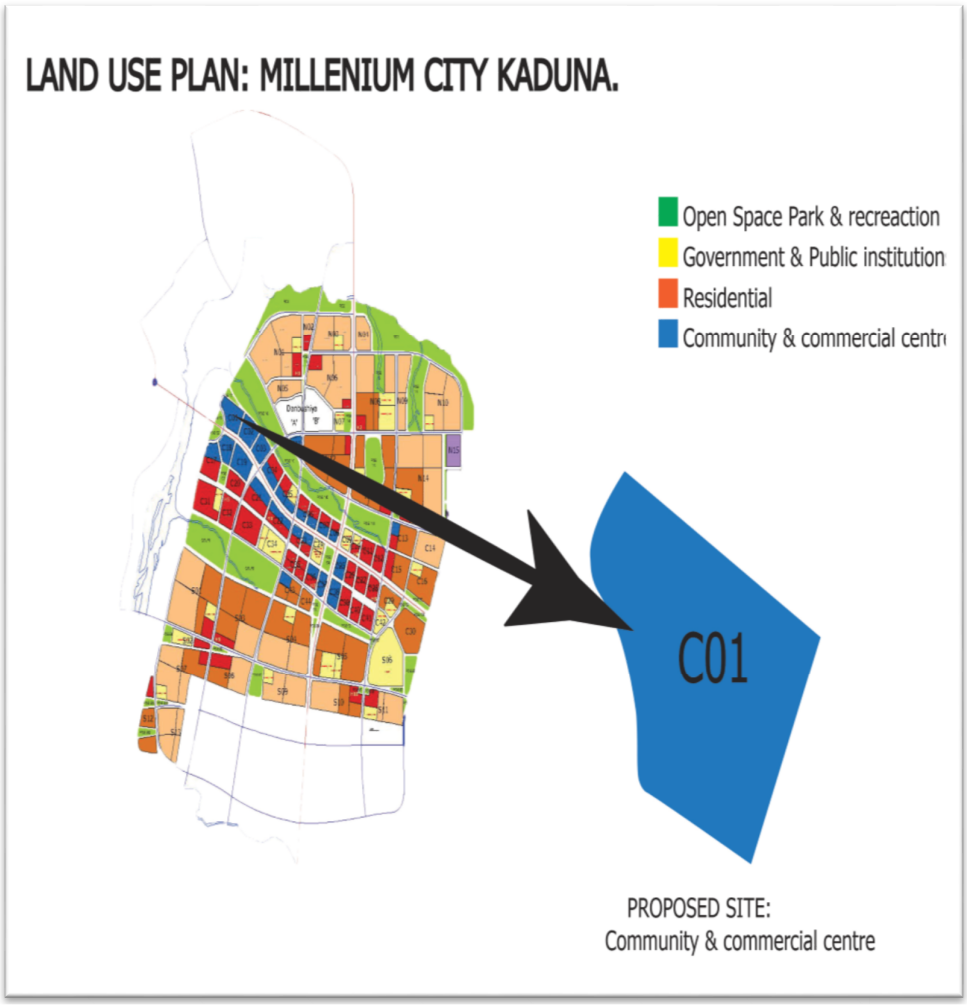


Figure 5.3: Land Use Plan showing proposed site. Source: Preliminary Analysis, 2017.

5.4 Site Analysis

This section covers the analyses of the climatic data of the site (Temperature, wind, Relative Humidity, precipitation, sunshine). It also covers the topography, soil, vegetation, services and neighbouring structures. See figure 5.4 and figure 5.5

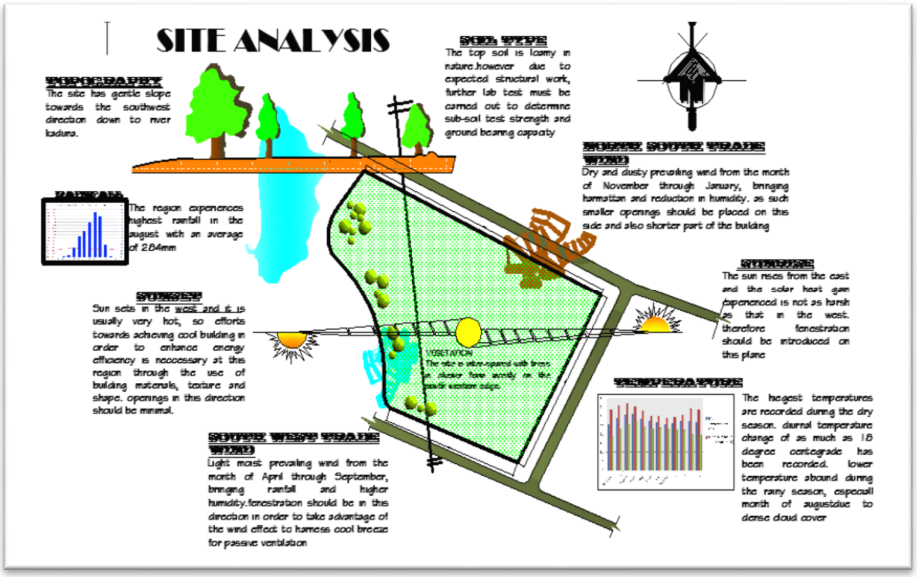


Figure5.4: Site climatic data Analysis.Source: Preliminary Analysis, 2017.

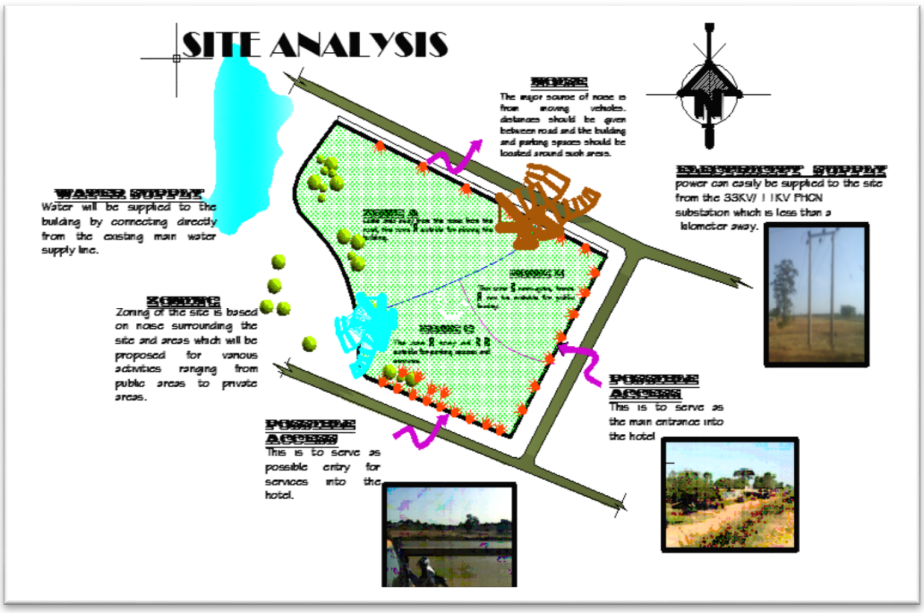


Figure 5.5: Site Analysis (Physical Properties). Source: Preliminary Analysis, 2017

5.4.1 Climate

The climate of Kaduna varies considerably with months and seasons. The cold and dusty hammattan season is experienced during the month of December to February and the hot dry season from the month of March with temperature ranging 34 to 37. The hot dry season is followed by raining season from April to September.

5.4.1.1 Temperature

The study area climate record temperature of up to 37C, with April as the hottest months of the year. The temperature range is between 34C to 37C with a mean temperature of 28C. During the cold month, the mean temperature is about 23C. However, the mean monthly temperature varies between 250C and 320C throughout the year (See figure 5.6).

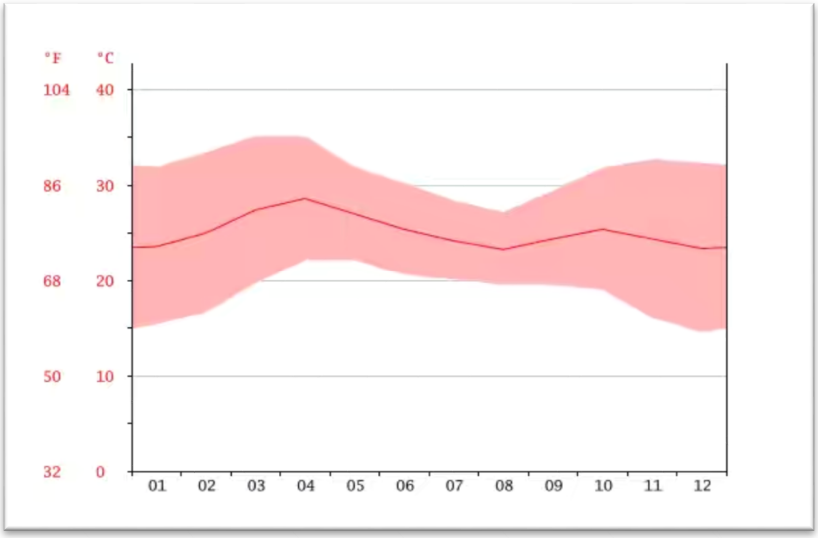


Figure 5.6: Temperature chart of Kaduna.Source: www.gaisma.com

5.4.1.2 Precipitation

There is 0mm of precipitation in the months January and December which are the months with the driest weather no rainfall (see figure 5.7) In August the precipitation reaches its peak (highest rainfall) with an average of 284mm. Annual total rainfall lies within a range of 960mm to 1150mm.

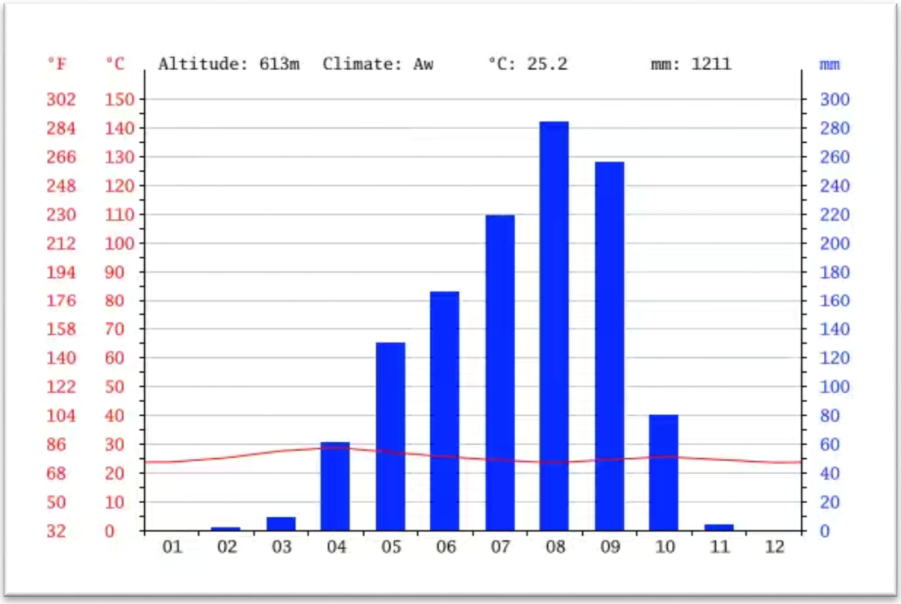


Figure 5.7: Percipitation chart of Kaduna.Source: www.gaisma.com

5.4.1.3 Relative Humidity

At the start of the dry season, relative humidity falls from 68% in October to 36% in November with the stabilization of the easterly winds. It further falls to 35% in January and 20% in February. Mean relative humidity reaches its maximum value of 80% in the month of August.

5.4.1.3 Sunshine

November sunshine hours vary from 8.9 to 9 hours per day. January sunshine hours are quite high, 8.7 to 9.5 hours. Minimum sunshine hours per day occur in August with as low as 5.1 hours per day.

5.4.2 Topograpy and soil

The site is relatively flat and has a gentle slope towards the southwest direction down to the river Kaduna. The top soil is mostly of a loamy nature(see plate 5.1). However due to expected structural work, further lab tests must be carried out to determine sub-soil strength and ground bearing capacity.



Plates 5.1: Topography of the site. Source: Field study, 2017.

5.4.3 Vegetation

The site is interspersed with tress in clusters mostly on the south western edges. (See plate 5.2)



Plates 5.2: Vegetation of the site. Source: Field study, 2017.

5.4.4 Services

The site will be accessed through a proposed road which is connected to the main road leading into the layout via the new completed bridge which connects old Kaduna city and the Millennium city (Makarfi Layout). Power can easily be supplied to the site from the 33KV/11KV PHCN substation which is less than a kilometer away. Also, water supply to the proposed site can be connected directly from the existing main-water supply line.

5.5 Schedule of Accommodation

The schedule of accommodation is produced by comparing the space areas of facilities with the standards from literature and those obtainable from case studies conducted on similar facilities. This is shown in the table below.

Table 5.1a:**Schedule of accommodation**

S/N	CATEGORY/ SPACES	SQUARE AREA		QUANTITY
		Area required	**Area provided**	
	Main building (Front house facilities)			
1	**Administrative area**			
	Front office	0.4sqm/person	0.6sqm/person	1
	Director office	24sqm	27sqm	1
	Secretary office	9.5sqm	13sqm	2
	Manager's office	15sqm	24sqm	1
	Offices	9.5sqm	13sqm	15
	Boardroom	40sqm	60sqm	1
	Staff lounge	1.2sqm/person	1.5sqm/person	2

Table 5.1b:Schedule of accommodation

2	**Accommodation spaces**			
	Ordinary single suites	21sqm	30sqm	130
	Double suites	24sqm	36sqm	52
	Superior suites	40sqm	56sqm	52
	Executive suites	92sqm	112sqm	20
	Presidential suites	100sqm	140sqm	4
3	**Commercial spaces**			
	Rental spaces	12-40sqm	40-60sqm	16
	Exhibition	40-60sqm	70sqm	1
	Conveniences	1.2sqm/person	1.4sqm/person	8
4	**Function areas**			
	Conference hall	1.2sqm/person	1.5sqm/person	1
	Meeting rooms	1.2sqm/person	1.4sqm/person	6
	Night club	1.5sqm/person	1.6sqm/person	1
	Casino	2.8sqm/person	3.2sqm/person	1
	Conveniences	1.2sqm/person	1.4sqm/person	8
5	**Indoor recreation**			
	Card games	2.1sqm/table	2.5sqm/table	6
	T.v games	1.2sqm/person	1.4sqm/person	3
	Table tennis	20sqm	24sqm	1
	Billard board	16.3sqm	18sqm	3
	Football	1.9sqm	2.1sqm	3
	Back of house facilities			
6	**Catering service**			
	Main kitchen	0,8sqm/person	1.2sqm/person	1
	Satellite kitchen	0,5sqm/person	1.0sqm/person	1

Table 5.1c:Schedule of accommodation

	Restaurant	2.0sqm/seat	2,4sqm/seat	2
	Bar	0.3sqm/person	0.5sqm/person	1
7	**Fitness and recreation**			
	Fitness/health club	72sqm	96sqm	1
	Supervisor's office	7.5sqm	9sqm	1
	Massage room	2.4sqm/person	3.0sqm/person	2
	Dance studio	24-48sqm	48sqm	1
	Aerobic studio	48sqm	60sqm	1
	Sauna	0.5-0.8sqm/person	1.0sqm/person	2
	Changing room	9sqm	12sqm	2
8	**Event hall**			
	Multipurpose hall	1.2sqm/person	1.4sqn/person	1
	Back stage	24sqm	36sqm	1
	Stage	30-60sqm	45sqm	1
	Stage manager office	9sqm	12sqm	1
	Control room	12sqm	16sqm	1
	Conveniences	1.2sqm/person	1.4sqm/person	8
9	**Site auxillary facilities**			
	Gate house	1.2sqm/person	1.4sqm/person	1
	Treatment plant	35sqm	50sqm	1
	Swimming pool	-	-	2
	Basket ball	346sqm	346sqm	1
	Volley ball	162sqm	162sqm	1
	Lawn tennis	260sqm	260sqm	1
	Bush bar	1.8sqm/person	1.8sqm/person	1

6.0 Design Report

6.1 Design Brief

The proposal is to design a 5 star hotel in which the Kaduna state government has granted allocation of a piece of land at the Kaduna new mellinium city layout for providing sufficient lodging and temporary comfort services for its transcient marketers and foreign tourists. The hotel is to be designed with conscious intention of safe guarding against deterioration of the ecology, providing economically viable means of energy generation, environmentally friendly and saves cost of maintenance. This is in line with the recreation of a new kaduna city which is to promote leisure, tourism, and commerce, a modern urban centrality for sustainable development where natural beauty and architectural icons must merge together to create an environment that is alive and productive that will attract more and more people and businesses from within and outside the country.

The hotel being proposed in this thesis would have provision for the following activities: administration, accommodation, catering, leisure/ recreational facilities and business/ commercial facilities.

6.2 Concept Development

Concepts are ways of integrating ideas, notions, thoughts and observations into one architectonic expression. The approach to this project is getting inspiration from nature to find possible sustainable solutions for the design of a hotel in the hot dry climate of Kaduna state. The conceptual design of the hotel takes the form and processes of a cactus plant since it is a self-cooling plant due to its anatomical and physiological features that help it to survive in hot - dry climates. The attributes of a cactus plant is translated into building elements on the facade of the design. (See plate 6.1)

Cactus attributes		**Translation into building form**
Shape of cactus plant	→	Form
Cooling ribs	→	Shading device
Spine	→	Reflective material (Teflon)
Skin of cactus	→	Insulated wall panel

The proposal is designed conceptually and architecturally to enhance passive cooling and also improve micro-climate of the interior spaces by incorporating nature.

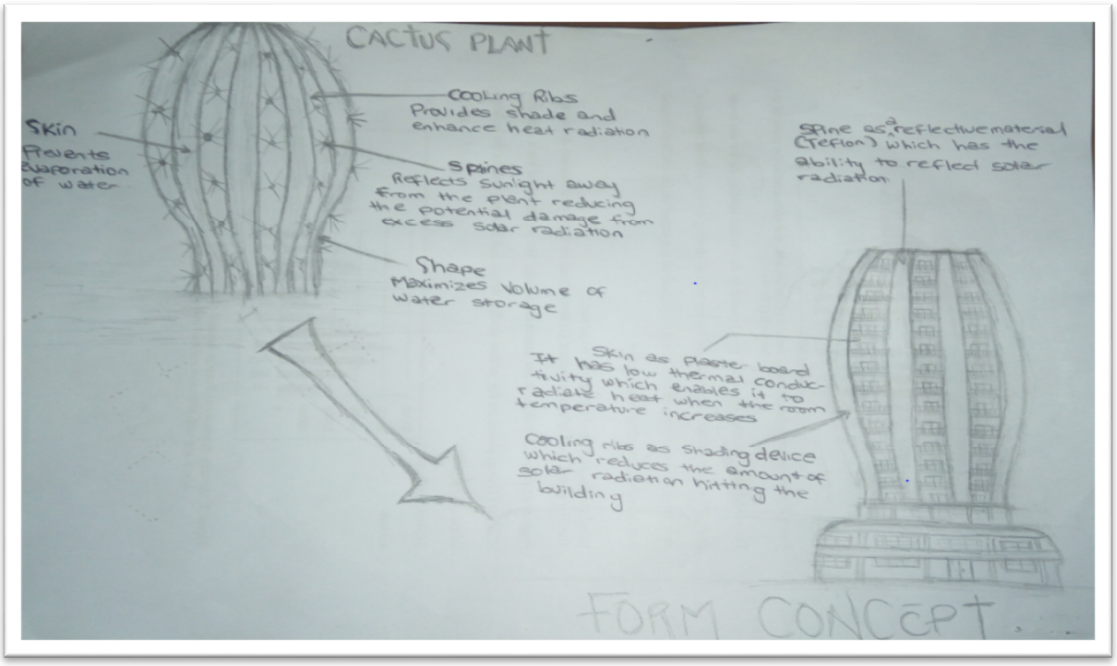


Figure 6.1: Form concept. Source: Author, 2017.

6.3 Site Planning and Landscaping

The orderly arrangement of building units and other supporting facilities allow for effective flow of traffic within the site and for proper utilization of both the site and climatic element. The pattern of movement on site is such that pedestrian is separated from vehicular circulation. As part of effort to increase human-built environment relationship, guest vehicular access is terminated at the front of house, while pedestrian circulation continues with emphasis on interaction with the surrounding nature. The

parking area, multi-purpose hall, recreational and sporting facilities are connected to the main building by pedestrian walkways and small access roads as shown in (figure 6.2). Recreational and relaxation areas were privately located and zoned for maximum privacy of the guest. Services and back-house were however located away from the sight of the hotel guests. . Within the facility, proper activity zoning is ensured which included clear separation of the back of house from the front of house facilities. The hotel has large site area well landscaped with green areas, large trees for shading, shrubs and water bodies for evaporative cooling.

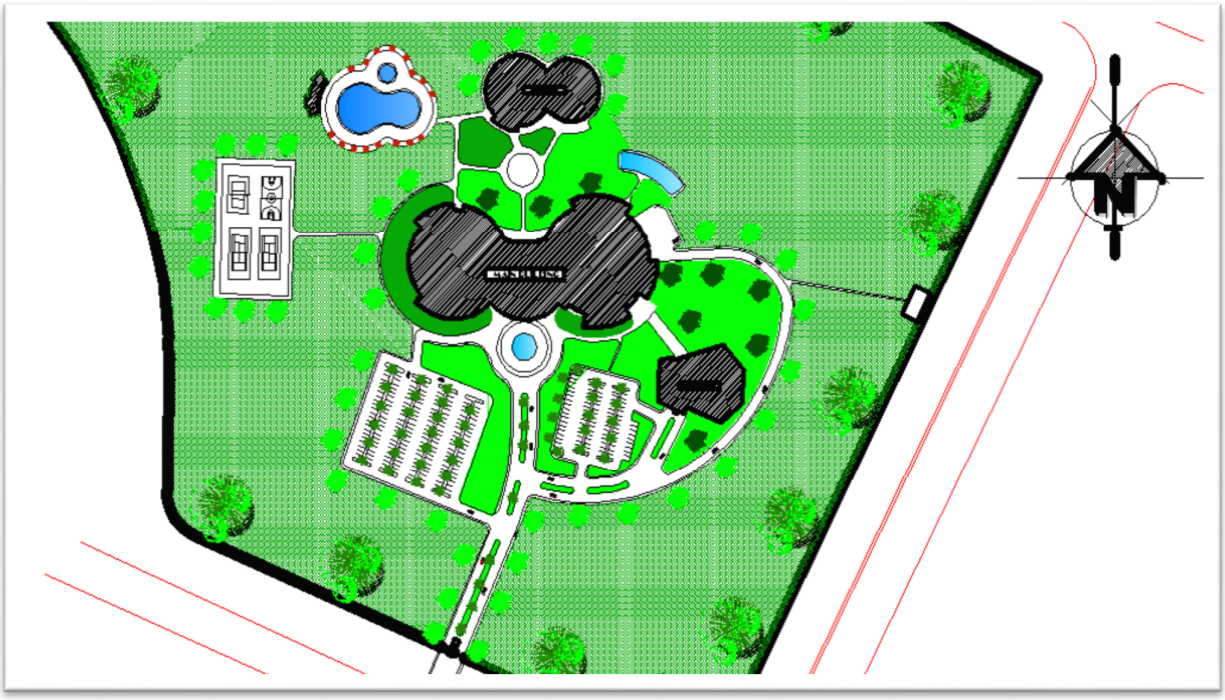


Figure 6.2: Hotel site planning and landscaping. Source: Author, 2017

6.4 Spatial Organisation

The compact shape of the building reduces the surface exposure to the elements of weather with its interior spaces laid out according to their space and functional requirements. The reception is the central area connecting the two towers. One of the tower terminates at the first floor. The second tower is the highest which ends at the

fourteen floor. On the ground floor, the vertical means (stairs and lifts) are located at the central core of both towers (see figure 6.3). The restaurants, main kitchen, laundry area, conference hall, shops, back house etc are located on the ground floor. The first floor houses, exhibition area, meeting rooms, restaurant, statellite kitchen and other commercial activities. The second floor is the service floor which allows for effective control of grey water and soil water from the rooms to channel them for recycling. The third floor houses the staff office, boardroom and staff lounge. Mean while, from the third floor up to the fourteenth floor it is design to house the guest room. The spatial arrangement of the guest room floors is single banking system and each room was designed with a green balcony. The hotel guest room total number is 258 rooms comprising of 130 ordinary single suites, 52 double suites, 52 superior suites, 20 and 4 executive and presidential suites respectively.

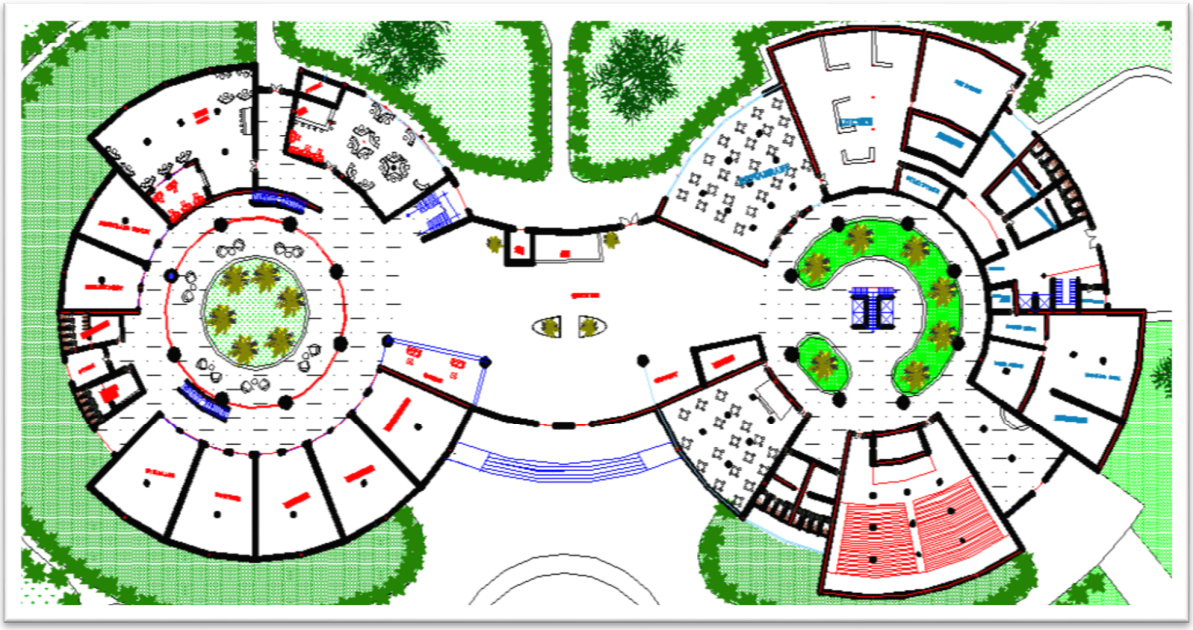


Figure 6.3**:** Hotel's ground floor plan. Source: Author, 2017

6.5 Application of Biomimicry Architecture Principles

6.5.1 Building form

The overall building form is designed based on the key attributes of a cactus plant. The attributes are shape and cooling ribs. The building takes the shape of a cactus, which is cylindrical with bulgy curves that tappers at the base. Also, the cooling ribs are in the form of vertical shading devices running from top of the buiding to the podium (see figure 6.4). These shading devices were integrated in the design to reduce the window area exposure to glaring sun in order to control heat gain for lower indoor temperature.

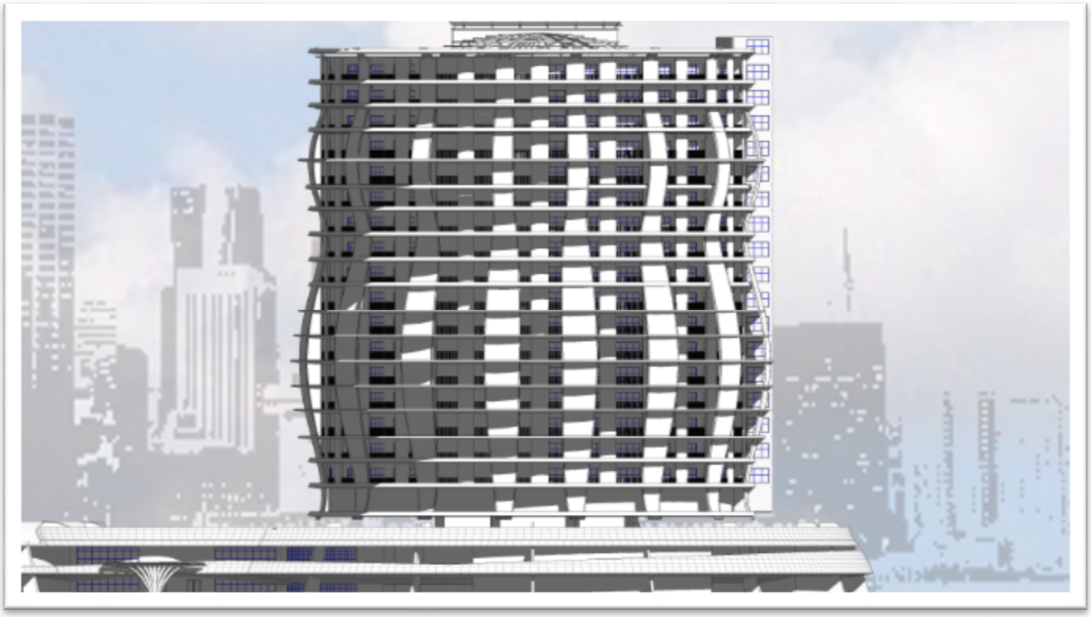


Figure 6.4: Building form. Source:Author, 2017.

6.5.2 Building relationship to site

The structure and other facilities blends with the natural topographic formations. The hotel has large site area well landscaped with the green area and hedges. The network of pathways within the hotel facility is well zoned preventing conflict between human and vehicular traffic.

6.5.3 Reusability of building material

Materials with less negative impact on the environment or that are recyclable have been adopted for the entire scheme. Titanium is applied in the atriums support system and the support system for the composite Teflon-amorphous Silicone solar material lining the building façade. Teflon is applied in atriums (see figure 6.6) to reduce glass use, and on main building façade as a composite solar material, laminated with amorphous silicon which generates solar energy alongside shading the building from the elements and giving the façade its form. Teflon is known as PTFE (polytetrafluoroethylene). This material(s) possesses several qualities which makes it a suitable material for sustainable construction. These includes; its light weight, flexibility, durability, green quality (recyclable), resistance to elements of weather, self-cleaning property and ability to span large areas and heights with little supporting.



Figure 6.5: Building materials. Source:Author, 2017.

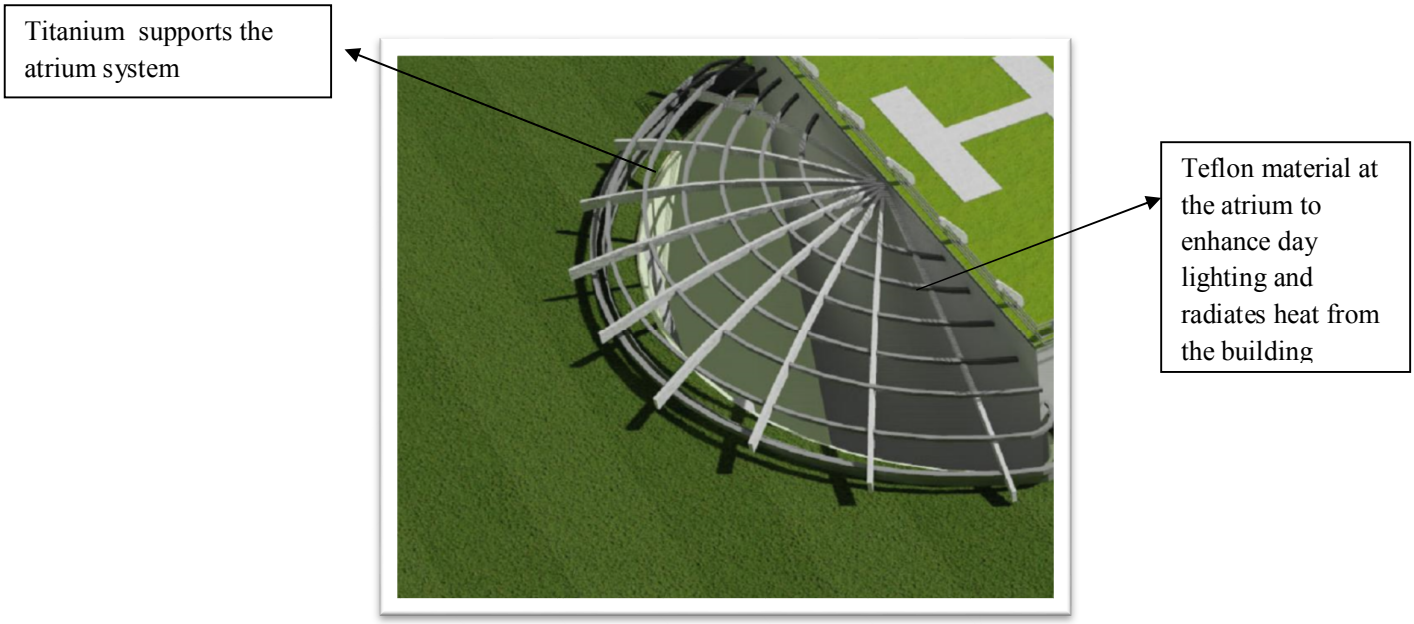


Figure 6.6: Atrium. Source: Author, 2017.

The type of glass employed is the low-e glass to avoid the penetration of heat and possesses (see figure 6.5). It is employed as the major element in the buildings permitting daylighting and creating visual contact with the environment. Insulated wall panel is been applied on the fabric of the wall. Mud bricks is employed in the Gazebos for its thermal properties and green qualities.

6.5.4 Energy sources

The proposal considered renewable energy sources as the alternative to the non-renewable and non-dependable energy sources of the country. Composite solar energy system on the building facade, alongside solar panels at lower roofs would augment power from the Grid to meet energy needs within the facility. (As seen in figure 6.7 and figure 6.8)

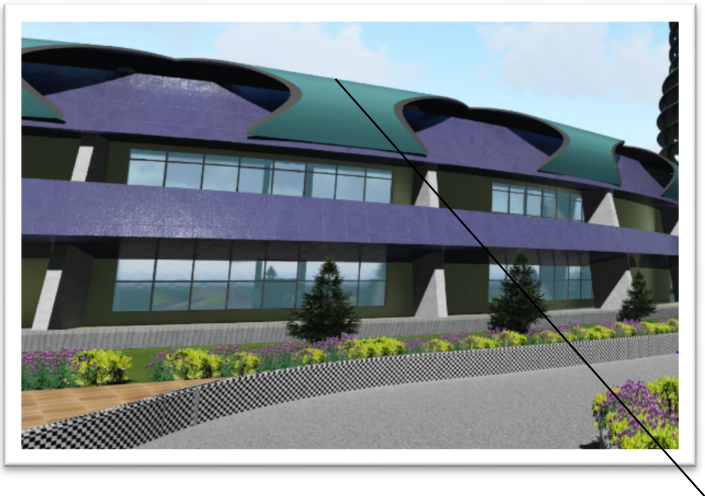


Figure 6.7: BIPV modules on the main building roof. Source:Author, 2017.

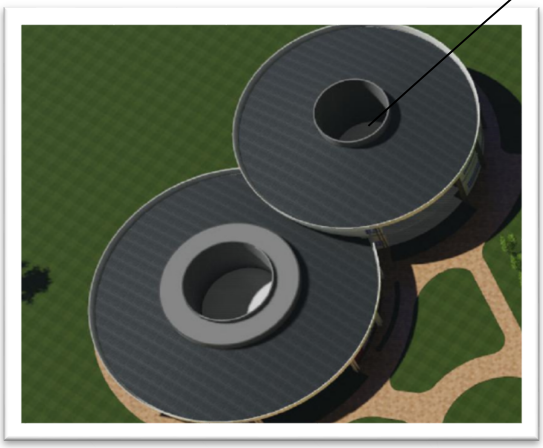


Figure 6.8: BIPV modules on roofs on fitness unit. Source:Author, 2017.

6.5.5 Water supply

The facility features several rain water harvesting schemes and water management strategies. This is via roofs, roof gardens (see figure 6.9) and ground water recharge techniques. Harvested rain water is stored in underground cistern and treated by an on-site solar powered treatment plant alongside treatment of grey water for non-portable uses.

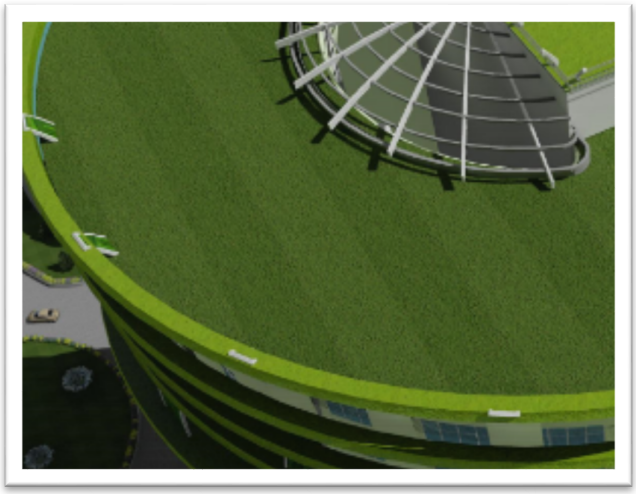


Figure 6.9: Rain water harvested via green roof. Source:Author, 2017.

6.5.6 Day lighting and ventilation

The building is naturally lit via the use of Teflon material, on full height atrium which brings in adequate light while resisting the penetration of heat. The atrium helps to create vertical circulation of air (see figure 6.10) and enhances the penetration of natural day lighting into the building. ventilation is achieved via Stack Ventilation (see figure 6.11) by using, side vents, atriums and water bodies for evaporative cooling as a form of passive cooling strategy.

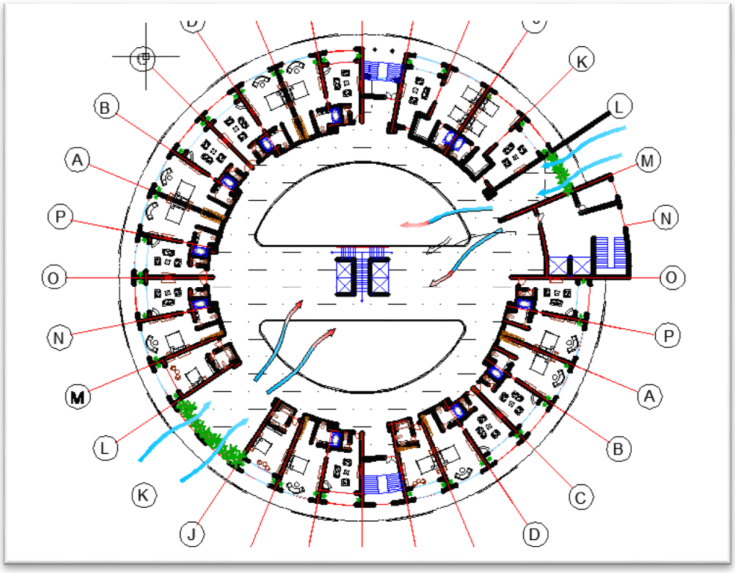


Figure 6.10: Air flow from side vents and translational spaces. Source:Author, 2017.

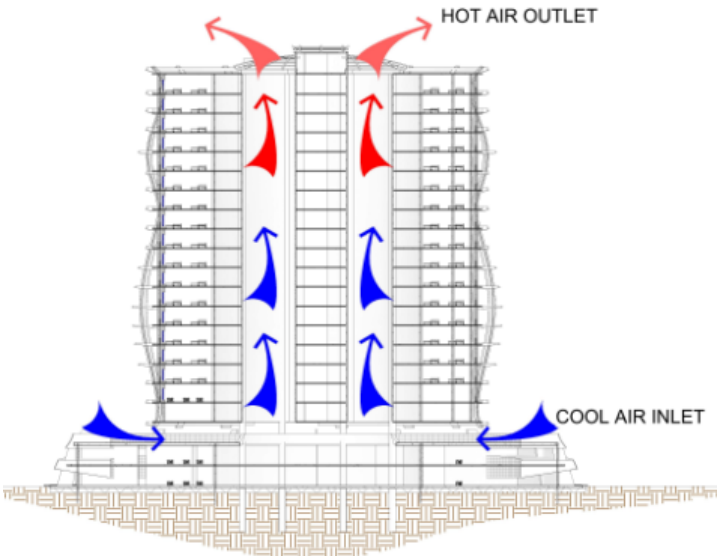


Figure 6.11: Ventilation within the building. Source:Author, 2017.

6.6 Site external works

The location of this hotel is on a site of advantageous interest and as described in the selection criteria. Therefore, its potentials were fully exploited to generate more revenue and create an environment that will be soothing to its guests.

6.6.1 Guest parking

The concept of the car parking lot of this hotel is chosen to achieve separate parking spaces for all the separate units on the site. The partial zoning of some of the parking spaces, for conference guests, shoppers would allow for an effective use of these facilities without necessarily congesting the main entrance to the hotel. The intention being for there not to be a bottleneck of traffic at the main entrance to the hotel.

6.6.2 Swimming pool

Two swimming pools namely the adult pool and the children's pool are provided within a paved area (see plate 6.12). These pools are located in the part of the site which offers guests the best view of the lake. Users of these pools are offered a good view of the

tennis courts basket ball court and volley ball, the intention being to create environment of "total recreation and relaxation" for the users.

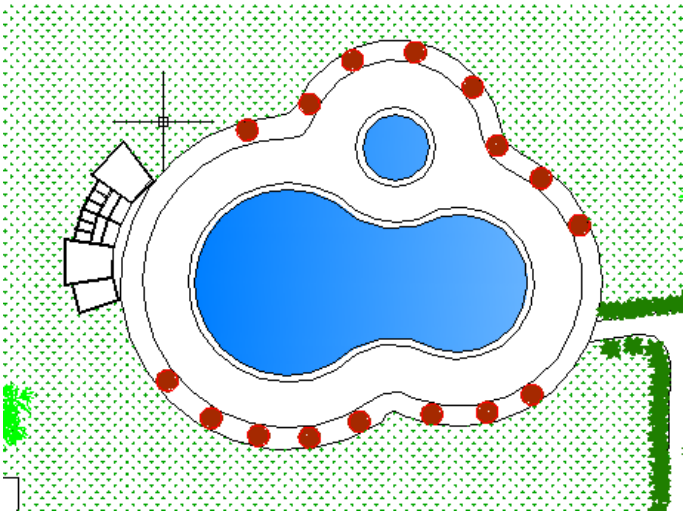


Figure 6.12**:** Adult and children swimming pool. Source:Author, 2017.

6.6.3 Water Supplies for Fire Fighting

Two independent sources of water at specified pressure for firefighting are provided. There exists on the one hand, water hydrants linked with the mains supply and on the other hand, a high level storage tank.

This high level storage tank is connected via a network of piping to

- Sprinklers with automatic opening at a set temperature at intervals of 4.Au in corridors, public rooms and lobbies.
- Hose reels and stand pipes placed on escape routes (adjacent to staircase enclosures) 20m apart.

6.6.4 Waste And Sewage Disposal

The design, construction and installation of these pipes are based on savings of cost and ease of assembly. This is achieved by grouping pairs of bathrooms adjacent to vertical ducts, with a multiple stack system of drainage installed, with each sanitary appliance draining straight down to large collecting pipes at the basement. These large connecting

pipes are laid at a gradient of 1.12 to empty into septic tanks (via manholes) from which soil wastes are by suction extracted say fortnightly by soil waste vehicles. The access route of these vehicles is from the service road i.e. away from the view of guest. The suction of soil waste would usually be done at night when cost guests would be asleep.

6.6.5 Maintenance Services

Access for maintenance services is provided to:

i. Rooms and closets for locating heating, circulation and control equipment (pumps, valves, boiler room equipment and electrical switchgear).

ii. Vertical ducts between bathrooms (soil wastes and ventilating pipes, hot and cold water supplies, and electrical equipment).

iii. Ceiling housed engineering services and equipment A/C ductwork, lighting fittings, electrical services, fire detecting, alarm and sprinklers systems, control and relay equipment.

iv. Wall mounted equipment, socket outlets, vacuum connections, light switches, fire alarms and indicators, recessed hose reels, table ducts and conduits and room status equipment. Access to ceiling equipment shall be through removable panels.

7.0 CONCULSION AND RECOMMENDATION

This chapter presents a conclusion of the whole research work. It itemizes the basic conclusion of the study, the recommendations of the study, contributions to knowledge and area for further research.

7.1 Conculsion

The introduction to the research began by establishing the natural principles and approaches to biomimicry and its relevance in architecture, further discussing how this vocabulary can be translated appropriately to find technical applications of these principles in the built form. The objective of this study is to explore the principles of bio mimicry in the design of hotels as a means of safeguarding against the deterioration of the ecology and providing economically viable means of energy generation. The studies carried out in the course of this research have shown that buildings account for up to 50% of total energy consumption for cooling accounting for most of the energy demands in buildings. The effect on hotels and other related tourism accommodation in Nigeria is that energy has to be generated privately sets that consume large amounts of fossil fuels to sufficiently cater for the energy demands of such institutions. Consequently there is a corresponding increase in hotel tariff by operators so as to provide hospitable accommodation. This circumstance has had crippling effect on the tourism industry and the hotel accommodation business. More over, Biomimicry architecture principles are not widely applied in hotel designs in Nigeria as seen in the cases reported in chapter 4, where it shown that in all the studied cases only a few number of the principles are applied. This situation makes it imperative to consider the use of natural principles and strategies of environmentally sensitive inspirations of biomimicry design in the provision of comfortable accommodation

The inferences drawn from these findings are the application of the mentioned principles of biomimicry design features in hotel designs in Nigeria , it is possible that the tourism industry will become more viable since it will enhance the comfortable accommodation of tourists while not compromising the quality of the environment. It is also important that buildings are designed with the thought of reducing energy consumption by optimized building siting, orientation and proper material selection to reduce total energy consumption and the need for air conditioning.

7.2 Recommendations

i. Based on the findings that there are minimal application of biomimicry principles of architecture in hotel designs in Nigeria, it is recommended therefore that hotel designs should be conceptualized architecturally to incorporate multiple biomimicry principles in order to achieve energy efficiency and sustainable designs.

ii. There should be encouragement in the use of architectural solutions based on the observation of natural principles that can reliably supplant artificial or mechanical means of energy generation and water management.

iii. With the awareness about the future climate, Biomimicry design strategies and new sustainable methods will be more important for the future climate. Therefore, Building professionals should work together in an integrated approach focusing on how to improve the energy performance of buildings; introducing new environmental and biomimicry architecture policies that will encourage the development/design of more energy efficient, integrated and sustainable buildings that will improve the future environment.

7.3 Contribution to Knowlegde

i. The attributes of a plant that has been able to survive the environmental challenges of a particular region, if translated into a building design can improve passive cooling within and probably around the building.

ii. An already degrading environment can be improved upon through conscious architectural efforts directed towards its improvement.

7.4 Area for Futher Research

The study has identified areas in which further inquiry in biomimicry architecture can be made. They are: The performance of structures utilizing biomimicry architecture principles, and also the study could be conducted in other climatic/ geographic regions within the country to identify biomimicry architecture features peculiar to these region(s) which could be adopted in hotel design.

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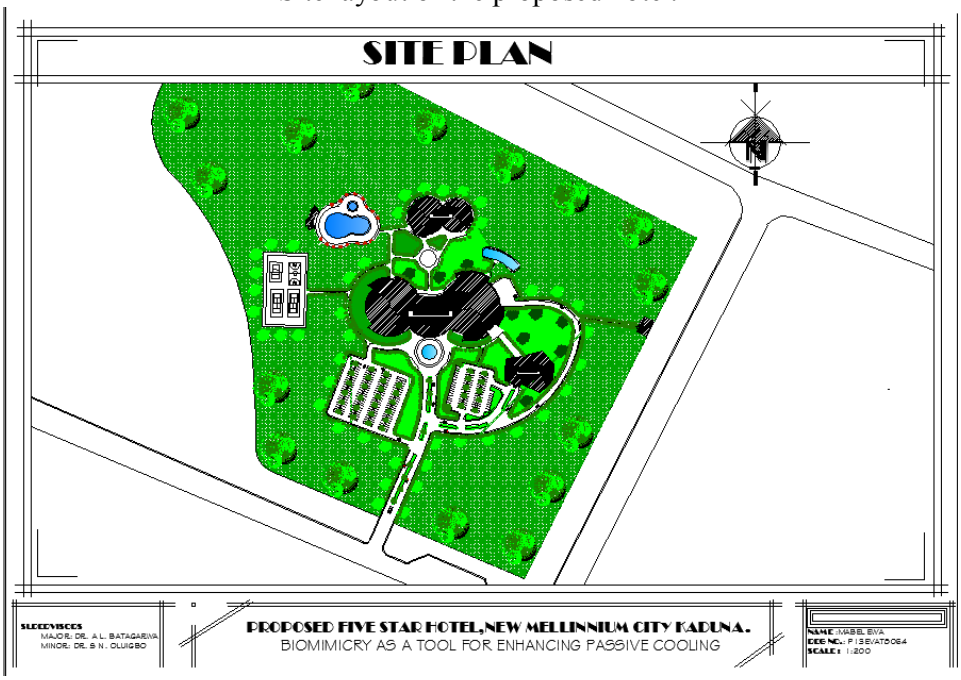
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APPENDICES

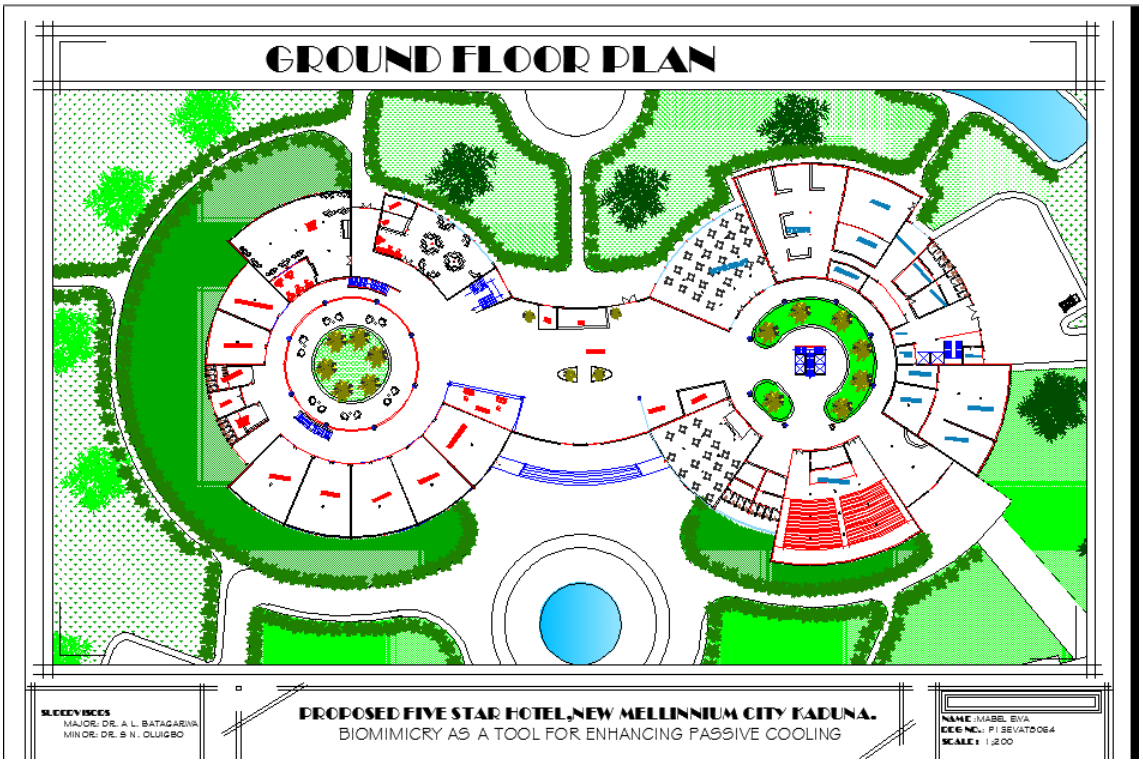
APPENDIX 'I'

Site layout of the proposed hotel.



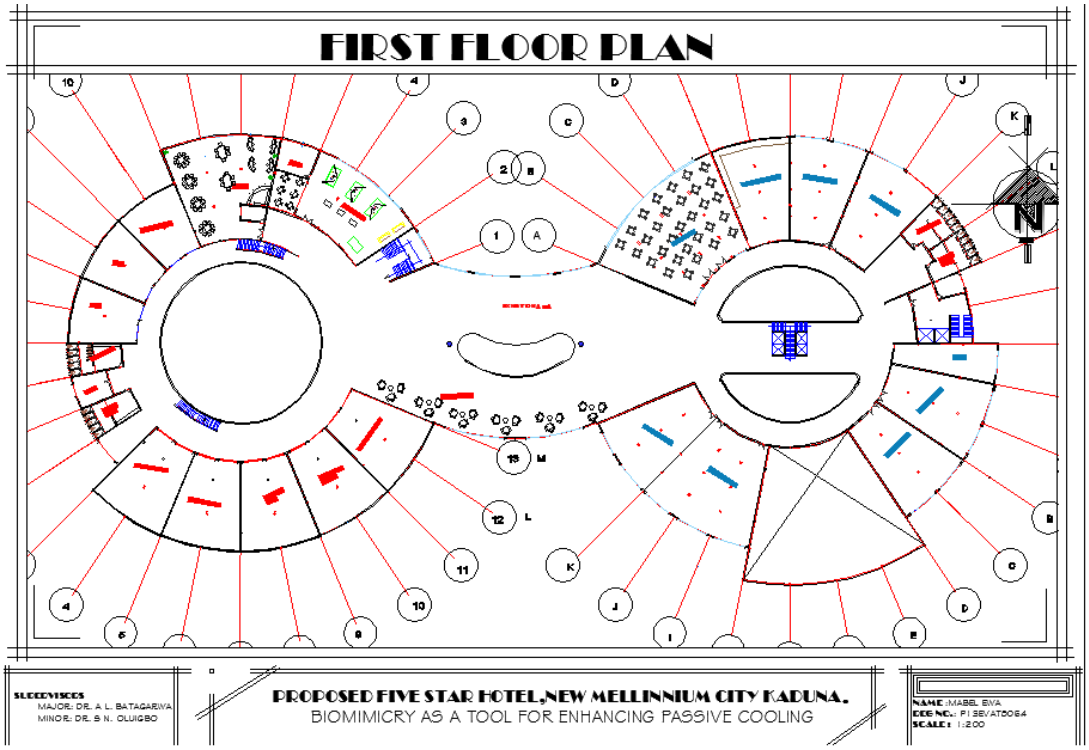
APPENDIX 'II'

Ground floor plan



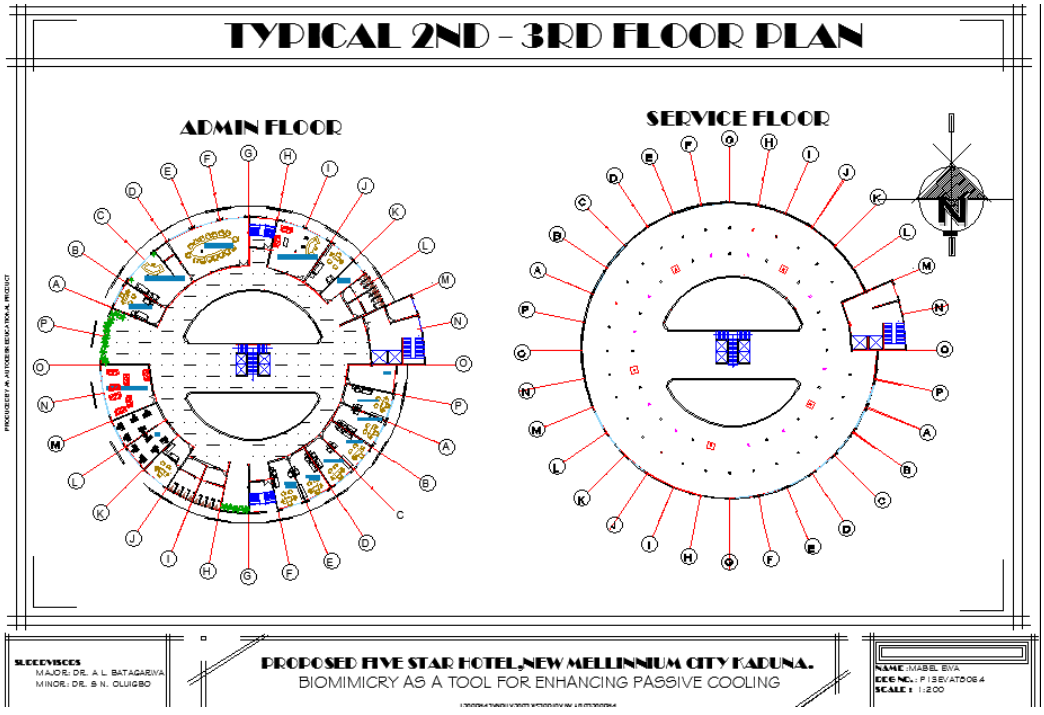
APPENDIX 'III'

First floor plan



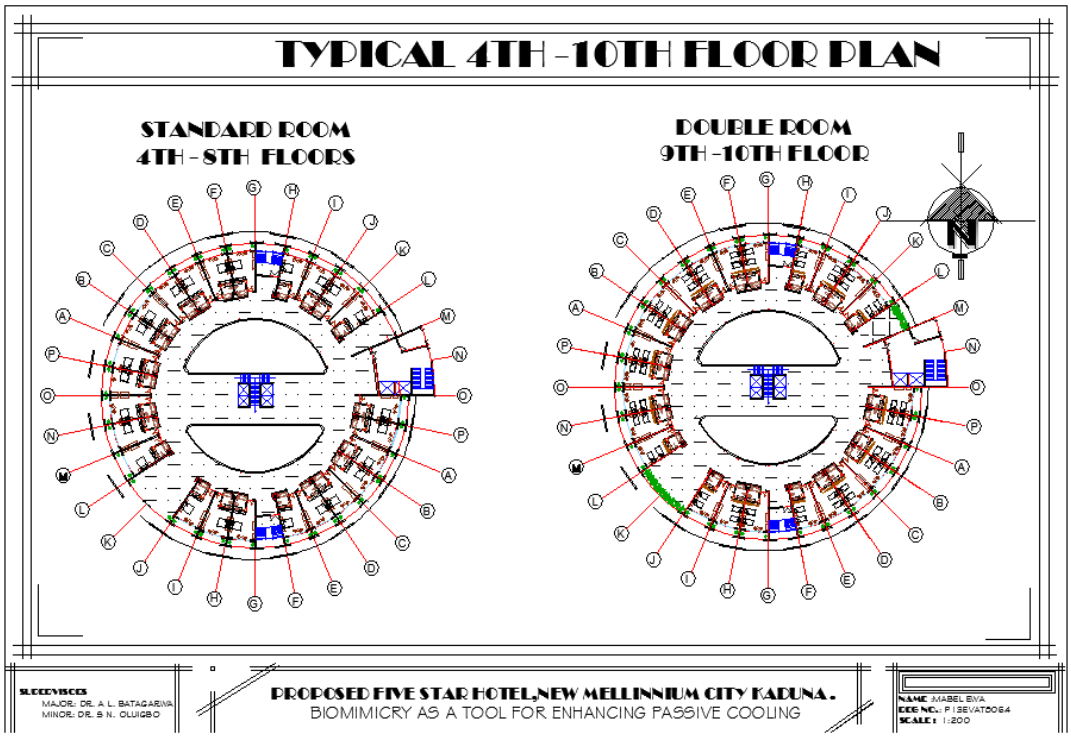
APPENDIX 'IV'

Typical 2nd – 3rd floor plan



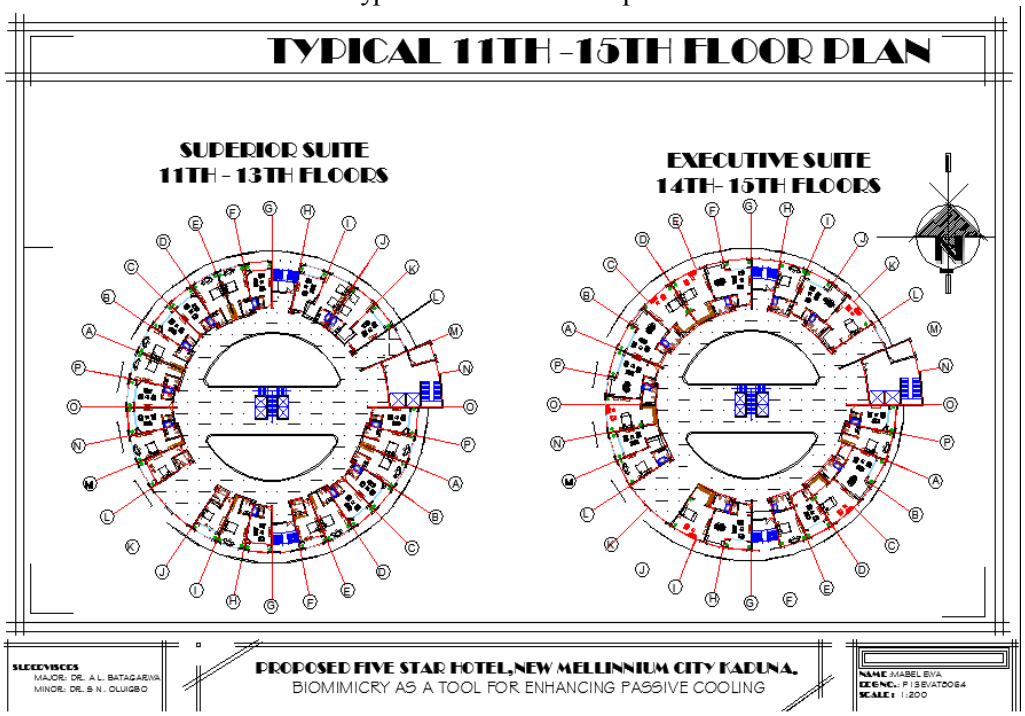
APPENDIX 'V'

Typical 4th -10th floor plan



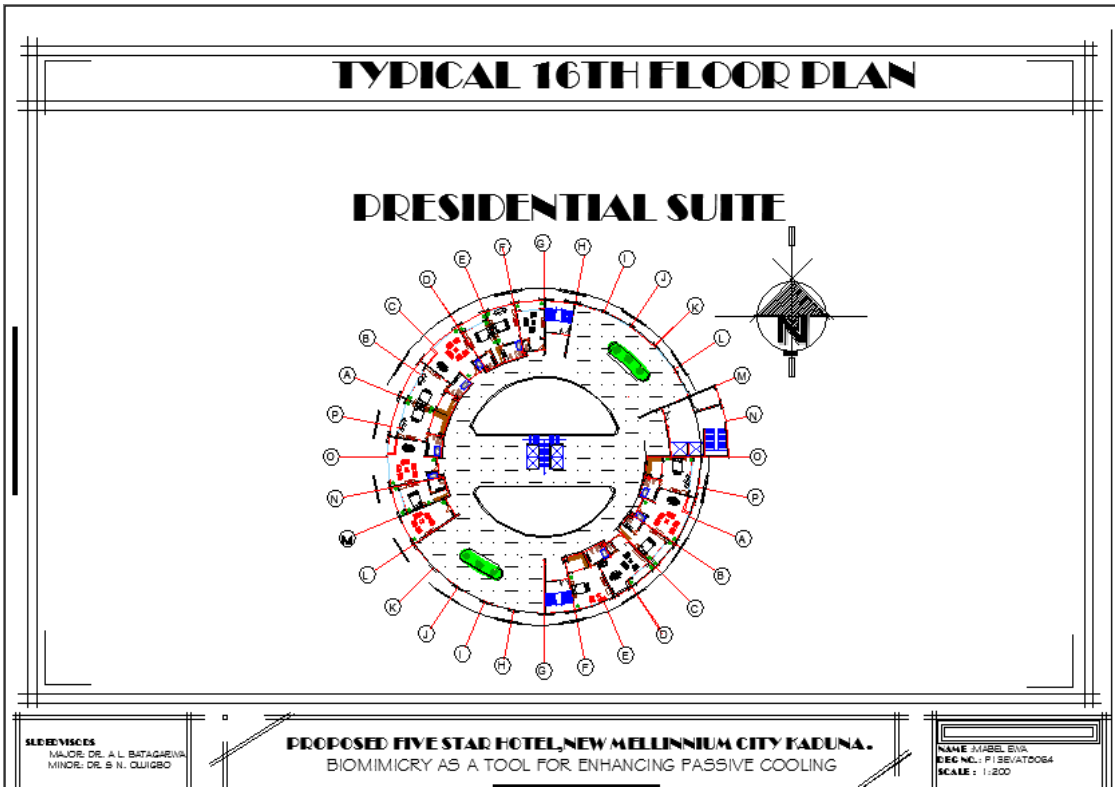
APPENDIX 'VI'

Typical 11th -15th floor plan



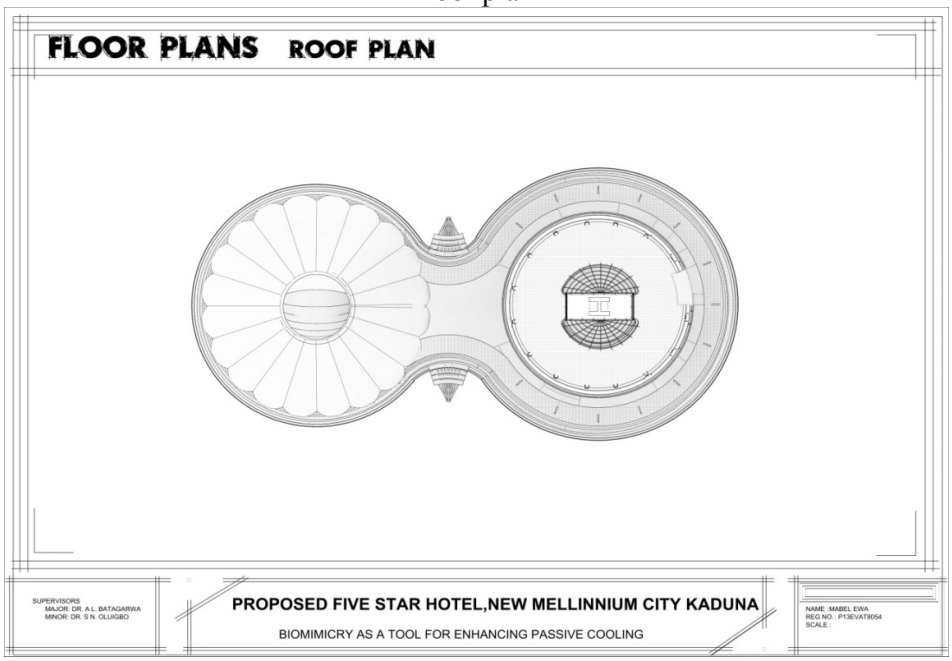
APPENDIX 'VII'

Typical 16th floor plan



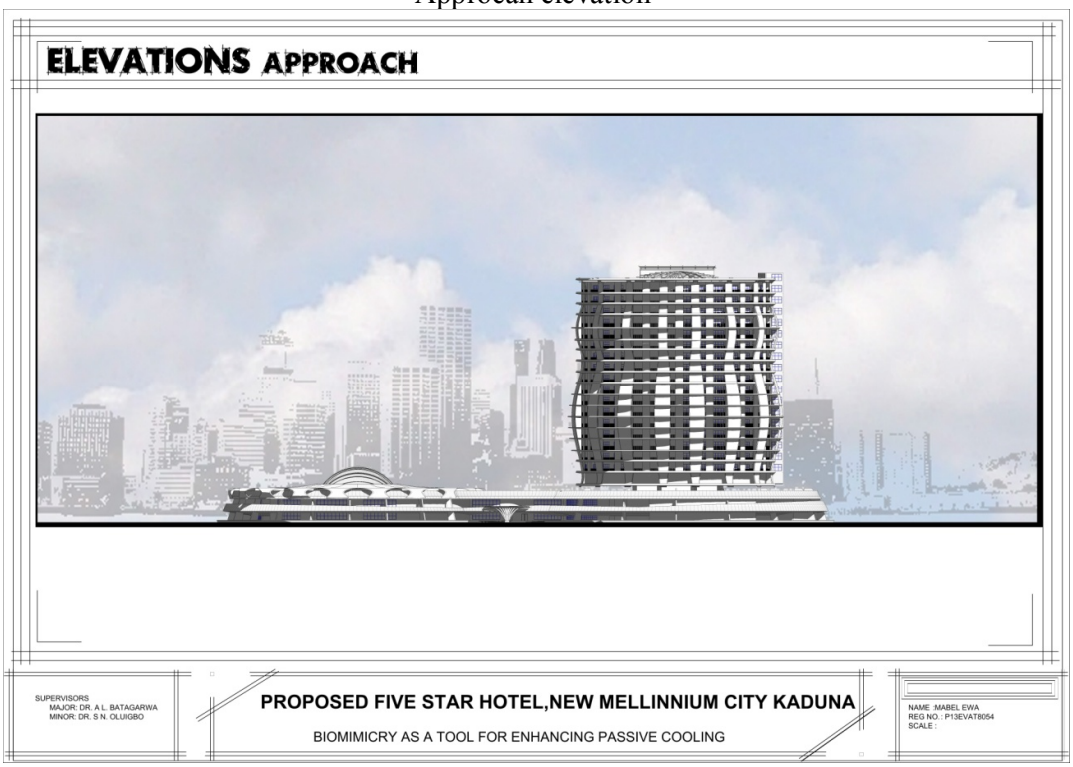
APPENDIX 'VIII'

Roof plan



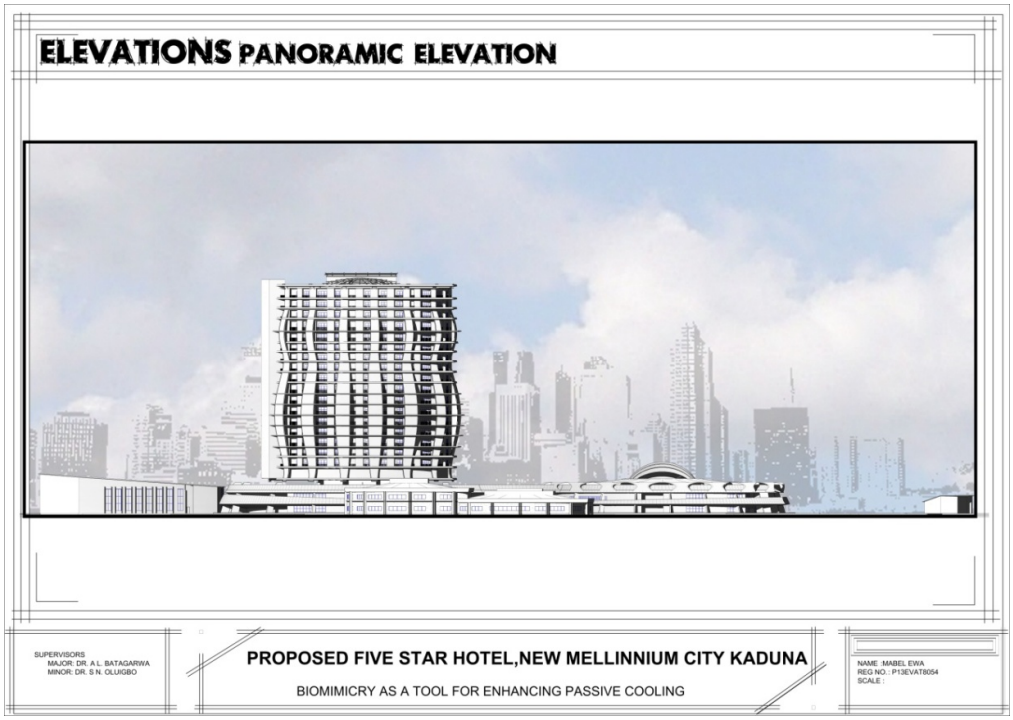
APPENDIX 'IX'

Approcah elevation



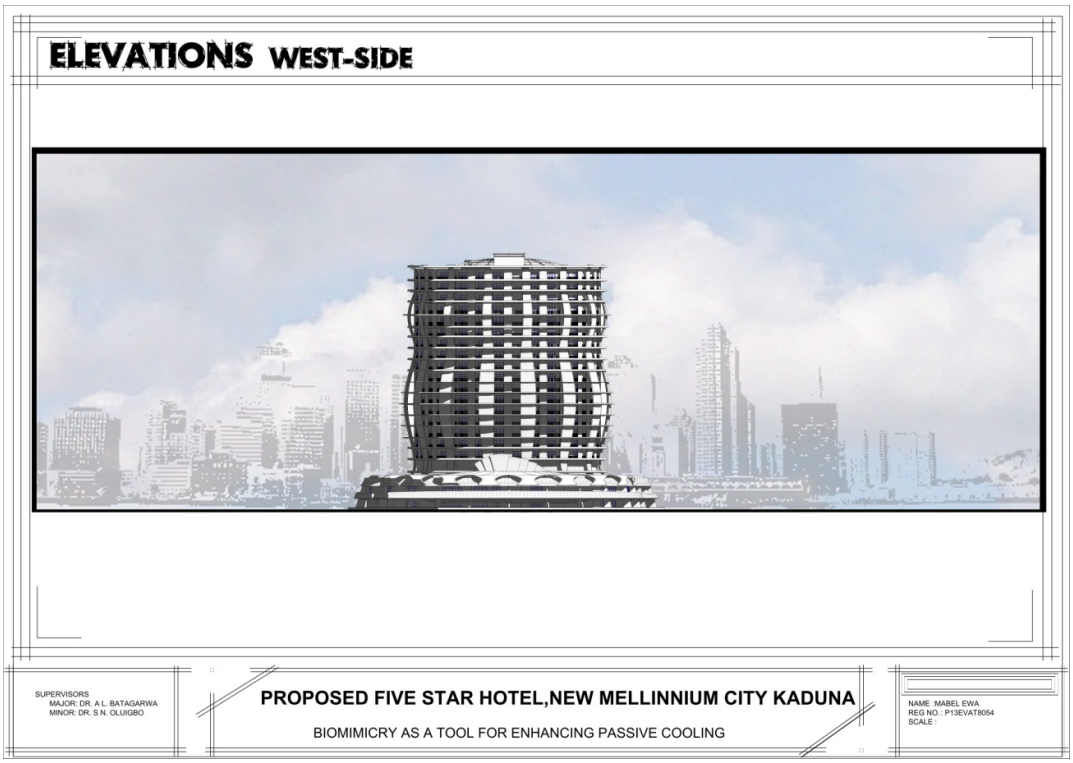
APPENDIX 'X'

Panoramic elevation



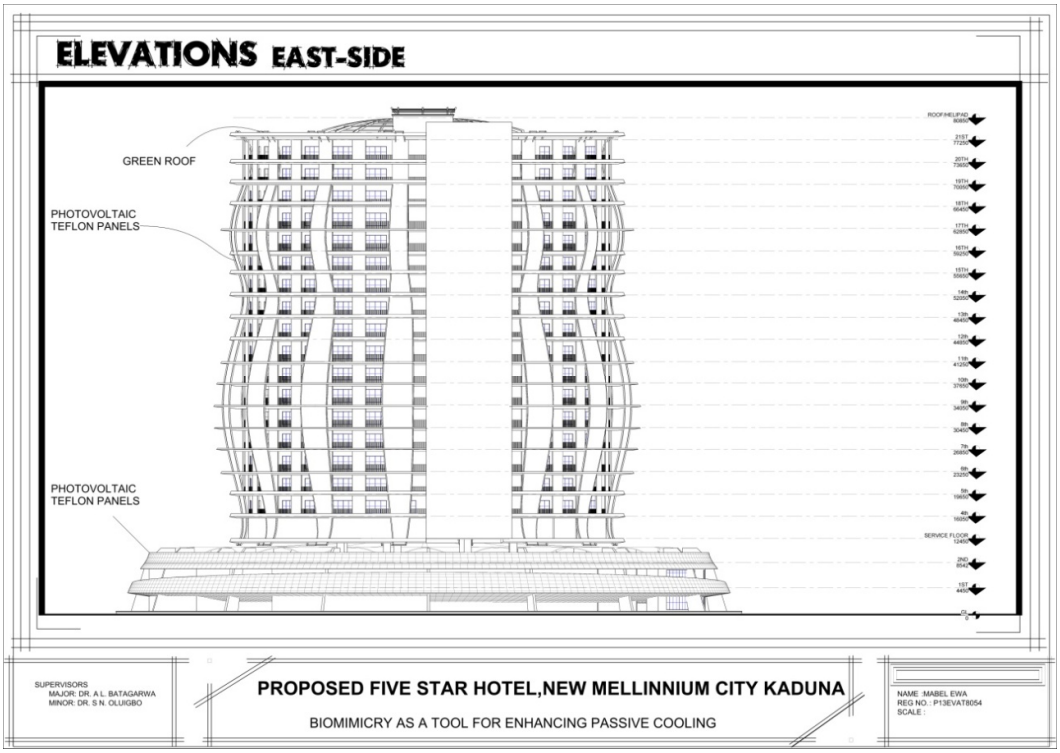
APPENDIX 'XI'

West elevation



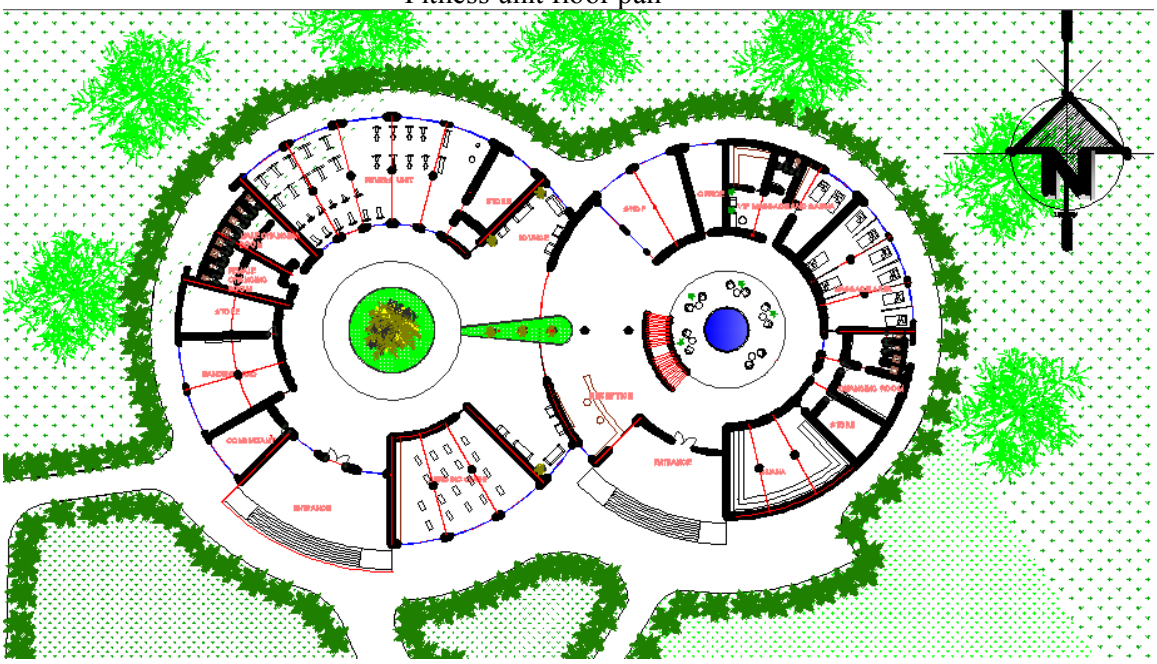
APPENDIX 'XII'

East elevation



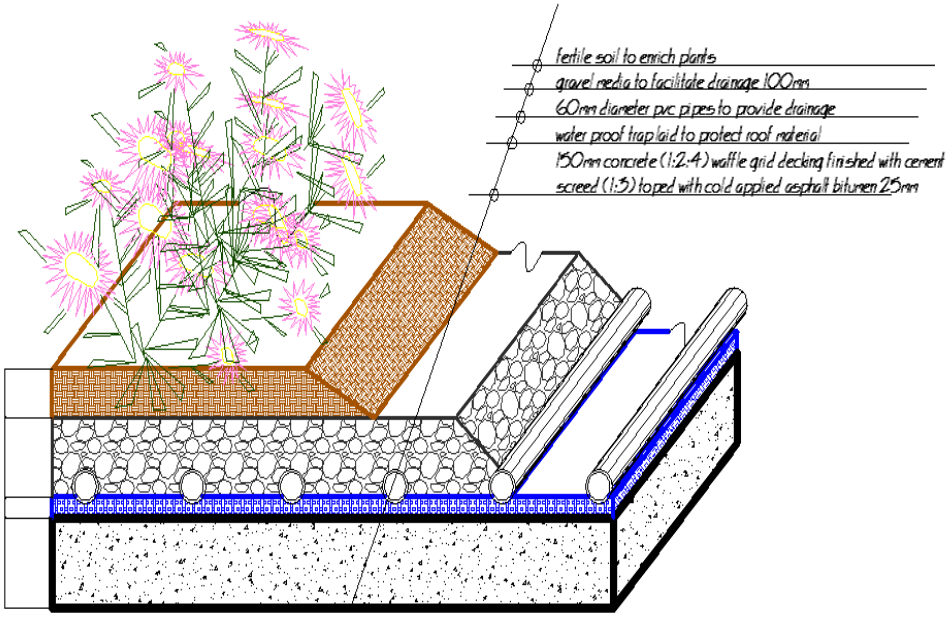
APPENDIX 'XIII'

Fitness unit floor pan



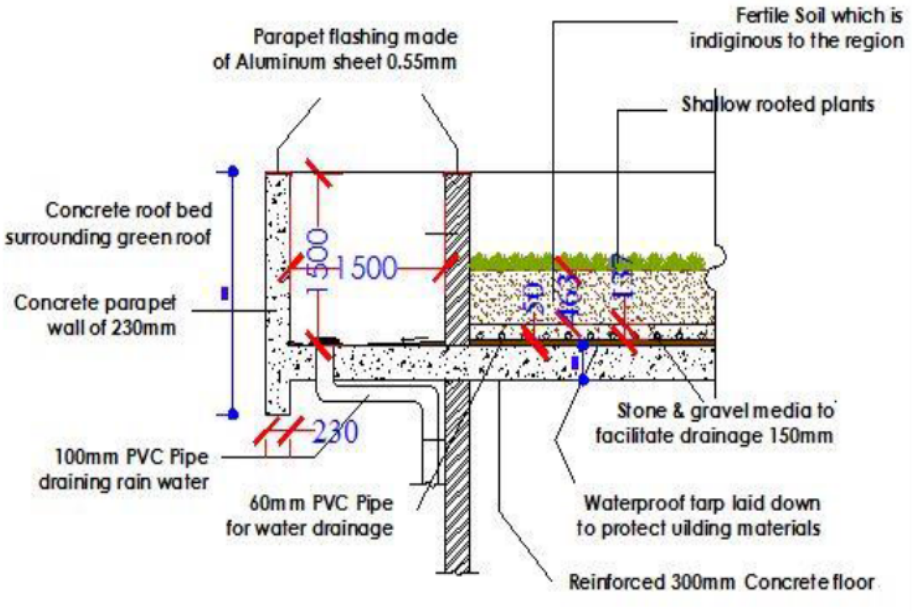
APPENDIX 'XIV'

Green Roof detail



APPENDIX 'XV'

Green roof and drainage



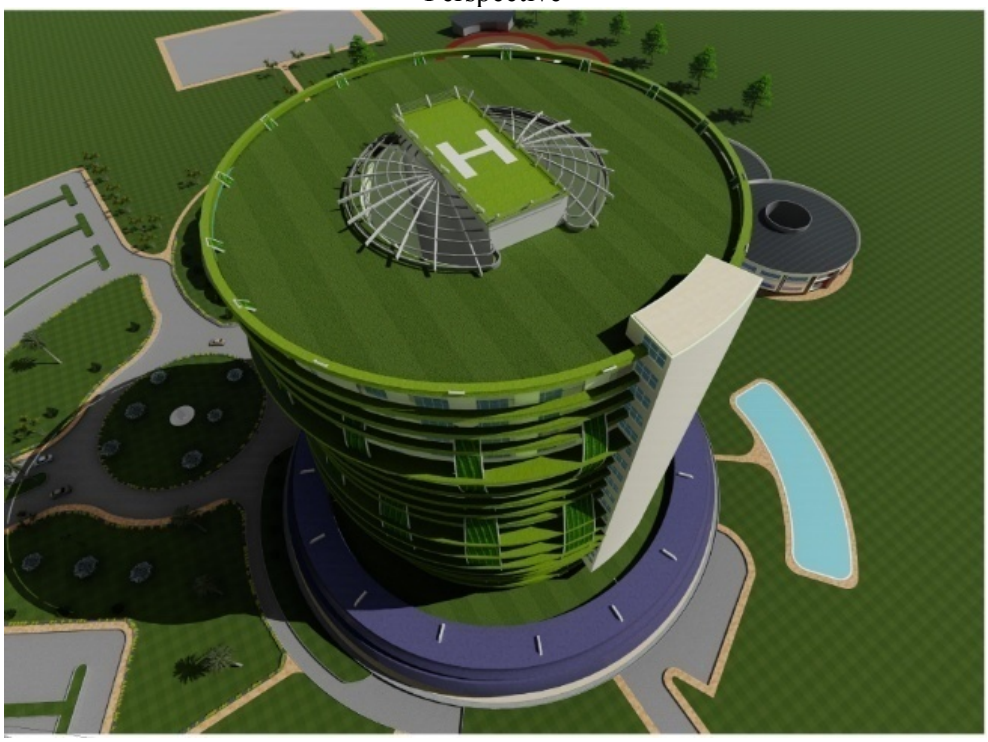
APPENDIX 'XVI'

3D Perspective



APPENDIX 'XVII'

Perspective



APPENDIX 'XVIII'

Arerial view perspective

