Inspirational Influence of Nature in Architectural Design – A Review on the Scope of Application in Nigeria Housing Policy

Tambe, E.B.[1*], Essaghah, A.E.A.[2], Ikegbunam, F.I.[3], Mbuka-Nwosu, I.E.[4], Okafor, N.M.[3], Ekpe, I.N.[1]

[1]Department of Environmental Management & Toxicology, Delta State University of Science and Technology, Ozoro, Nigeria.
[2]Department of Urban and Regional Planning, Delta State University of Science and Technology, Ozoro, Nigeria.
[3]Department of Environmental Management, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria.
[4]Department of Environmental Management, Federal University of Technology, Owerri, Nigeria.

**Corresponding author: tambe_besong2001@yahoo.com or tambebe@dsust.edu.ng*

Abstract: The growing need for housing and infrastructural development is depleting and transforming green spaces to built environment. This transformation is altering the functioning of the natural processes that sustain life. However, conservation strategies through the science of biomimetic architecture show how nature offers the best ideas for regenerative infrastructural designs that humans can incorporate in planning. These natural forms of life provide insight on how designing housing and public infrastructures can promote efficiency in energy savings, waste management, nutrient provision, water management, adaptation to local condition, accommodating ecological hazards, sustaining the wellbeing of the occupants and reducing the frequency of visiting the natural capital. In Nigeria, housing policy programmes have primarily been focusing on ensuring affordable and available housing for all Nigerians. However, while the policy is being challenged in achieving its primary objective, it lacks biomimetic design in its elements, and ecological hazards (floods and erosion) are degrading/or destroying existing infrastructures in some Nigerian communities. Consequently, there is a need to integrate biomimetic designs in Nigeria housing policy and programme so as to capture the philosophy that a house is not only limited in providing shelter for humans, but also how the design of the house integrates into the natural functioning of the environment in resource provision, energy savings and environmental sustenance. The application of this approach can be achieved through the inclusion of biomimetic design incentives in building permit approval process to manage externalities associated with the infrastructure, while also taking into cognisance the housing needs of the poor, and the huge infrastructural investments of high income earners and the public. This approach will reshape consumption behaviour; develops a built environment that integrates and functions without resistance with its local condition in resource provision, waste management for its occupants, and enhance sustainability of resources base.

Keywords: *Architecture, Biomimicry, Design, Externality, Housing policy, Nature*

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1. Introduction

As human society hurtles towards an urban future and its concomitant demand for space and resources, the natural world is being replaced by products of human ingenuity. With the unceasing quest for development of settlements, public infrastructures, agricultural facilities and advanced technological systems in view of improving human condition and dignity, the quality of the environment and resource sustenance is being challenged (United Nations, 2017; FAO, 2018). This is aligned to the ever growing human numbers and its related pressure on resource base (UNDESA, 2019). However, when the built environment, such as residential houses, public infrastructures and industrial developments are designed in relation with the functioning of the natural system, energy savings and resource conservation can be improved, resulting to sustainability of resource base (Olusegun, 2018).

The inspiration obtained from nature in achieving fascinating infrastructural designs that function in line with nature's ability of self-regulating and environmental sustenance has been widely opined in architectural sciences (Vahedi, 2009; El-Ghobashy & Mosaad, 2016). During nature's 3.8 billion years of research and development, it has evolved highly efficient systems and processes that can inform solutions to many of the waste generated, resource efficiency and management of problems we grapple with today (Benyus, 2002; Sudhakaran, 2017). Nature has solutions to our infrastructural designs as it knows what works, what is appropriate and what lasts here on earth. Thus, integrating the functioning of nature in our built environment, especially in provision of accommodation could assists in energy savings, waste management, water conservation, food security, mitigate ecological hazards among others for the occupants of the building. Consequently, it reduces the frequency of extracting these resources from the natural stock.

However, providing accommodation for humans is a global challenge, and governments across the world have been taking measures to reduce the number of homeless people (Kalu, Agbarakwe, & Anowor, 2014). Addressing this issue is interconnected to reducing poverty and sustaining environmental quality. In Nigeria, the government has been restructuring her policy on housing in order to enhance the provision of affordable and sustainable housing for her citizens (Olawale, Lawal, & Alabi, 2015). With the country losing 5% of her forests annually (the highest rate of forest loss in the world) to give way for settlements and other developmental activities (FAO, 2016), growing energy challenges (World Bank, 2018), achieving sustainable housing and improved environmental quality for Nigerians are some of the worrisome issues (Olotuah, 2010). In contemporary times, a house is not only limited in providing shelter for humans, but also how the design of the house integrates into the natural functioning of the environment in resource provision, energy savings and environmental sustenance (Benyus, 2002). The house should be designed with consideration on how it will assist in providing its own water, food, energy, waste management, accommodate ecological hazards (for example, flooding and erosion) for the occupants without frequent visit to the natural capital. Following the increasing demand for resources and settlements, and the need to achieve sustainable development agenda, this article seeks to review nature-inspired architectural designs and the place of these designs within the ambit of Nigeria housing policy (especially within approval of building plan). This is with a view of suggesting a workable regenerative housing approach that will sustain resources and also provide comfort for the occupants.

2. Materials and methods

The keywords and phrases revolved around the themes of sustainable architecture, biomimicry, nature-inspired design, ecosystem function, and the integration of natural processes into human-built environments. The above-mentioned keywords were employed to conduct a thorough literature search on prominent journal databases, including Science Direct, Springer, and Google Scholar, as well as platforms like ResearchGate and Academia. This comprehensive methodology was instrumental in gathering relevant and current literature for the development of this review paper on biomimicry, nature-inspired architecture, and their integration into housing policies. The selected keywords were strategically chosen to target key concepts related to sustainable architecture, regenerative design, and the symbiotic relationship between human-built environments and natural processes.

3. Results and discussion

3.1. Nature – An Architect for Infrastructural Design in Resources Management

Architect-Builder Relationship and Biomimicry

An architect plans and conceives a building, keeping functional requirements in mind. A builder executes and makes it a reality. Nature (architect) offers best ideas in designs that humans (builder) can imitate in providing innovative and sustainable solutions for residential housing and public infrastructures. This innovative science which studies nature's best ideas and then imitates these ideas and processes to provide innovative and sustainable solutions is termed Biomimicry. The term Biomimicry means to imitate life and originates from the Greek words bios (life) and mimesis (imitate) (Nkandu & Alibaba, 2018). Biomimicry examines nature, its models, systems and processes for the purpose of gaining inspiration in order to solve man-made problems (Pawlyn, 2011). This contemporary philosophy in architecture seeks sustainability in nature, not by replicating the natural forms, but by understanding the roles governing those forms. It goes beyond biomorphism, which uses nature as inspiration for the aesthetic components of built form or using nature for aesthetics and symbolic association (Figures 1a and 1b), but instead seeks to use nature to solve problems of the building's function. While biomorphism creates a spectacular space, the infrastructure has nothing functionally in common with the inspired organism. However, where form is intrinsic to an organism's function, then a building modelled on life form's processes may end up looking like the organism too.

Figure 1a: The Trans World Airline (TWA) terminal at John F Kennedy Airport, New York, is designed using biomorphic forms to capture the poetry of flight.
Source: Pawlyn (2011)

Figure 1b: Water lilies building
Source: Pawlyn (2011)

The term biomimicry first appeared in scientific literature in 1962, however, it was not popularly used (Nessim, 2016). The term became popularised after the publication by Janine Benyus in her book Biomimicry: Innovations Inspired by Nature (Benyus, 2002). The author has developed nine criteria by which a design can be tested to measure how well it succeeds at mimicking nature.

1- Nature runs on sunlight – Does the design run on sunlight?

2- Nature uses only the energy it needs – Does the design/structure consume only the energy it needs to function?

3- Nature fits form to function – Is the shape of the building derived from what it is supposed to achieve?

4- Nature recycles everything – How effective does it handle wastes?

5- Nature rewards cooperation – How well does it relate with its surrounding environment?

6- Nature banks on diversity – Is the design tailored to its environment or is it a one-size fits all type of building?

7- Nature demands local expertise – How well does it make use of local resources?

8- Nature curb excesses from within – Is there a good economy of building materials such that it only uses the amount of material it needs to function and is not overbuilt.

9- Nature taps the power of limits – Is it able to maintain the narrow range of values suitable for its inhabitants without need for supplementary devices like air conditioning and heating systems?

Regenerative Design Approaches: Design to Nature or Nature to Design

A regenerative design practice can be achieved when buildings in an estate are designed to mimic the outlined tenets of ecosystem function of the local environment (Olusegun, 2018; Zari, 2009). The design approach can either work from design to nature or nature to design. Design to nature means identifying a design problem and finding a parallel problem in nature for solution. For example, the bionic car (Fig 2a) that looked to the box fish (Fig 2b) to build an aerodynamic body to overcome air resistance and enhance efficiency of energy use (Pawlyn, 2011). Efficiency in utilising resources is interconnected in ways that benefit society and promote environmental resilience (Tambe, Okonkwo, & Eme, 2022). For example, efficiency in energy use associated with the bionic car means reducing emissions, sustaining a healthy climate for man and other species, strengthening agricultural systems and sustainability of resources, promoting a green planet and improving the livelihood of communities.

(2a) Bionic car

(2b) Box fish

Figure 2: Design to nature approach
Source: Pawlyn (2011).

The nature to design method is a solution-driven biologically inspired design. In this approach, designers start with a specific biological solution in mind and apply it to design. An example is the Sto's lotusan paint, which is self-cleaning, an idea presented by the lotus flower (Figure 3), which emerges clean from swampy water (Zari, 2010). Recurrent repainting of a house to cover stains and dirt (hence sustaining its aesthetic) using conventional paint types that lack nature-inspired designs requires frequent use of resources, such as water, energy, chemicals among others. These resources use and their implications are interconnected in ways that weaken the networks of human goals and aspirations (Anukwonke, Tambe, Nwafor, & Khired, 2022). These include challenge to air, water and soil quality; waste management, human capital, quality of life and environmental health.

Figure 3: Nature to design approach – Self-cleaning of lotus flower enables buildings to be self-cleaning using lotusan paint.
Source: Zari (2010).

Levels of Mimicry and Application in Resource Management

Infrastructural designs in line with biomimicry can work at three levels: organism, behaviour and ecosystem level (Biomimicry Guild, 2007; Othmani, Yunos, Ismail, & Abd. Rahman, 2018; Zari, 2007). Buildings at the organism level mimic a specific organism. However, working on this level alone without mimicking how the organism participates in a larger context may not be sufficient to produce a building that integrates well with its environment; because an organism always functions and respond to a larger context. At the organism level, the architect looks to the organism itself, applying its form/or function to a building. Norman Foster's Gherkin Tower in London (Figure 4a) has a hexagonal skin inspired by the venus flower basket sponge (Figure 4b). This sponge sits in an underwater current and its lattice-like exoskeleton and round shape help disperses these stresses on the organism (Ehsaan, 2010). Thus, the form and subsequently its function ensures that the building is stable in withstanding to the stresses of such environment. This means that environments with these conditions have the potential to weaken buildings that are not capable of accommodating this stress. Consequently, repairs and reinforcement become frequent and their associated resource utilisation, emissions and degrading quality of the environment.

(4a) Gherkin Tower, London

(4b) Venus Flower Basket
Figure 4: Biomimicry at the organism level.
Source: Ehsaan (2010)

At the behaviour level, the building mimics how the organism interacts with its environment to build a structure that can also fit in without resisting its surrounding environment. The Eastgate Centre (Figure 5), a large office and shopping complex in Harare, Zimbabwe is found in a region where temperature varies from as low as 5 ºC to 33 ºC (Pawlyn, 2011). However, it was designed to minimise the potential cost of regulating the building's inner temperature between 21ºC and 25ºC using inspiration from the self-cooling mounds of African termites. The ten storey shopping complex has no air-conditioning or heating system, however, it regulates its temperature using only about 10% the amount of energy used by buildings of the same size.

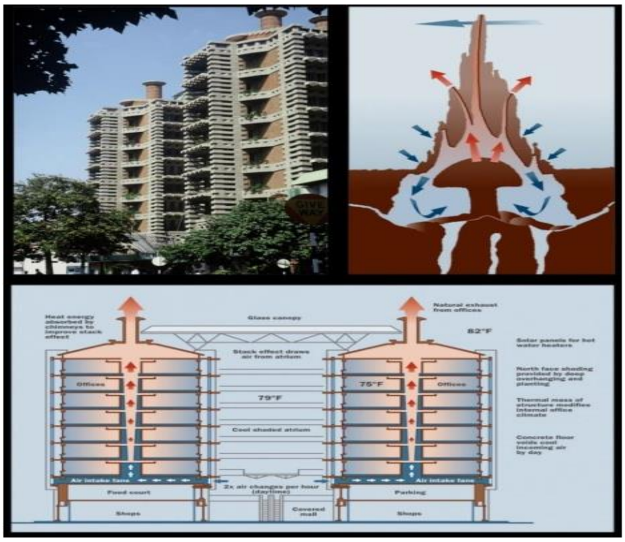

Figure 5: The Eastgate Centre, Harare Showing Behaviour Level of Biomimicry
Sources: Nkandu and Alibaba (2018); Okeke et al,. (2017).

The structure of a termite mound is such that cool air comes in at the base and is channeled through a number of channels and as it warms, it rises up to the top where it escapes then more cool air is sucked in at the base, replacing the lost hot air, and thereby a constant internal temperature(Aiki, Pirk, & Yusuf, 2019). The Eastgate Centre functions in the same manner as a termite mound.

However, it is equipped with low speed back-up fans that bring in the cold air at night and distribute it throughout the building keeping it cool, and as the air gets warmer as the day progresses, the warm air escapes through the top of the building.

The survival of cactus plant in dry and scorching climate has been used as a model for building in the desert such as that of the Minister of Municipal Affairs and Agriculture in Qatar (Bastola et al., 2021). Sun shades on the windows of the building open and close in response to heat, just as the cactus undergoes transpiration at night rather than during the day to retain water. The project reaches out to the ecosystem level in its adjoining botanical dome whose waste management system follows processes that conserve water and has minimum waste outputs. Incorporating living organism into the breakdown stage of the wastewater minimizes the amount of external energy resources needed to fulfill this task. The dome would create a climate and air controlled space that can be used for the cultivation of a food source for employees.

Biomimetic design at the ecosystem level involves mimicking how many environmental components work together and tends to be on the urban scale or a larger project with multiple elements rather than a solitary structure (Biomimicry Guild, 2007; Zari 2010). At this level, the building mimics natural processes and cycle of the greater environment. The building follows principles of ecosystem such as dependent on sunlight; optimise the system rather than its components, attuned to and dependent on local conditions, diverse in components, relationships and information, create conditions favourable to sustain life, adapt and evolve at different levels and at different rates (Unvan & Erbaş, 2019).

For example, Lavasa, India is a region subject to monsoon flooding and a proposed 8000-acre city. It was determined that the site's original ecosystem was a moist deciduous forest before it became an arid landscape. In response to the seasonal flooding, the building's foundations are designed to store water like the former trees did. The city roof tops are designed to mimic the drip-tip system of the banyan fig leaf that allows water to run off while simultaneously cleaning its surface (Gendall, 2009). The strategy to remove excess water through channels is borrowed from local harvester ants, which use multi-path channels to divert water away from their nests.

The Cardboard to Caviar Project in Wakefield, United Kingdom is a cyclical closed-loop system (Figure 6) using waste as a nutrient (Pawlyn, 2011). Restaurants are paid for their cardboard; the cardboards are shredded and sold to equestrian centres for horse bedding. The soiled bedding is bought and put into a composting system, which produces a lot of worms. The worms are fed to roe fish, which produce caviar, and is sold back to the restaurants

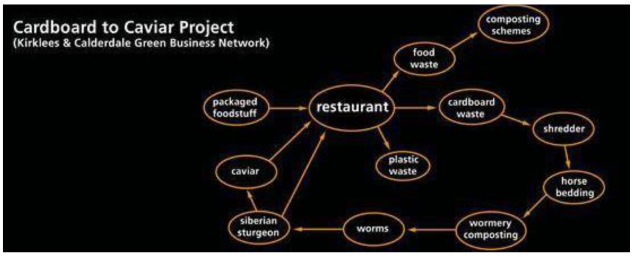

Figure 6: The Cardboard to Caviar Project in Wakefield, United Kingdom showing Biomimicry at Ecosystem Level. Source: Nkandu and Alibaba (2018)

3.2. Nigeria Housing Policy and the Place of Biomimicry

Housing Development Policy and Scope of Application of Biomimicry in Nigeria

The provision of accommodation is a challenge for millions across the world, and available and affordable housing is central to the existence and wellbeing of man (Ofori, 2020; Rolfeet al.,2020). Following the relationship between accommodation and human welfare, many governments and international organisations have been working through setting targets to reduce the number of homeless people. The formal intervention into housing sector, policy and programme restructuring in Nigeria dated back to the colonial administration, after the unfortunate outbreak of the bubonic plaque of 1928 in Lagos (Waziri & Roosli, 2013). Adeshina and Idaeho (2019) maintained that the evolution and development of housing policy in Nigeria could be categorised under five distinct periods; the colonial period (before 1960), post-independence period (1960-1979), the second civilian administration period (1979-1983), the military administration period (1984-1999) and the post military period (1999-date).

These periods are characterised with restructuring of the policy and programme on housing; with each phase setting specific target in measuring programme achievement, and with the fundamental objectives being to realise affordable and available housing for all Nigerians ((Festus & Amos, 2015; Kalu et al., 2014). Despite these efforts, the country still grapples with achieving housing needs for her citizens. Studies have inferred that the goal of affordable and available housing for all has largely been unrealistic, unattainable and ineffective because majority of the people are low income earners who cannot afford housing under various housing programmes (Festus & Amos, 2015). Furthermore, the housing policy of Nigeria stated the need to promote the use of certified locally produced building materials and the use of appropriate technology in housing construction. The use of locally produced building materials are tenets of enhancing low ecological footprints and a healthy society.

Although the housing policy emphasised on the need for appropriate technology in housing construction, specific emphasis has not been made on the need for biomimetic design as a precondition for housing approval and development. In contemporary times, the construction of a residential/or public infrastructure is not only limited to the usual philosophy of providing shelter for the occupants, but how the design should assist in resource provision and mitigating current environmental crisis such as flooding, erosion, emissions, climate change and their interconnected impacts. While the poor are in dare need of basic accommodation, and even when the house /public infrastructure is well funded and occupied by higher status individuals of the society, buildings design in Nigeria still fall short of meeting designs that could reduce resource exploitation and ecologically acceptable. Abazuon and Okolie (2017) showed that a larger proportion (79%) of the designed houses in Ngozika housing estate, Awka lack regenerative designs that would have been assisting in energy savings and protect the environment. In a related study, Soba, Zaki and Aliyu (2016) found that some biomimetic attributes such as biosphere enhancement and adapt and evolve are ranked good in the Faculty of Medicine Building, Kaduna State University. Furthermore, other attributes of the building that were assessed and ranked fair are: use of free energy, use of minimal energy and materials.

Ecological Hazards in Nigeria and Biomimicry: Challenges and Prospects

Over the years, for example, some Nigerian States have been suffering from severe ecological hazards such as floods and gully erosion (National Emergency Management Agency, 2012; UNICEF, 2022). These hazards are resulting to loss of lives, properties, exacerbate human suffering and undermine the prospect of achieving sustainable development. Since the causes of floods, for example, are both natural and anthropogenic, with anthropogenic causes leading these causal factors, and nature having a strategy of regulating itself, reviewing our anthropogenic practices are essential to mitigate flood related hazards (Mfon, Oguike, Eteng, & Etim, 2022). Also, flooding and floodplains offer windows of interconnected opportunities such as increasing soil fertility, boosting agricultural output, enhancing sources of livelihoods and promote socio-economic networks(Afu, Isong, & Awaogu, 2019; Frankeet al., 2019).Following the pros and cons of flood events, there is a growing philosophy of living with floods, and this constitute a viable approach in its management (mitigation and adaptation), (Serra-Llobet, 2018). In this regard, biomimetic built environment can offer sustainable solutions in flood prone settlements in Nigeria. This means, designing resilient pathways – planning to absorb the shocks, recover and adapt to the hazards. Buildings within such settlements could be designed to function in line with ecosystem characteristics of the local environment. In consideration of the local environment, the house and its design should align with the topography of the area, the fauna and flora that are capable of thriving in this environment (resilient and capable of accommodating perturbations) and interacting with its environment in regulating resource use, recycling waste and stabilising its conditions for the occupants.

Biomimetic architecture is an emerging and transdisciplinary area of study, embracing biology, ecology and design (Nkandu & Alibaba, 2018). Following the emerging and transdisciplinary attribute of this discipline, studies related to assessing a building's biomimetic design and the role of Nigeria housing policy in addressing biomimetic design prior to construction of an infrastructure is still at infancy. Addressing biomimetic characteristics of a building or any infrastructural development prior to approval for construction could assist to enhance the training of biomimetic architects/civil engineers, facilitate the availability of regenerative buildings, improve on environmental health and sustain resources. This could be achieved through internalising the externality of the buildings design in the cost of the building permit (Figure 7). The application of this approach could take cognisance of the housing needs of the poor and the complex infrastructures developed by high income earners and the public. These could include income status of the developer, location, size of the project, ecological importance/vulnerability of the area among others.

Where a building's design is in conformity with the tenets of biomimetic architecture, the externality is reduced and the incentive associated to the reduced externality is discounted in proportion to its achievement of biomimetic design. For example, if a building plan is designed to depend on fossil fuel using a generator to pump its own water and provide electricity for the occupants, then the externality of this parameter, using fossil fuel, could be fully internalised into the cost of the building plan. On the contrary, if the building plan shows design and dependency on solar roofing system to pump its own water and provide electricity for the occupants, the externality of the design is reduced because using solar energy lowers emissions when compared to using fossil fuels. In this regard, the incentive for this externality is discounted. Furthermore, if the same building is dependent on collecting its own water for the occupants during some periods of the year, especially during the wet seasons, using expandable water storage vessels, designed with lightweight membranes and mimicking how the cactus plant survives to manage its water in desert condition (Nessim, 2016), and assisting in reducing flooding in flood prone areas, the externality is reduced and the incentive in the building permit for that parameter is further discounted.

The use of ecological information for sustainable housing designs means ecological data for endemic species and how they interact to form a resilient environment are essential in developing regenerative housing that align with these environments. Where such settlements could be achieved on a large scale (many towns and cities in the nation, Nigeria), and indicating quantification of carbon capture, collaborations within these settlements can earn carbon credits from the Clean Development Mechanism (CDM) which could be sold to some countries, especially the industrialised economies (Chitre, 2013). Consequently, this can assist these economies to achieve their emission reduction target while promoting environmentally friendly investments in Nigeria. While full compliance with biomimetic design in housing development can earn carbon credit from CDM, the funds generated from biomimetic design deficiency(full incentives and/or partial incentives for the externality of buildings' design) could be used for developing ecological restoration sites in Nigeria. These pathways can contribute to improving the livelihood of community residents and strengthen achievement of sustainable development.

The need to internalise environmental costs of products in order to manage consumption behaviour and sustain environmental health and resources are becoming attractive approaches in environmental management (Eidelwein, Collatto, Rodrigues, Lacerda, & Piran, 2018; Tambe & Okonkwo, 2017). The nexus between resource consumption, human well-being, climate change and its related impacts implies the integration of biomimicry as a viable approach in sustaining our built environment cannot be relegated. This study suggests the inclusion of biomimetic design probe in housing permit and infrastructural development prior to approval of the plan in Nigeria. However, the approach should take into cognisance the housing needs of the poor, huge infrastructural investments made by higher income earners and the public, so as to balance social needs and sustain a productive environment.

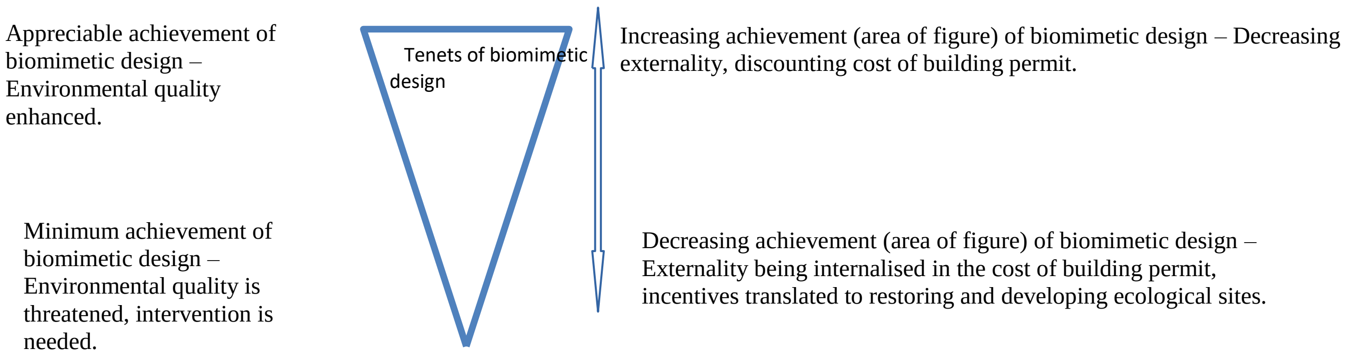

Figure 7: Costing the externalities of infrastructures in bulding permit approval process.

4. Conclusion

The growing demand for space in order to develop infrastructures is transforming and altering the functioning of the ecological system. Globally, there is unceasing quest for conservation of natural resources; however, the strength of any conservation approach is measured in the level of harmonising conservation and development. Thus, balancing the need for housing for Nigerians and sustaining the natural stock that we rely on requires an approach which integrates infrastructural development and ecological functioning. Nature offers windows of opportunities through the science of biomimetic architecture that we could incorporate in our designs in order to assist in designing infrastructures that fits into the functioning of nature in ways that enhance resource management and reduce environmental crisis. However, addressing the need to integrate biomimetic designs prior to approval in building permit constitute a missing tenet in Nigeria housing policy. The integration of this approach in Nigeria housing policy could guarantee a more habitable built environment and enhance sustainability of resources base.

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