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Development of a Building Performance Assessment and Design Tool for Residential Buildings in Nigeria.

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Abstract

Building performance and assessment tools are not new to the global audience. What are new however are the concerns, on the part of policy makers and building practitioners, with their adaptation to the Nigerian context. These concerns have become especially salient in the face of continued climate change and excessive environmental perturbations.
This paper presents the development of a building performance and design tool that is intended to assist the Nigerian government with its building codes and policies and also building practitioners with the design process. The methodology is based on a review of existing building rating systems such as LEED and BREEAM, from which a system adapted to the requirements of the Nigerian National Building Code for residential buildings is proposed. The methodology is further developed into a design tool whose features include a schematic design serving as a reference building validated through energy simulation.
The underlying proposal of this paper will assist the Nigerian National Building Code in establishing policies favourable to the built environment and aid designers in the creation of sustainable buildings in Nigeria, as well as serving as an exemplar to other developing African countries.

Keywords: Performance Assessment, Nigeria, Design tool, LEED, BREEAM, residential building.

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1. Introduction

The primary objective of a building is the provision of shelter, comfort, and safety for its occupants. Therefore to attain this purpose buildings are designed, planned, constructed and managed according to certain codes and regulations, governed by experts and government bodies [1-4]. The adverse effect of climatic change and the increase in public environmental awareness in the building industry has resulted in the development of creative solutions to reduce the Green House Gas [5-9]. Building assessment tools are being developed worldwide with a considerable amount of success, such as the Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED). These assessment tools provide an effective framework to measure the environmental performance of the building and construction process. Considerable research has been put into development of effective assessment tools for different localities, due to differences in each country’s climatic conditions, availability of material, land, cultural adaptation, population growth, public awareness and legal support. In this paper a detailed analysis of existing performance assessment tools will be conducted with a view to their adaptation for Nigerian conditions. The research adopts a qualitative approach, with the main instrument of data collection generated from literature sources such as books, journals, articles, libraries and databases. An analytical discussion of pre-existing building performance assessment tools will be used to develop a framework to assess the Nigerian case. The derived framework is then incorporated into a design tool which features a schematic design validated through energy simulation for residential buildings.

2. Appraisal of Existing Performance Tools

Two performance assessment tools have been selected for appraisal, due to their popularity and widespread usage: BREEAM which was the predecessor of all green building rating tools; and LEED which is one of the most widely recognized building environmental assessment schemes.

BREEAM was first developed in 1990, with the most recent updated version produced in 2014 [8]. The main function of this assessment tool is primarily on building specification evaluation including the design, construction and use [10] based on four assessment tools that can be used at different stages of a building’s life cycle. BREEAM methodology is calculated by awarding a point or credit that is based on the following categories (management, health & wellbeing, energy, transport, water, material, waste, land use & ecology, pollution and innovation) which determine the environmental impact of the building. The total number of credits awarded in each category is multiplied by an environmental weighting factor which defines the importance of the category. The category scores are added up to produce an overall score, designated as Unclassified, Pass, Good, Very Good, Excellent, and Outstanding. A star rating from 1-5 is also provided. The BREEAM International certification system also uses a star rating system [11].

LEED was founded by the U.S. Green Building Council (USGBC) in 1998. According to LEED [12] more than 72,000 LEED certified projects across 150+ countries, comprising over 13.8 billion square feet (approx.12.8 billion square metres) has been executed, which makes it one of the most widely used assessment tools. The latest version “LEED Version 4” [9] was officially launched in 2014, and includes schemes for Building Design & Construction, Building Operations & Maintenance, Interior Design & Construction, Neighborhood Development and Homes. The LEED Neighborhood Development scheme is one of the first developed schemes for community sustainability evaluation; however it overlooks essential issues such as the local economy and the provision of jobs and affordable houses [13]. LEED consists of nine categories namely: integration process, location & transportation, sustainable site, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, innovation in design, and regional priority. Here, building grades are classified as follows: Certified (40-49points), Silver (50-59 points), Gold (60-79 points), and Platinum (80-above points) [9]. In order to establish an explicit understanding of these systems, each is examined comprehensively highlighting their respective strengths and potential as listed in Table 1 and described in what follows.
There are a number of categories comprehensively established by the building assessment tools for BREEAM and LEED. These categories are noted in Table 1, with their indicators and sub-indictors. These categories will be reviewed with reference to the subject location (Nigeria) and the findings incorporated into the proposed framework.

Table 1. Comparison of performance assessment tools

Categories	BREEAM	LEED	Categories	BREEAM	LEED
Sustainable site and Ecology			**Economic Aspect**		
Ecological status			Operation and maintenance cost	√	√
Biodiversity protection	√	√			
Contaminated Land	√	√	**Pollution**		
Enhancing site Ecology	√	√	Prevention of refrigerant leakage	√	
Ecological impact	√	√	NOx emission	√	√
Construction site			Co2 emission	√	√
Site protection	√	√	Night light	√	√
Site selection	√	√	Noise pollution	√	√
Site Development	√	√	Watercourse pollution	√	√
			Natural disasters	√	√

Energy		
Natural Resources		
Renewable energy strategy	√	√
Energy performance		
HVAC	√	√
Lighting (internal)	√	√
Lighting (external)	√	
Ventilation	√	√
Heat transmission	√	√
Operational		
Energy monitoring	√	√
Optimizing energy	√	√
CO2 reduction strategy	√	√
Insulant GWP	√	
Innovation		
Exceptional performance	√	√
Innovation in design	√	√
Transport and Location		
Accessibility	√	√
Car park capacity	√	√
Pedestrian access	√	√
Cycling safety	√	√
Density development	√	√
Community connection	√	√
Water and Waste management		
Water		
Water consumption	√	√
Indoor water reduction		√
Outdoor water reduction		√
Irrigation system	√	√
Rain water harvesting	√	√
Water conservation/metering	√	√
Grey water recycling	√	√
Waste water technology	√	√
Waste		
Construction waste management	√	√
Waste treatment	√	√
Recycling Activities	√	√
Indoor Environment & Health		
Ventilation		
CO_2 monitoring	√	√
Provision of natural ventilation	√	√
Ventilation system	√	√
Fresh air supply	√	√
Lighting and Illumination		
Daylight	√	√
View out and Glare control	√	√
Lighting control	√	√
Illumination level	√	√
Noise and acoustics		
Noise level	√	√
Sound insulation	√	
Contaminate level		
Volatile organic compounds (VOC)	√	√
Microbiological contaminate level	√	√
Thermal comfort		
Cooling/heating and humidity control	√	√
Proper zoned control	√	√
Social aspect		
Equity		
Education		
Participation		
Social Cohesion		
Materials		
Low environmental impact materials	√	√
Renewable natural materials	√	√
Insulation	√	√
Source of raw material	√	√
Re –use of structural material	√	√
Use of non- structural frame material	√	√
Use of finishing material	√	√
Efficient use of material over if life cycle	√	√
Management		
Commissioning	√	√
Construction site management	√	
Consultancy	√	
User guide	√	
Security	√	

Sustainable site and Ecology - The intent of this indicator is to reduce potential site pollution from construction activities by controlling soil erosion, waterway sedimentation, biodiversity and airborne dust [14, 15]. In BREEAM it is identified under land use and ecology, which is equivalent to sustainable site in LEED.

Energy - Due to its environmental impact, the energy category shares the largest portion of credit distributed amongst the environmental indicators [14, 15]. Therefore vital importance is placed on the energy design, energy management, renewable energy strategies, energy conservation and monitoring [16]. Both methods made use of supplementary tools for this aspect such as Standard Assessment Procedure (SAP) for BREEAM and American Society of Heating, Refrigerating and Airconditioning Engineers (ASHRAE), American National Standards Institute (ANSI) and Illuminating Engineering Society of North America (IESNA) for LEED.

Water and Waste management - This category analyses the water consumption in and out of the building, water treatment, the health impacts and environmental pollution from waste water and solid waste. It also deals with waste management in construction, where waste materials are recycled back to manufacturing process and waste management plans are implemented for demolitions.

Material - The aim of this category is to ensure best practice for resources consumption in terms of materials. BREEAM relies on a Green Guide to Specification, which contains over 1500 building materials specifications and plays a vital role in decision making for materials and their environmental impacts [14]. Meanwhile LEED focuses mainly on the reusability and maintenance of construction materials.

Management - The management of site and construction activities are also key factors in attaining sustainable development, providing an opportunity to assess the commissioning level, and provision of guidance for the building and a clear understanding of how it operates. This is apparent in BREEAM under the heading management, while LEED only gives it a passing mention.

Indoor Environment & Health - The quality of the indoor environment is regarded as a vital aspect of all assessment tools. It aims at delivering a healthy indoor space including lighting, noise, acoustics, ventilation rate, thermal comfort, quality of view, daylight and protection from hazardous substances on the occupants health life [14,15]. The category is described as Health & Wellbeing in BREEAM and Indoor Environmental Quality (IEQ) in LEED. LEED includes low-emitting materials, while BREEAM covers Heating Ventilation and Air-Conditioning (HVAC) systems.

Economic aspect - The economic aspect discusses the operational, constructional and maintenance costs. Both assessment tools deal with these issues poorly [16, 17].

Pollution - Pollution is assessed in both schemes. BREEAM assesses the factors from a more global perspective, relating to global warming potentials and related impacts due to refrigerant leaks, NOx and CO_2 evaluations, while “Heat island effects” are evaluated by LEED [18].

Innovation - In light of the sustainable developments criteria, both assessment tools created room to encourage and recognise exceptional performance in all sustainable aspects.

Transport and Location- This aspect helps improve accessibility to site in order to reduce the vehicular mile ratio to site, increase the protection of farmland and wildlife habitat, and also improve human health while encouraging physical activity [14, 15].

Social aspect - This aspect entails building and community related issues like improvement of health, comfort, awareness, quality of life, social cohesion, equity, satisfaction, education, safety security, accessibility and participation, which are key determinants to achieving a sustainable building. These aspects have been given less consideration in performance assessment tools. According to [19-21] performance assessment tools have failed to understand what social matter truly means.

The eleven categories selected above for comparison between BREEAM and LEED, were based on the importance level in the Nigerian context, with each category relating to one another in order to set a guide in the development of a framework for Nigeria. These listed categories are generally applicable to every nation in order to help improve environmental sustainability, with each aspect regarded as a key attribute while improving the environment.

3. Building Performance Tools and the Nigerian context

This section introduces the Nigerian environment and its sustainable status, highlighting the level of sustainable development. It also expands on the creation and evaluation of an assessment framework.
Nigeria as a country has no locally-based green building assessment tool or application procedure. The Green Building Council of Nigeria (GBCN) is newly developed and still on a prospective membership level of registration with the World Green Building Council (WGBC) as of January 2014. GBCN is newly established and thus has not produced an environmental rating tool that could be used for office, retail, multi-unit residential, public and education building projects in Nigeria [22].
There are a few LEED certified buildings in Nigeria namely: The Heritage Place in Ikoyi, Lagos for (LEED BD+C Core and Shell v3-LEED 2009); The NOX building in Abuja a Gold rated building for (LEED BD+ C: New Construction v3-LEED 2009); P&G Nigeria MDO Warehouse rated Silver building for (LEED BD+ C: New Construction v3-LEED 2009); RFA HS-Classroom North in Abuja for (LEED BD+C: School v3 – LEED 2009); RFA HS- Classroom South in Abuja for (LEED BD+C: School v3 – LEED 2009); AfDB Nigeria Field Office in Abuja for (LEED BD+ C: New Construction v3-LEED 2009), No 4 Bourdilon Street in Lagos for (LEED BD+ C: New Construction v3-LEED 2009); and Asdads Building for (LEED BD+ C: New Construction v3-LEED 2009) [24]. Other performance assessment tools like BREEAM, CASBEE and Green Star and others have not been used to certify any buildings in Nigeria.

The formation of a framework for the Nigerian context will now be described, with examples from BREEAM and LEED to determine its adaptability to the Nigerian context, while listing factors that hinder its application within the Nigerian context.

3.1. Development of an Assessment Framework for Nigeria

As stated earlier most building performance assessment tools were developed for their specific locality [24-27] and are not fully applicable to all regions. Factors hindering the direct use of any performance assessment tool in other regions include: climatic conditions, potential for renewable energy gain, land, geographical characteristics, resource consumption, government policies, public awareness, availability of raw materials, technical knowledge, population growth, appreciation of historical value and many more. It is evident that prime building performance tools in developed countries are limited to their particular regions. Therefore, a context based framework relevant to local conditions in Nigeria is required, one heedful of the vernacular architecture and with a clear understanding of the socio-cultural and economic dynamics of the region.

Since 2014, Nigeria has being a prospective member of USGBC World as stated earlier, therefore a rating system for non-residential and residential building types, with design specifications needs to be established to protect the geographical identity, environmental, cultural and social development of Nigeria. To establish a performance assessment tool for Nigeria, the LEED and BREEAM assessment tools have been studied and some aspects have being identified as key areas that needs to be addressed. In LEED, under sustainable site credit for example, a fuel-efficient car lending programme must be provided for a minimum of 3% of the building occupants. This cannot be effective in the rural environment in Nigeria - the LEED system is geared toward the urban rich, while neglecting the urban poor. The lack of equality in decision making is identified in this aspect. Both LEED and BREEAM proposed a compact design system where all buildings work as a unit - however in an average Nigerian home, the interior and exterior spaces are not as integrated due to socio-cultural influences. An average Nigerian home has cultural and social characteristics that should be examined before a code or design standard is applied. Also the use of energy and the renewable energy commissioning systems in LEED and BREEAM favour developed countries; whereas in Nigeria, laws and regulation compliance are a weak part of the economy. For developed nations the government assists in maintaining energy production and distribution, therefore to attain sustainability in Nigeria emphasis should be on the application and actualization of building design codes, policies and regulations by the citizens and officials.

From Table 1 above, the eleven categories listed for measuring sustainable development were considered while formulating a new framework for assessing a building's performance. It indicates the key criteria for developing a new framework for assessment in Nigeria, and highlights the missing aspects in the existing assessment tools.

The name of the proposed performance assessment framework is the Comprehensive Performance Assessment System for Nigeria (CPASN). It consists of three major stages: the outcome, the indicators, and the sustainability level. The conceptual framework is shown below in Fig 1. The proposed assessment attempts to evaluate current building practices as a whole and also evaluate the environmental performance of individual buildings in Nigeria within the designated areas. Based on findings that include the performance assessment categories and indicators, it was identified that in the Nigerian context the social and economic aspect are key to the development strategy of a performance assessment tool. Therefore to develop a credible framework, these aspects were specifically added to the proposed criteria for the Nigerian performance assessment tool development.

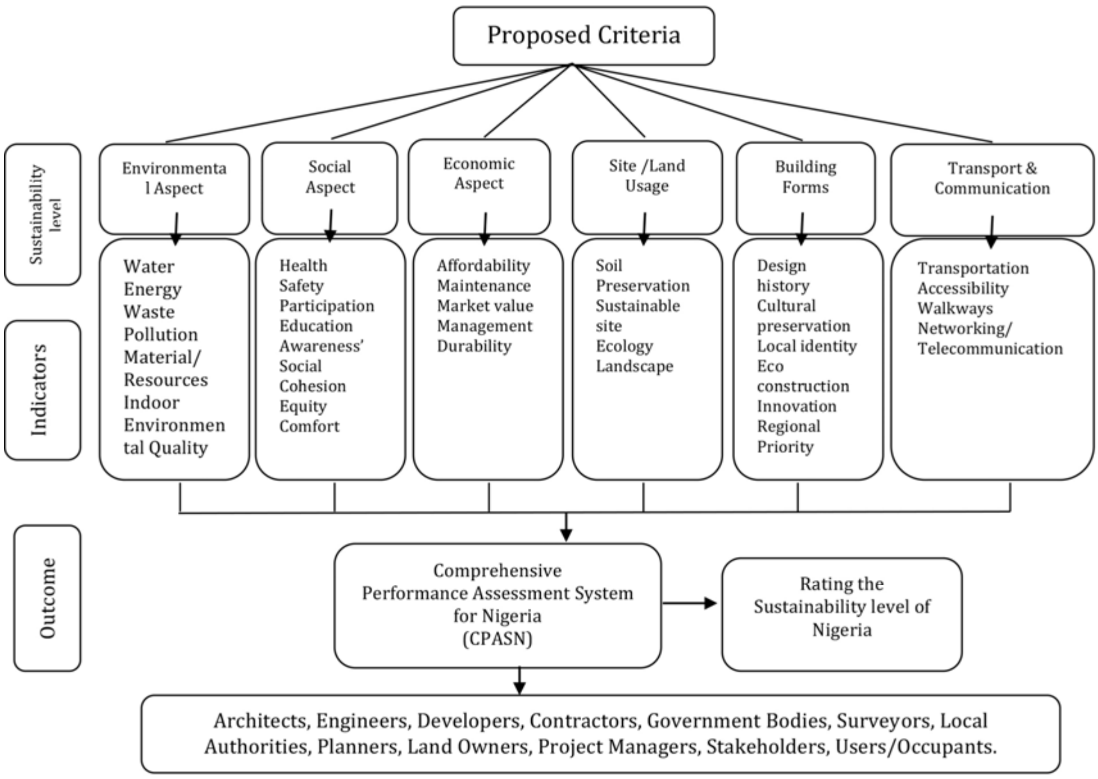

Figure 1. Comprehensive Performance Assessment System for Nigeria (CPASN).

In order to determine the overall score, it is necessary to define the values for each component at the indicator level. The indicators of the framework were derived from a comprehensive literature review and also established performance assessment tools that have been applied in several buildings both in developed and developing countries. The proposed framework should be a benchmark for quality performance assessment in Nigerian sustainable development. Four essential objectives of sustainable development in developing countries are noted in Fig 1. They include: "(a) expanding economic opportunities (especially for poor people); (b) meeting basic human needs (food, clean water, shelter, health care, education and fulfilment of the human spirit); (c) protecting and enhancing the environment; and (d) promoting pluralism and democratic participation (especially by poor people)"[28]. The recognition of performance assessment is shown in the conceptual framework of the CPASN as shown in Fig 1. The aim of this performance frameworks is to embrace various sustainable criteria namely, environment, social and economic, land usage, building forms and transportation facilities.

4. An Adapted Design Tool Based on the Developed Assessment Framework

The proposed design tool is an offspring of the developed assessment framework for the Nigerian context addressing the sustainability level, indicators and projected outcome (see Fig 1). The order in which the framework was derived encompasses an approach where all assessment tool indicators/criteria were grouped in order to fit the Nigerian context, with the indictors as the focal point derived from existing literature and studies. The design tool is aimed at producing a design-oriented approach that would assist designers/architects with its outlined procedure. In order to create efficient buildings and for the effectiveness of the assessment tools, houses should be planned from conception to counteract climatic extremes [29]. In the interest of practicality and page restrictions, the scope of the design tool has been restricted to the fundamentals of climate, physiological, psychological, operational and functional issues. Cognizant of these, the tool guides designers through a decision-making process that leads to four generalized synergies, supported by a range of design strategies. Sections 4.1 to 4.5 provide an overview of the proposed tools. In the interest of clarity, the temperature and relative humidity in the region ranges from 18^0C to 43^0C and from 21% to 100% respectively and it lies between latitudes 0^0N and 35^0N. Wind speeds range from 1m/s to 9m/s on average with annual rainfall from 88m to 2500mm. The length of daylight does not vary substantially through the year, staying close to an average of 12hours/day with fairly similar nocturnal and diurnal temperatures [30].

4.1 Building Configuration

In hot humid regions natural ventilation is the most effective method for abating the physiological effects of high temperature and humidity. The building configuration should be designed to provide optimal cross-ventilation through the building envelope in synchrony with the external landscaping, solar radiation and wind direction [31]. An open spread-out building is the most effective way of optimizing cross-ventilation by providing more wall areas in different directions for catching the winds Givoni [32]. The exposure to the sun should be minimized with the longer axis of the building oriented towards the East-West direction [33].

4.2. Landscaping

Landscaping has a profound effect on the microclimate. It can influence the ambient temperature directly by shading the building from unwanted solar gains and redirecting the wind flow into the building for natural ventilation, and indirectly by evapotranspiration [34]. Research has shown that about 25 to 80% savings on auxiliary cooling can be achieved with well-planned landscaping [35]. The type and species of trees used is very important, they should be selected cognizant of the shade they provide, aesthetic appearance and their ability to act as pest-repellent considering the rise of vector-borne disease in the region. LEED [36] recommends an outdoor space greater than or equal to 30% of the entire site area with a minimum of 25% of that space serving as vegetative cover or overhead vegetated canopy.

4.3. Building Materials

The thermo-physical properties of the building materials affect the rate of heat flow in and out of the building, and subsequently the indoor thermal conditions. These properties include the thermal conductivity, reflectivity, absorptivity and emissivity, surface convective coefficient and heat capacity of the material. External walls should be lightweight with a low heat capacity, light coloured and highly thermally resistive, preferable of locally sourced materials like stabilized adobe bricks. Internal walls could be heavy if annual range is above 20 ^{0}C [37]. Ceilings and roofs should also be lightweight and highly resistive. Reflective roof surfaces are an easy and cheap technique for reducing overheating and the dependence of cooling devices. External wall/structural materials should be impervious to climate extremes of rainfall and wind, preferably with the use of large roof overhangs.

4.4. Building Envelope

Cross ventilation is the simplest strategy for improving indoor thermal comfort in hot humid regions. The air exchange from the exterior through the building envelope improves the indoor air quality and provides a direct physiological effect by increasing the rate of sweat evaporation, thus minimizing discomfort. Apertures should be large and well shaded, between 40 and 80% of the north and south walls with respect to the wind direction and positioned at different heights below and above the door level to enhance stack ventilation if necessary [38]. Windows should be configured in response to sunlight to provide sufficient lighting into the building interior.

4.5. Water and Energy Efficiency

For a sustainable built environment, architects and builders in Nigeria must move towards efficient energy and water management. Considering the significant amount of annual rainfall of 88mm to 2500mm, rainwater harvesting can provide a considerable volume of water saving varying from 30% to 60% depending on the demand and roof area [39]. This should be addressed during the building design and construction process by incorporating appropriate roof drains and strategically locating water tanks with the necessary plumbing fittings to transfer the water into building. Solar power systems should also be installed as an alternative source of power cognizant of the solar irradiance range of 2.5-6.7kWh/m^2.day experienced in most parts of the country [40]. Photovoltaic panels should be incorporated at the design and construction stages. Other alternative sources of power such as geothermal energy should be explored.

5. Application of the proposed design tool

The following schematic floor plan and model were developed based on the adapted design tools on the building configuration outlined in Section 4, using ArchiCAD and the model transferred to Google Sketchup where EnergyPlus was used to conduct a year-long simulation. The model was divided into Zone 1 consisting of the sitting room, dining and kitchen and Zone 2 consisting of the three bedrooms, toilets and verandah respectively (see Fig 3). The results and weather conditions for January 1st, between 1.00am to 12.00Midnight are shown in Fig 2 indicating the most extreme weather condition of the year. The highest indoor temperature of 30^{0}C in Zone 1 is attributed to the fact that the Landscaping was not included in the simulation. The application of the design tool provided an indoor temperature below the outdoor level without the use of auxiliary cooling devices. Based on the simulation, the reference building provides sufficient indoor comfort whilst being energy efficient.

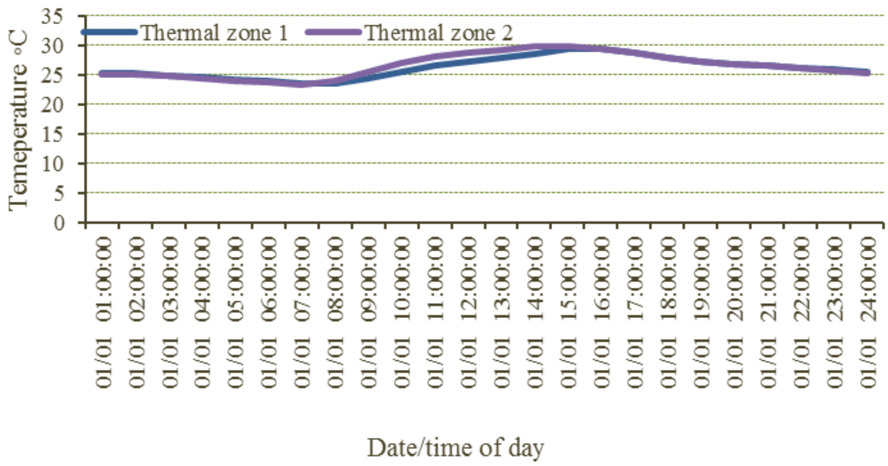

Figure 2: Hourly simulation using Energy Plus from 1am – 12midnight.

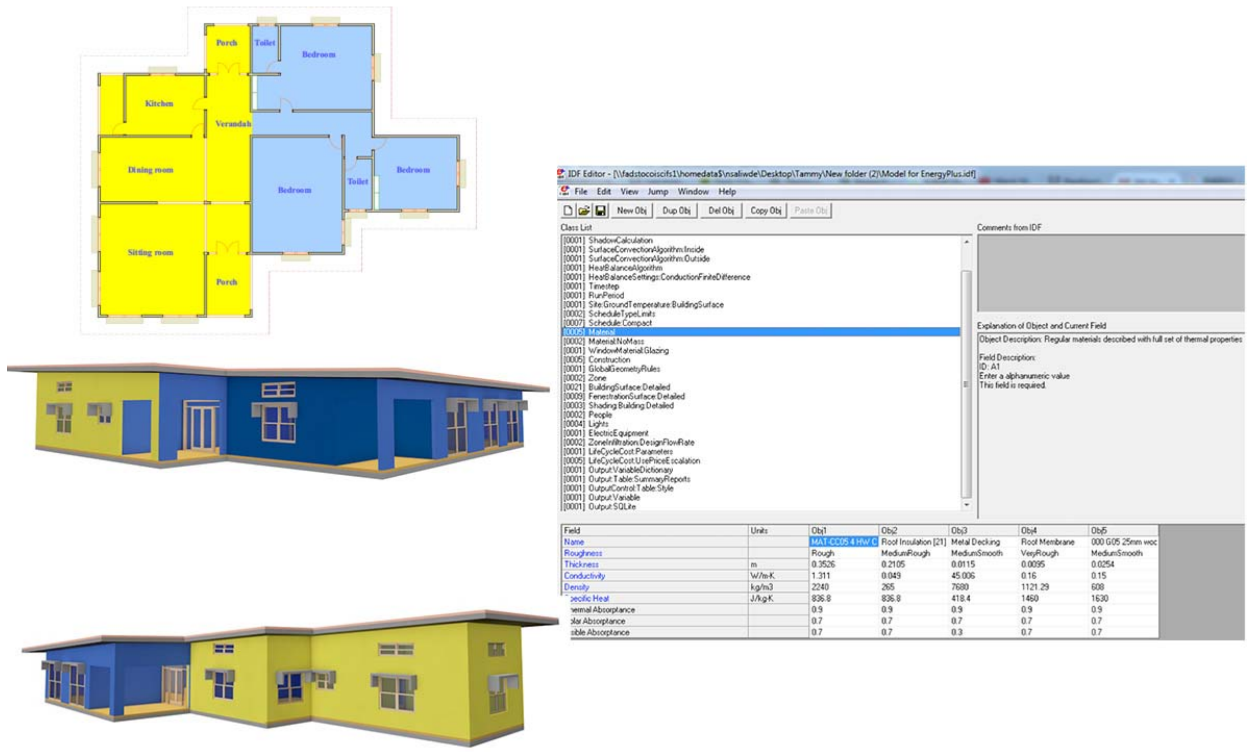

Figure 3: The schematic model and floor plan highlighting zones 1 and 2

6. Conclusion

With the rapid degradation of the environment and excessive reliance on unsustainable energy in Nigeria, the need to initiate controlled building measures is overdue. This paper has provided a comprehensive assessment and design tool to assist designers and the Government in improving the existing building codes. Building challenges are not pre-defined, but rather need to be contextually explored as an iterative process as was the case of the model simulation in this paper where the building elements had to be adjusted iteratively to optimize the output. Inherent in this view is the need for futher exploration of a comprehensive design tool applicable to the Nigerian context. As stated earlier the efficacy of rating schemes depends significantly on their ability to address the contextual issues of the region and incorporate a comprehensive but rudimentary design tool.

References

1. Khalil, N., Husin, H.N., (2009): Post Occupancy Evaluation towards Indoor Environment Improvement in Malaysia's Office Buildings. Journal of Sustainable Development, 2 (1), 186–191.
2. Ukoha, O.M.,Beamish, J.O.,(1997): Assessment of resident's satisfaction with public housing in Abuja, Nigeria. Habitat International 21(4), 445–460.
3. Zeiler, W., Boxem, G., (2008): Sustainable schools: better than traditional schools? In: Proceedings of the Indoor Air 2008 Conference, Copenhagen, Denmark, 17–22 August, Paper ID: 10.
4. Meir, I.A., Garb, Y., Jiao, D., Cicelsky, A., (2009): Post-occupancy evaluation: an inevitable step toward sustainability. Advances in Building Energy Research 3, 189–220.
5. Erten,D. Henderson, K. Kobas, B., (2009): A Review of International Green Building Certification Methods: A Roadmap for Certification System in Turkey. Fifth International Conference on Construction in the 21st Century (CITC-V) "Collaboration and Integration in Engineering, Management and Technology". May 20922, Istanbul. Turkey.
6. Assefa G, Glaumann M, Malmqvist T, Kindembe B, Hult M, Myhr U, et al (2005): Environmental assessment of real estate's – where natural and social sciences meet: the case of eco effect. p. 2055–62 In: Proceedings of the 2005 world sustainable building conference (SB05Tokyo), 2005 Sep 27–29. Tokyo.
7. CASBEE. (2006): "An Overview of CASBEE", Web page from the CASBEE Web site. Japan Sustainable Building Consortium. 2006. [Online] Available: http://www.ibec.or.jp/casbee/english/index.htm (Retrieved January 6, 2016).
8. BREEAM. (2014): BREEAM New Construction Technical Manual SD5076: 0.1 (Draft) - 2014. BRE Global Ltd.
9. LEED. (2013): LEED Reference Guide for Building Design and Construction 2013 Edition, Leadership in Energy and Environmental Design Program. US Green Building Council.
10. BREEAM. (2013): BREEAM homepage. Retrieved January 15, 2013, from http://www.breeam.org/about.jsp?id=66
11. BREEAM, (2012): Operational Guidance for the BREEAM In-Use Scheme. BRE Global Ltd.
12. LEED (2016) http://leed.usgbc.org/leed.html?gclid=COvH1POp6swCFdYK0wodfCkK1g. Accessed, May, 2016.
13. Sharifi A, Murayama A. (2013): A critical review of seven selected neighborhood sustainability assessment tools. Environmental Impact Assessment Revision 38:73–87.
14. BRE (2014) BREEAM UK New construction. Available from: http://www.breeam.com/filelibrary/BREEAM%20UK%20NC%202014%20Resources/SD5076_DRAFT_BREEAM_UK_New_Construction_2014_Technical_Manual_ISSUE_0.1.pdf [cited July, 2016]
15. USGBC (2013) LEED Reference Guide for Building Design and Construction. Available from http://greenguard.org/uploads/images/LEEDv4forBuildingDesignandConstructionBallotVersion.pdf [cited July, 2016]
16. Lee, W, L., & Burnett, J. (2006). Customization of GBTool in Hong Kong. Building and Environment, 41 (12), 1831-1846.
17. Grace, K.C.D (2008). Sustainable construction- The role of environmental assessment tools. Journal of Environmental management, 86(3), 451-464.
18. Kawazu, Y. S. N, Yokoo, N., & Oka, T. (2005). Comparison of assessment results of BREEAM, LEED, GBTool and CASBEE. In Proceedings of the 2015 sustainable building conference (SB05) Tokyo, Japan.
19. Empacher, C. and Wehling, P. (1999) *Indikatoren Sozialer Nachhaltigkeit. Grundlagen und Konkretisierungen,* Institut fUr sozial-okologische Forschung (ISOE) (Ed.), ISOE Discussion Papers 13, Frankfurt am Main.
20. KopfmUller,1. *et al.* (2001) *Nachhaltige Entwicklung Integrativ Betrachtet. Konstitutive Elemente, Regeln, Indikatoren,* Edition Sigma, Berlin.
21. Griebler, E. and Littig, B. (2004) *Soziale Nachhaltigkeit,* Arbeiterkammer Wien (Ed.) Informationen zur Umweltpolitik 160, Wien.
22. GBCSA. Green Building Council South Africa. (2014): https://www.gbcsa.org.za/wp-content/uploads/2013/05/Green-Star-SA-Nigeria-Local-Context-Report-Rev-7-GBCSA-GBCA-Appr....pdf (Accessed, October, 2015).
23. http://www.usgbc.org/projects?title_sort=ASC&changed_sort=unsorted&created_sort=unsorted&k
24. Cole, R. J. (1998). Emerging trends in building environmental assessment methods. Building Research and Information, 26(1), 3–16.
25. Cooper, I. (1999): Which focus for building assessment methods – Environmental performance or sustainability? Building Research & Information, 27(4–5), 321–331.
26. Crawley, D., & Aho, I. (1999): Building environmental assessment methods: Applications and development trends. Building Research and Information, 27(4–5), 300–308.
27. Kohler, N. (1999): The relevance of Green Building Challenge: An observer's perspective. Building Research & Information, 27(4–5), 309–320. Laustsen, J., & Lorenzen
28. Alexander, N. Reeves, D. Beckmann. D. (1993). Foreign Aid: What Counts Toward Sustainable Development and Humanitarian Relief? Washington D.C.: Bread for the World Institute. p. 1-2.
29. Mahoney, C., (1971). Climate and house design, in Design of low-cost housing and community facilities, a.P.U.N.D.o.E.a.S.A. Centre for Housing and Building, Editor. United Nations: New York, USA. p. 93.
30. WMO, The climate in Africa: 2015, in World Meteorological Organization, W.M. Organization, Editor. 2015, World Meteorological Organization: Geneva, Switzerland. p. 10 - 24.
31. Amasuomo, T.T, Amasuomo. J.O., (2016). Perceived Thermal Discomfort and Stress Behaviours Affecting Students' Learning in Lecture Theatres in the Humid Tropics. Buildings. **6**(18): p. 80-97.
32. Baruch, G.,(1994). Passive and low energy cooling of buildings, ed. G. Baruch. New York, USA: Van Nostrand Reinhold. 259.
33. Ogunsote, O.O., (2010). Optimizing passive cooling systems in residential buildings: A case study of Akure, nigeria, O.O.O.B. Prucnal-Ogunsote, Editor. Department of Architecture, Faculty of Environmental Sciences University of Jos, Jos, Nigeria: Jos, Nigeria. p. 1-15.
34. Misni, A., (2013). Modifying the Outdoor Temperature around Single-Family Residences: The influence of landscaping. Procedia - Social and Behavioral Sciences. **105**: p. 664-673.
35. Wong, Y.C.N.H., (2009). *Tropical Urban Heat Islands: Climate Buildings and Greenery*. 1st edition. Oxon, United Kingdom: Routledge.
36. LEED, (2016) *LEED v4 for BUILDING DESIGN AND CONSTRUCTION*. United State Green Building Council: Washington, USA. p. 1-147.
37. Givoni, B., (1976). *Man, Climate and Architecture*. 2 ed, ed. H.J. Cowan. United Kingdom: Applied Science Publishers.
38. DeKay, M.B., G.Z., (2014). *Sun, Wind, and Light: Architectural Design Strategies*. 4th edition. New Jersey: Wiley.
39. Abdulla, A.W.A.-S.F.A., (2009). *Roof rainwater harvesting systems for household water supply in Jordan.* Desalination. **243**(1-3): p. 195 -207.
40. Osueke, P.U.I.D.O.C.O., (2013). *Study and Evaluation of Solar Energy Variation in Nigeria.* International Journal of Emerging Technology and Advanced Engineering. **3**(6): p. 501-505