Application of Passive Cooling Principles in Selected Hotel Buildings in Southwest Nigeria

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M. E. James[1], O. A. Fulani [2] and C. F. Azoji [3]

Department of Architecture, KM 10 Idiroko Road. Covenant University, Ota, Ogun State, Nigeria.

Authors emails: [1]mbuotidem.jamespgs@stu.cu.edu.ng
[2]omoyeni.fulani@covenantuniversity.edu.ng
[3]chibueze.azojipgs@stu.cu.edu.ng

Abstract: This study was initiated in response to the high energy consumption connected with tourism-related activities. Air conditioning uses the majority of the energy required, typically exceeding 40%. Hotels in the tropics have higher average annual energy use intensity (avg. EUI) rates than those in the temperate zones; Regardless of the climate zone, the highest category hotels (i.e., five-star hotels) have a higher energy use index. When their efficiency is assessed and understood to ensure continuous improvement in their energy conservation, hotel buildings will make a much greater contribution to energy management. The objective of this paper is to investigate the extent to which Passive Cooling Principles were applied in hotel buildings in Nigeria, and the impact of these principles on the selected hotels; towards assessing the achieved level of energy conservation. The study is limited to selected hotel buildings in Nigeria; and they were studied in-depth to determine their compliance levels to passive cooling principles. Non-participant observation was carried out to obtain are objective data. As Lagos State houses a larger number of the five-star hotels in the study population, two of the selected case studies were from this location; and the last was from Abuja, which represented the North and Central Region of the country. The sampling technique used for this research is purposive sampling. The Five-Star hotels were selected based on their star rating according to set standards that have been identified in Literature; and they include prominent hotels in both Lagos and Abuja. The application rate of 64% also creates a basis for determining the minimum application rate targeted for the five-star hotel design carried out along-side this paper; which is 75%. This relays the extent to which Passive Cooling Principles are applied in hotel buildings in Nigeria; and also provides a benchmark for future researches and designers that intend to implement or study Passive Cooling Principles.

Keywords: Hotel, Passive Cooling, Energy Conservation, Tourism

1. Introduction

The overall quantity of energy consumed by the construction industry is significant, and it is anticipated to expand as living standards improve and the world population continues to grow. (Xu & Wang, 2020). Artificial cooling of buildings consumes a great deal of energy. Energy-intensive equipment and associated behavior have been recognized as a key influencing element on overall building energy usage (Hu, Yan, Guo, Cui, & Dong, 2017). The Energy Commission of Nigeria (2019), states that the power (about 5,000 MW) supplied presently in Nigeria is insufficient and volatile. This drives a substantial proportion of manufacturing, enterprises and residences to depend on gasoline and diesel generators; which is an expensive predominant or substitute source of energy and as a major contributor to greenhouse gas production. Furthermore, due to wasteful behavior and the use of energy-intensive and ineffective technology, a large amount of energy produced in Nigeria is wasted (Alagbe, Caiafas, Olayemi, & Joel, 2019). Hotels in the tropics have higher average annual energy use intensity (avg. EUI) rates than those in the temperate zones (Biantoro, 2018). Bedi & Toshniwal (2019) bring to light that as a result of the high energy demand connected with tourism activities, it is important to develop effective energy management methods in order to decrease their environmental impact while also lowering their operating expenses. Heat and air conditioning (HVAC), lights, domestic hot water (DHW), swimming pool heating, kitchens, and recreational activities are some of the activities that consume the most energy in the hotel business. Techniques for passive cooling include the use of sun

and heat management systems, the dispersion of excess heat into low temperature natural sinks such as the air, the ground, and water, and the amortization of heat surpluses through the use of extra thermal mass in the structure (Santamouris, 2016). It is critical to attain a high degree of thermal comfort by natural means, which can be helped by passive cooling techniques, as opposed to artificial ones. Consequently, the interior thermal comfort of the building is improved, and the quantity of energy consumed by the building is reduced to its bare minimum, resulting in an energy-efficient structure in the end (Ibem, Udezi, Oti, & Fakorede, 2019).

This study is aimed at investigating the use of passive cooling principles in hotel buildings in Nigeria, and the impact of these principles on the selected hotels; towards assessing the achieved level of energy conservation; as there is a need to evolve architecture that would respond to the changing climate of the world and the global boom of the hotel industry promoting green buildings to solve the problem of climate change and increased energy consumption. Consequently, the sole research question formulated for the study is: to what extent have Passive Cooling Principles been applied in hotel buildings in Nigeria? The scope of the study is limited hotel buildings in Nigeria, as the high energy in Nigeria is particularly significant in hotel buildings. The study investigation was also restricted to hotel buildings in Lagos State and Abuja because Lagos houses the highest number of Economic activities in the country as well as high-end hotel facilities; while Abuja is the central area of the country, as the Capital it is a major tourism site and it also represents the Northern and North-central regions. The next portions of this work are organized into the following categories: Literature Review, Methodology, Results and Discussion, Conclusion, Acknowledgements, and References.

2. Literature Review

According to Hotels and Catering Economic Development Committee, South Africa, (2002), A hotel is an institution of a permanent type that consists of four or more guestrooms and that provides bed and breakfast services on a short-term basis while meeting specified basic requirements. . Similarly, Lawson (2015) defined hotel as a commercial institution that provides travelers and guests with two important services: shelter and cuisine in return for money. A 'hotel' or 'inn' is defined by British law as a location where a legitimate visitor can receive shelter and food, provided he is capable of paying for it and is in a way fit to accept it.. Since hotel guest are transient, special consideration must be given to the potential threat to their life safety and comfort while they stay in the hotel. This led to development of diverse hotel types. Based on its location, target segment, and other distinguishing qualities such as size and class, hotels are usually categorized by the type of client they serve. Even though a hotel may fit into several categories, each hotel has a different goal - regardless of the nature of client it seeks. (Institute of Hotel Management Bhubaneswar, 2017).

Constructions have been highlighted as one of the five important energy users where creativity is needed to achieve massive energy reductions. They account for roughly 40% of the primary energy source in the majority of countries, and demand is rising in parallel with usage. (Adeleke, 2013). Energy conservation is described as the method of lowering energy usage while maintaining reasonable levels of comfort, air quality, and other accommodation criteria. (World Business Council for Sustainable Development, 2021). The International Energy Agency (IEA, 2019) predicts that present conditions in building energy consumption will promote roughly half of all electricity generation developments through 2030. United Nations World Tourism Organization (UNWTO, 2018) reported that, given the vast increase in new building projects in developing countries such as Nigeria and the shortfalls of existing building stock globally, emissions of greenhouse gases from buildings would more than double by 2050 if nothing is done.

Passive ways of temperature control and humidity within structures were initially used to manage the environment in ancient times. These strategies gradually became outdated as a result of the extensive usage of electrical energy and artificial systems. (Alagbe et al., 2019). The passive ventilation systems could reduce the power consumption in a building by using a non-energy solution to reduce the peak cooling load. Also, it could provide the indoor atmosphere with balanced heating and cooling conditions (Krimly, 2020). Passive cooling techniques serve to minimise high cooling loads in structures, resulting in a reduction in the size of air conditioning equipment as well as the time it is required. Passive cooling is a building design strategy that uses the design of the building to reduce energy consumption while enhancing thermal comfort.

According to Geetha (2012), passive cooling in buildings is classified into two classes namely: Heat Prevention/Reduction (Reduce heat gains); and Heat Dissipation (Remove internal heat gains). **Heat Prevention/Reduction** is a passive cooling technique, which prevents heat from the surrounding from gaining access into the building. It moreover includes strategies for lowering ambient heat through the use of cooling measures that cool the neighboring hot air when they come into contact with it. The main architectural solution for keeping the structure cool is solar control.. Some of the solar control measures as outlined by Geetha (2012) are as follows. The first being, "*Building Orientation*" and this involves placing the building on the site-taking cognizance of the sun path to minimize surfaces exposed to solar radiation. The second solar control measure is, "*Shading devices*" and it includes; overhangs, awnings, exterior shades, venetian blinds, curtains and drapers. The third measure is, "*Landscaping*" and it includes all soft landscape such as plants, trees etc., which absorbs most of the solar radiation incident on to the building by lowering the air and surface temperatures as well as increase the relative humidity of the surrounding air thereby making the air cold. The fourth and last solar control measure is, "*Building insulation*" and here thermal transfer occurs naturally when heat moves from one warm room to another cold space; insulation acts as a barrier to heat transfer, lowering the amount of energy required to keep a structure warm in the winter and cool in the summer. The R-value, or the ability of the insulation to resist heat transfer, is widely used when discussing building insulation. Concrete block insulation, insulating concrete forms, spray foam, rigid foam, and natural fiber insulation are all options in addition to blanket insulation. **Heat Dissipation** is a passive cooling technique, which removes excess heat from the interior of a building by the use of natural heat sinks. Heat dissipation techniques are used to direct excess heat generated by a structure to a heat sink with a lower temperature, such as the ambient air, water, the ground, or the sky. Some of the heat dissipation measures stated by Geetha (2012) include: Natural ventilation (air as heat sink), Ground cooling (earth as heat sink), Evaporative cooling (water as heat sink); However, only Natural ventilation and Ground cooling are employed in tropical climates.

The principles of passive cooling and ventilation are climate-responsive architectural design approaches and tactics that naturally create pleasant interior conditions.These concepts assist in the collection, storage, transmission, and control of transfer of energy into the building via natural cooling and ventilation processes. (Marin, 2007). Preventing heat from entering a building or removing it requires two conditions: the presence of a heat sink that is cooler than the interior air temperature and the encouragement of heat transfer towards the heat sink. . According to Marin, (2007), there are five basic principles of passive cooling peculiar to composite of hot-humid/hot-dry climate namely: Building orientation/Massing, Thermal mass/insulation, Ventilation/Air movement, Overhangs/Shading devices, Materials/Construction. The first principle being, "*Building orientation/Massing*"; Good building orientation increases the energy efficiency of a building making it more comfortable to live in and cheaper to run (Marin, 2007). Orientation refers to the azimuth angle of a surface relative to true north (eCubed, 2008). The second principle, "*Thermal mass/insulation"* is the ability of a material to absorb and store heat when there is an excess of solar energy and/or internal gain in buildings and releases the stored heat when the building starts to cool down. Thermal mass also reduces the extreme swings in peak temperature (Donn, Grant, 2010). The third principle is "*Ventilation/Air movement*" and Willmert, (2001) stated that Ventilation/Air movement is a process of removal of moisture from buildings to alleviate dampness by the circulation of air around the building. Openings are important design elements for ventilation and air movement. Openings help in admitting daylight, airflow, providing cross ventilation and views. Lipping et al. (2017) claim that ventilation and indoor air quality can be improved by increasing the window to wall ratios (WWR), but it would also increase solar heat gain. There has always been a conflict with daylight provision and exclusion of solar penetration in designing windows. The fourth principle is "*Overhangs/Shading devices*" and they prevent solar access, exclude rainfall into the building, and thereby helps to keep the building cool. Shades over building entrances and outdoor spaces can help to lower temperatures and conserve energy, and because east and west facades receive low morning and afternoon sun, shading them is more challenging, keep east and west facing glazing to a minimum if low sun is an issue (Passive design tool kit, 2004). The fifth and last of the five basic principles of passive cooling is "*Materials/Construction*". International Federation of Consulting Engineers (IFCE, 2015) state that the choice of materials and construction techniques for a project requires considerations of aesthetic appeal and initial and ongoing costs, life cycle assessment considerations (such as material performance, availability and impact on the environment) and the

ability to reuse, recycle or dispose of the material at the end of its life. Proper material selection and construction technique is considered for flooring, walling, ceiling and roofing in buildings for passive cooling and energy conservation purpose (IFCE, 2015).

3. Methodology

This study was conducted to investigate the use of passive cooling principles in hotel buildings in Nigeria, and the impact of these principles on the selected hotels; towards assessing the achieved level of energy conservation. Qualitative research is a methodological school of inquiry that focuses on the study of a social or human phenomenon. The researcher develops a full, holistic picture, analyzes language, documents informant information, and conducts the study in a natural context. (Khan, 2014). Hence, qualitative research approach was considered suitable and adopted. Due to the fact that data were obtained from several case studies, this study qualifies as a multiple case study research. Case study research is defined as exploratory, explanatory, or descriptive, with a bias for addressing the "how" and "why" issues. (Sholanke & Agomuo, 2020), which conforms with the target of the study. The study is limited to selected hotels in Nigeria; and they were studied in-depth to determine their compliance levels to passive cooling principles. Non-participant observation was carried out to obtain are objective data; This choice should have been thoroughly reviewed and evaluated prior to reaching the conclusion (Creswell, 2018).

As Lagos State houses a larger number of the hotels in the study population, two of the selected case studies were from this location; and the last was from Abuja, which represented the North and Central Region of the country. The sampling technique used for this research is purposive sampling. To select the hotel buildings that constitute the sample size, Lagos state was divided into two zones: Island and Mainland. After which one hotel was selected to represent each zone. The hotel building chosen on the mainland is the Radisson Blu Hotel, Ikeja; while the Federal Palace Hotel and Casino, Victoria Island, Lagos is the hotel building that was selected on the Island. The third and last case study which was chosen from Abuja, is the Transcorp Hilton, Maitama, Abuja. These hotels were selected because they were identified by the researcher to suit the given purpose most, as well as being easily accessible by the researcher.

To collect field data, relevant literature was combed through to extract data that would be utilized to build an observation guide. The observation guide was utilized to collect data from the sample size of three hotel buildings. The observation guide emphasized the Passive Cooling characteristics that needed to be discovered; these characteristics were noted, photographed, and additional comments were offered. The field data were collected between June 2021 and July 2021. In order to evaluate the data, the characteristics of the principles of passive cooling were first recognized, then grouped into themes and the substance of the themes was examined. The final product was content-analyzed and presented utilizing a descriptive technique with the help of photographs.

4. Results and Discussion

4.1. Radisson Blu Hotel, Ikeja, Lagos

Plate.1 and Plate 2: Exterior View showing window types and compact building form

Source: Author's Fieldwork (2021)

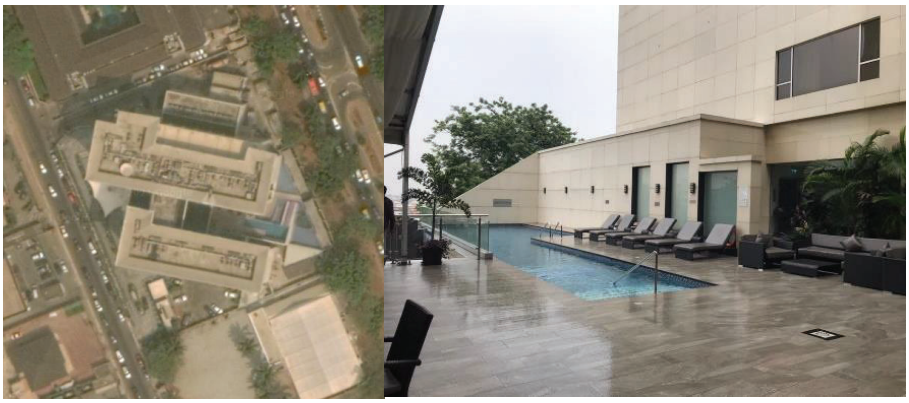


Plate 3 and Plate 4: Building Orientation and Building materials in pool area

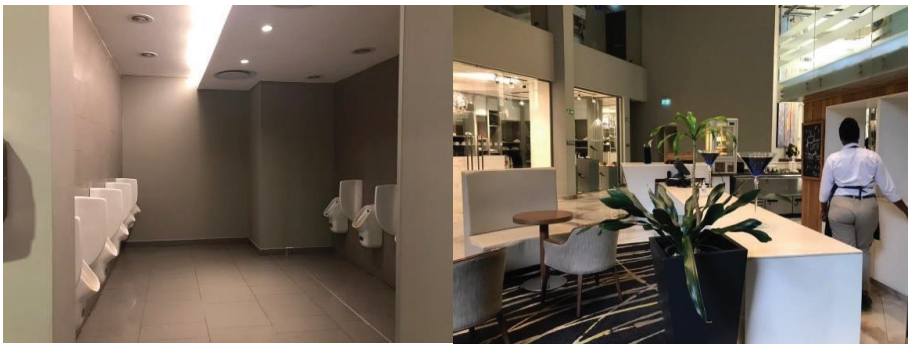


Plate 5 and Plate 6: Interior Finishes

Table 4.1: Analysis of the principles of passive cooling of the Radisson Blu Hotel

PRINCIPLES	FEATURES	RATING										COMMENTS
		1	2	3	4	5	6	7	8	9	10	
Building Orientation	Should Orient Toward North-South Direction							√				The hotel was aligned purposely towards the north/south coordinates which maximized its tendency to be cooled appropriately from the favourable Tradewinds.
Building Form	A Compact Building					√						
Natural Ventilation	Openings & Windows Sizes								√			Incorporation of a closed courtyard centrally located within the building allowing for proper airflow to the building.
	Atrium (For Stack Effect Ventilation).	√										

	Vent Windows (For Dissipation of Heated Air)					√						
	Courtyards									√		
Shading Devices	Roof Shading (Eaves)							√				The building makes use of mono-pitched roofs with large overhangs of about 2 meters. These form adequate coverage from direct sunlight, even though the room windows themselves have no other shading devices.
	Overhang Shadings (Window Hoods, Fins)						√					
Landscaping	Trees		√									
	Green and Soft Elements (Shrubs Etc.)		√									
Materials/ Finishes	Use of Sustainable Building Materials					√						
Thermal Insulation	Use of Insulating Materials					√						

The Ratings were done on a Likert scale of 1-10 and were judged by the Expert Knowledge of the Researchers based on the conformity of each selected hotel to the various Features of Passive Cooling. If the feature of passive cooling is satisfactorily present, then the rating given would be high; and vice versa.

4.2. Federal Palace Hotel and Casino, Victoria Island, Lagos

Plate 7 and Plate 8: Window types, Building Orientation and Landscaping

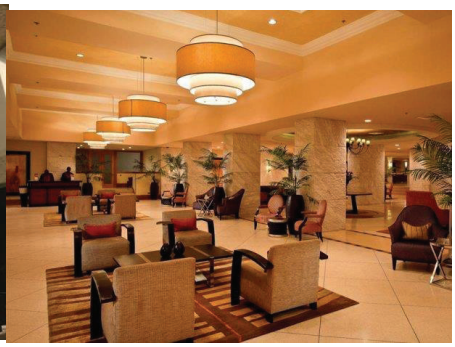



Plate 9 and Plate 10: Exterior and Interior Finishes

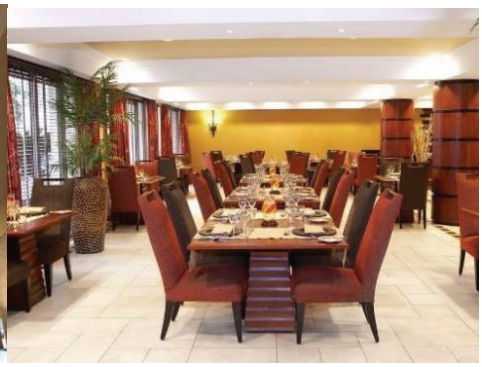



Plate 11 and Plate 12: Interior Finishes

Table 4.2: Analysis of the principles of passive cooling of the Federal Palace Hotel and Casino

PRINCIPLES	FEATURES	RATING										COMMENTS
		1	2	3	4	5	6	7	8	9	10	
Building Orientation	Should Orient Toward North-South Direction									√		The hotel 45 degree angle and was parallel to the north/south coordinates which maximized its tendency to be cooled appropriately from the Tradewinds.
Building Form	A Compact Building							√				The building utilizes a slender rectangular shape to distribute its functions.
Natural Ventilation	Openings & Windows								√			
	Atrium	√										
	Vent Windows								√			
	Courtyards									√		

Shading Devices	Roof Shading					√						The hotel uses recesses and protrusions in the structure and design to allow for coverage over the windows and openings; as there is no roof overhang
	Overhang Shadings								√			
Landscaping	Trees									√		The buildings' site is surrounded by a large amount of plants, trees, and landscaping due to the generous amount of land present and available.
	Green and Soft Elements (Shrubs Etc.)									√		
Material/ Finish	Sustainable Materials							√				
Thermal Insulation	Insulating Materials					√						

The Ratings were done on a Likert scale of 1-10 and were judged by the Expert Knowledge of the Researchers based on the conformity of each selected hotel to the various Features of Passive Cooling. If the feature of passive cooling is satisfactorily present, then the rating given would be high; and vice versa.

4.3. Transcorp Hilton, Maitama, Abuja

Plate 13 and Plate 14: Exterior Finishes and Landscaping

Plate 15 and Plate 16: Building Form and Interior Finishes


Plate 17 and Plate 18: Interior Finishes

Table 4.3: Analysis of the principles of passive cooling of the Transcorp Hilton

PRINCIPLES	FEATURES	RATING										COMMENTS
		1	2	3	4	5	6	7	8	9	10	
Building Orientation	Should Orient Toward North-South Direction									√		
Building Form	A Compact Building								√			The hotel is designed with three slender wings radiating away from a central core. each of these wings fulfil the requirement of a compact building as they are where the rooms are located to maximize airflow around the building.
Natural Ventilation	Openings & Windows Sizes									√		There are high level windows strategically placed to allow the escape of hot air; especially in public areas of the building. A large number of windows are slanted to a certain degree to control airflow to some extent.
	Atrium									√		
	Vent Windows						√					
	Courtyards	√										
Shading Devices	Roof Shading	√										There is an extensive system of projected fins along with slanted metallic shading members to properly control the amount of solar radiation to the building.
	Overhang Shadings									√		
Landscaping	Trees					√						
	Green and Soft Elements					√						

Materials/ Finishes	Sustainable Building Materials							√				
Thermal Insulation	Insulating Materials							√				

The Ratings were done on a Likert scale of 1-10 and were judged by the Expert Knowledge of the Researchers based on the conformity of each selected hotel to the various Features of Passive Cooling. If the feature of passive cooling is satisfactorily present, then the rating given would be high; and vice versa.

4.4. Determine the extent to which Passive Cooling Principles are applied in hotel buildings in Nigeria

Table 4.4: Compiled analysis of the principles of passive cooling for selected hotels

		Federal Palace Hotel	Radisson Blu Hotel	Transcorp Hilton
PCP 1	Building Orientation	9	7	9
PCP 2	Building form	7	5	8
PCP 3	Openings & Windows Sizes	8	8	9
	Atrium	1	1	9
	Vent Windows	8	5	6
	Courtyards	9	9	1
PCP 4	Roof shading	5	7	1
	Overhang shadings	8	6	9
PCP 5	Trees	9	2	5
	Green and soft elements	9	2	5
PCP 6	Sustainable Building Materials	7	5	7
PCP 7	Insulating Materials	5	5	7

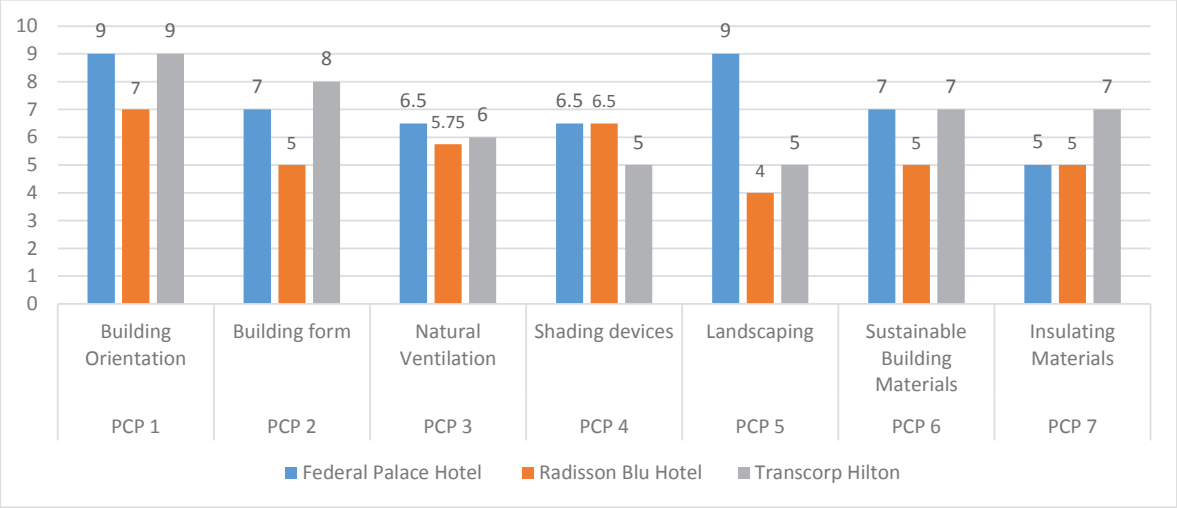
The Table 4.4 above shows the summary of the observation guide carried out in each hotel that was visited. It displays the results as shown in table 4.1, table 4.2 and table 4.3. From the table, it is shown that the building orientation, openings and window sizes (grouped under Natural Ventilation), and overhang shading (grouped under Shading Devices); have a higher frequency of positive ratings across the three hotels. Adequately designed courtyards were identified in the Federal Palace Hotel and Radisson Blu but there was no courtyard present in the Transcorp Hilton; and this significantly would reduce the cumulative Rated score for the Passive Cooling Principle of Natural ventilation. This is also

coupled with a low rating for Atriums in the Federal Palace Hotel and Radisson Blu, but a higher rating in the Transcorp Hilton. Therefore, it is deduced that the Transcorp Hilton makes up for its lack of a courtyard with the presence of an Atrium; also justified with the fact that it is the tallest and covers the largest area among all the hotels visited. The Radisson Blu Hotel had the least amount of space on site which attributed to its lack of trees and green elements (grouped under Landscaping). Although they made some effort to provide potted plants and minor green elements within the building. The table shows an average consideration for Sustainable and Insulating building materials; which is because they were achieved to some extent, and this was not because of a direct intention to do so.

Table 4.5: compiled analysis of the principles of passive cooling for selected hotels

	PCP 1	PCP 2	PCP 3	PCP 4	PCP 5	PCP 6	PCP 7	
	Building Orientation	Building form	Natural Ventilation	Shading devices	Landscaping	Sustainable \Materials	Insulating Materials	
Federal Palace Hotel	9	7	6.5	6.5	9	7	5	
Radisson Blu Hotel	7	5	5.75	6.5	4	5	5	
Transcorp Hilton	9	8	6	5	5	7	7	
	25	20	18.25	18	18	19	17	135

Figure 4.1: Compiled analysis of the principles of passive cooling for selected hotels



The Table 4.5 above highlights the cumulative average of each of the passive principles and their subgroups that were shown in table 4.4. It is seen that although the Principles of Natural Ventilation and Shading Devices had several high ratings, they also had the highest number of low ratings and this brought their cumulative average to ranges of 5 - 6.5 points; as they also had the highest number of sub-groups among the passive cooling principle that are utilized. Figure 4.1 shows the pictorial representation of table 4. 5; which aids in determining that all the principles have a high level of application in all the hotels that were visited, well over 50%. The average of each principle was

determined in table 4. 5, of which the highest points that could be acquired were 30 for each principle. The range of points as distributed between each passive cooling principle was 25-17 points and with the 50% mark being 15 points; this shows that the application rate of these principles was well above average. The highest cumulative mark that could have resulted is 210 points and the 50% mark would be at 105 points.

From the table 4.5, the cumulative rating is 135 points which amounts to a 64% application rate. This relays the extent to which Passive Cooling Principles are applied in hotel buildings in Nigeria; and also provides a benchmark for future researches and designers that intend to implement or study Passive Cooling Principles. The application rate of 64% also creates a basis for determining the minimum application rate targeted for the five-star hotel design carried out along-side this paper; which is 75%.

5. Conclusion & Recommendations

According to the objectives of this study, passive cooling principles are being used to cool hotel buildings in Nigeria, and the influence of these principles on the selected hotels is being investigated in order to determine the amount of energy conservation that has been accomplished. Three different hotel buildings were studied. In addition to the Radisson Blu Hotel on Ikeja, Lagos mainland; The Federal Palace Hotel and Casino in Victoria Island, Nigeria's Lagos Island; and the Transcorp Hilton in Maitama, Abuja. This research has contributed empirical data on the passive cooling principles adopted by the selected hotels, to the available body of knowledge in line with the research topic.

The application rate of 64% also creates a basis for determining the minimum application rate targeted for the five-star hotel design carried out along-side this paper; which is 75%. This relays the extent to which Passive Cooling Principles are applied in hotel buildings in Nigeria; and also provides a benchmark for future researches and designers that intend to implement or study Passive Cooling Principles.

The researchers recommend that, although the impact of HVAC systems in the selected hotels is still very high; It is seen that a higher percentage application of passive cooling principles would be needed in future hotel establishments- above 75%, but ideally above 85%- so as to take full advantage of the effect of passive cooling, and ultimately reduce the use of HVAC (particularly Cooling) systems in hotel buildings.

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