Design Strategies for Energy-Efficient Commercial Buildings in Nigeria

BLESSING C. VINCENT-OHIZU[1], IFEOLUWA AKANDE[2], TEMINIJESU I. OKE[3]
[1, 2, 3] *Department of Architecture, Bells University of Technology, Ota*

Abstract*—The process of designing a structure that considers energy efficiency starts with understanding the right design strategy while considering the regional climate and unique characteristics of a particular area. In terms of ongoing development, the need for electricity in commercial buildings is increasing, particularly in Africa, due to the economy's fast expansion, development, and urbanisation. PHCN records reveal that at least 10% of commercial buildings in Nigeria are classified as Maximum Demand (MD) customers, the buildings account for 40% of energy consumption and 36% of CO2 emissions. Therefore, this study aims to examine the energy efficiency design strategies of commercial buildings in other to propose a framework for a sustainable business incubation centre. To accomplish these goals, the research employed a mixed-method technique of data collection to investigate the energy efficiency design approaches employed in commercial buildings through documentation analysis. Case studies were carried out on the selected commercial buildings to investigate design strategies. It was discovered that the primary sources of commercial building energy generation in the study areas are Generators, Distribution Companies (disco/PHCN), Solar power, and Inverters. The study further revealed that mostly active energy-efficient design strategies like solar power, inverters, and wind turbines, were incorporated into the design of the buildings while passive design strategies like building orientation, landscaping, and wind direction are not widely considered. The study, therefore, recommends the federal government should establish strict regulations for energy-efficient construction and make sure that each state complies with them while also implementing an energy-efficiency program and offering sufficient incentives for customers to embrace it.

Indexed terms*—Business incubators, Commercial buildings, Design strategies, Eco-system, Energy, Energy efficiency.

I. INTRODUCTION

A business incubator is an organization that helps innovative and fledgling businesses grow by providing services such as office space and management training [1]. Business incubators add value by combining start-ups' entrepreneurial mindset with the resources normally accessible to new enterprises and assisting new entrepreneurs in turning their business ideas into reality [2]. It provides operational and strategic support for entrepreneurship's growth and success. It supports businesses and assists them in reaching their full potential, both socially and economically [3]. It is necessary to explore the effects of business incubator services on entrepreneurship development to estimate the potential advantages of a business incubator [4]. For the development and growth of technology-based entrepreneurship, business incubators require a conducive ecosystem. Commercial buildings require a lot of energy during construction and operation, which has negative repercussions for the environment as well as the health and comfort of their users [5]. According to [6] in Europe, energy use and consumption in office buildings have risen to an alarming 36 percent, while non-residential buildings consume roughly 27.5 percent. Commercial buildings often lack the resources required for a full-scale assessment of their energy consumption.

Lighting, cooling, heating, ventilation, plug load, and HVAC (Heating, Ventilation, Air Conditioning) control and equipment modifications are among the energy load emitted by a business incubator where plug loads and lights consume the most energy, accounting for 33% and 20% of total energy usage, respectively [7]. In designing a building that prioritizes energy efficiency, the process begins with knowing the proper design strategy and considering the local climate and particular characteristics within the area. One of the most important elements affecting the degree of building energy consumption is the form coefficient. Increase the surface area of the structure as the form coefficient rises. When the heat dissipation area grows, the yearly heating energy used by the structure decreases [8]. Shading devices have an important role in reducing building energy use, particularly in hot climates where global radiation is high [9]. On the other hand, exterior shading needs greater thinking and innovative design due to the large range of materials, kinds, designs, dimensions, orientation, external visualization, and performance at various sun angles [10].

The cost of electrical energy accounts for the majority of the utility bill in most commercial buildings. The electrical systems that consume the most energy in commercial buildings are lighting, office equipment, and engines [11]. To conserve energy in buildings, an exchange between the quality of the interior environment and energy savings may indeed be essential [12]. Literature has revealed that there is little or no solution to the challenges of energy efficiency in commercial buildings. Most of the studies have made recommendations for residential buildings, office buildings, and institutional buildings [13]. Hence, there is a need to attempt to provide energy-efficiency design strategies for commercial buildings.

II. RESEARCH METHODS

The research framework for this study, which directs the data collection and analysis, was a descriptive survey research design and case study. The users who used the commercial buildings in the research region made up the study's target group. Data analysis methods included document analysis and descriptive statistics (Mean Item Score). The study area's commercial building users were surveyed using a questionnaire survey, and the results—known as the Mean Item Score—were utilized to address the study's objectives.

III. RESULTS

Table 1: Do you have a controllable shading device on windows in the building?

	Frequency (F)	Percent %	Cumulative %
Yes (Full control)	48	24	24
Yes (Partial control)	98	49	73
No	54	27	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

In table 1 above, forty-eight (48) respondents, representing a total of 24% indicated Yes (Full control) that they have total control about their shading device on windows in the building. Of a total of ninety-eight (98) people, 49% of the respondents indicated that they have Yes (Partial control), fifty-four (54) respondents, and about 27% have no control over it. This implies that most of the respondents have only partial control of the shading devices available in the buildings.

Table 2: What time of the day are you thermally uncomfortable?

	Frequency (F)	Percent %	Cumulative %
All day	24	12	12
In the morning	44	22	34
Mid-day	86	43	77
Late afternoon	29	14.5	91.5
Evening	17	8.5	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

Table 2 above shows that twenty-four (24) respondents, representing a total of 12%respondend being thermally uncomfortable All day. A total of forty-four (44) people representing a total of 22% of the respondents indicated In the morning is the time of the day they are thermally uncomfortable, eighty-six (86) representing a total of 43% of respondents agreed to be thermally uncomfortable at Mid-day, twenty-nine(29) representing a total of 14.5% respondents indicated to be thermally uncomfortable at Late afternoon, seventeen (17) representing a total of 8.5% indicated Evening as the time of the day they are thermally uncomfortable. This indicates that most of the buildings within the study area have the least thermal comfort at midday.

Table 3: How would you rate the flow of air movement within/out of the space?

	Frequency (F)	Percent %	Cumulative %
Severe	7	3.5	3.5
Moderate	138	69	72.5
Mild	41	20.5	93
Very mild	14	7	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

In table 3 above, seven (7) respondents, representing a total of 3.5% indicated that the rate of air movement within/out of the space is Severe, one hundred and eight (138) representing a total of 69% indicated that the rate of air movement within/out of the space is Moderate. A total of forty-one (41) people, 20.5% of the respondents indicated that the rate of air movement is Mild, and fourteen (14) respondents, about 7% indicate that the rate of air movement is Very mild. This means that most of the buildings in the study area have moderate air movement within/out of the space.

Table 4: How would you rate the number of trees around the building?

	Frequency (F)	Percent %	Cumulative %
High	20	10	10
Moderate	73	36.5	46.5
Low	64	32	78.5
Very low	43	21.5	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

Table 4 shows that twenty (20) respondents, representing a total of 10% responded that the number of trees around the building is High. A total of seventy-three (73) people representing a total of 36.5% of the respondents indicated a moderate the rate of trees in the commercial building in the study area, sixty-four (64) representing a total of 32% of respondents to the number of trees as been Low, forty-three respondents (43) representing a total of 21.5% rate the number of trees around the building as Very low.

Table 5: How would you rate the soft scape (trees, shrubs) ratio to hardscape (interlocking, pavement)?

	Frequency (F)	Percent %	Cumulative %
High	20	10	10
Moderate	81	40.5	40.5
Low	73	36.5	77
Very low	26	13	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

Table 5, above shows the ratio of softscape to hardscape was rated by twenty (20) respondents, representing a total of 10% responded as being High. A total of eighty-one (81) people representing a total of 36.5% of the respondents indicated Moderate as the ratio of softscape to hardscape, seventy-three (73) representing a total of 36.5% of respondents to the ratio of softscape to the hardscape as being Low, twenty-six respondents (26) representing a total of 13% ratio of softscape to hardscape as Very low.

Table 6: How effective are the trees in blocking sun rays from the building?

	Frequency (F)	Percent %	Cumulative %
High	20	10	10
Moderate	73	36.5	46.5
Low	64	32	78.5
Very low	43	21.5	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

Table 6, above shows the effectivity of tress twenty (20) respondents, representing a total of 10% responded gave that response. A total of seventy-three (73) people representing a total of 36.5% of the respondents indicated a Moderate ratio of softscape to hardscape, seventy-three (64) representing a total of 32% of respondents to the effectiveness of the trees blocking rays from the building ratio as being Low, forty-three respondents (43) representing a total of 21.5% indicating the effectiveness as Very low.

Table 7: How often do you need active cooling e.g., fans, and air-conditioners in the building space?

	Frequency (F)	Percent %	Cumulative %
Always	80	40	40
Often	88	44	84
Rarely	30	15	99
Never	2	1	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

Table 7 above shows the rate at which active design of (80) respondents, representing a total of 40% responded as Always. A total of eighty-eight (88) people representing a total of 44% of the respondents indicated Often. Thirty people (30) representing a total of 15% of respondents Indicate, and forty-three respondents (2) representing a total of 1% indicated the rate at which the need for active cooling.

This implies that most respondents of commercial buildings in the study area often need active cooling to function.

Table 8: How would you rate the thermal comfort of the building?

	Frequency (F)	Percent %	Cumulative %
Completely satisfied	10	5	5
Very satisfied	50	25	30
Moderately satisfied	99	49.5	79.5
Slightly satisfied	35	17.5	97
Not at all satisfied	6	3	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

In table 8, ten (10) respondents, representing a total of 5% were completely satisfied with the rate of thermal comfort of a commercial building. Of a total of seventy (50) people, about 25% of the respondents were very satisfied with the statement, ninety-nine (99) respondents, about 49.5% were moderately satisfied with it, thirty-five (35) respondents, about 17.5% were slightly satisfied with it, six (6) respondents, about 3% were not at all satisfied about it. This implies that most of the respondents are moderately satisfied with the thermal comfort of the commercial buildings in the study area.

Table 9: How satisfied are you with the number and sizes of windows in the space?

	Frequency (F)	Percent %	Cumulative %
Completely satisfied	15	7.5	7.5
Very satisfied	61	30.5	38
Moderately satisfied	82	41	79
Slightly satisfied	30	15	94
Not at all satisfied	12	6	100
Total	200	100	

Source: Researcher's computation (2022); Field Survey (2022)

In table 9 above, fifteen (15) respondents, representing a total of 7.5% were completely satisfied with the number and size of windows of a commercial building. A total of sixty-one (61) people, about 30.5% of the respondents were very satisfied with the statement, eighty-two (82) respondents, about 41% were moderately satisfied with it, thirty (30) respondents, about 15% were slightly satisfied with it, twelve (12) respondents, about 6% were not at all satisfied about it. This indicates that most respondents are moderately satisfied with the number and sizes of windows of the buildings.

IV. DISCUSSION AND CONCLUSION

The study assessed the energy-efficient design strategies in Nigeria in other to propose an energy-efficient business incubation center in view. To attain the objectives, the researcher adopted a variety of architectural methods of research analysis and standard research quality. Case studies, documentary analysis, and descriptive research techniques are the techniques used. the documentary analysis was employed to attain the first research objective. While the descriptive analysis was used to attain the second and architectural design was advocated to fulfil the third research objective. According to the findings of the first research objective, the energy-efficient design methods employed in commercial buildings include passive design strategies like; site analysis, building orientation, landscaping, building form, and building envelope, whereas active design strategies are fans, evaporative coolers, and heat pumps.

The aforementioned design techniques serve as the foundation for design strategies that will aid in the construction of an energy-efficient commercial building. Furthermore, the findings of the second research goal indicated that the primary source of energy for commercial buildings in the study area is ordered as Generator, Distribution business (Disco/PHCN), Solar power, and inverter, with no electrical generation from Bio-gas. Office buildings and shopping malls were identified as commercial structures that utilize the most energy. Data from objective two proved that the thermal comfort of commercial buildings is generally moderate throughout the day, except the time between 12 pm and 3 pm, when the occupants are thermally uncomfortable. Based on the data, the landscape surrounding the commercial buildings was determined to be averagely low. Objective two confirmed that the daylight in commercial buildings is moderately satisfactory when time differences were exploited to achieve outcomes.

CONCLUSION

The study examined commercial buildings in Nigeria with the expectation of identifying the most sustainable strategy, particularly on a long-term basis, to gain a better understanding of how they generate power for their facilities, and to propose a Business Incubation Center that would be functional and reduce the building's energy use. In addition to the study's aim, three objectives were identified and examined utilising applicable architectural methodological approaches. According to the findings of objective one, the study indicated that the energy-efficient design strategies are Site Analysis, Building Orientation, Landscaping, Building Form, and Building Envelope, whereas active design strategies include Fans, Evaporative coolers, and Heat pumps.

These strategies are significant in the area of architecture to develop an energy-efficient building. For instance, when designing a building, the orientation of the site must be considered; this influences the design since it helps to improve the efficiency of various passive cooling systems (Albayyaa, Hagare, & Saha, 2019).

The study determined that the mode of electricity generation is a determinant of the type of commercial building based on the findings of research objective two. When it comes to finding a balance between natural ventilation and lighting systems in commercial buildings, window openings have a more significant role in energy that is wall to window ratio, which affects the thermal comfort and daylight of the facility. Openings are necessary to design elements for allowing light, airflow, cross-ventilation, and perspectives. The majority of the respondents' appliances are inefficient, adding significantly to the demand for energy. Technology is the issue here. In this study, design techniques and material selection that will minimize the energy requirement for cooling as well as provide an architecture that is appropriate to the climatic climate and will promote energy efficiency were examined.

RECOMMENDATIONS

Business incubation is a new trend in the country at large and with the fast growth of Ogun state due to its proximity to Lagos state, it is a necessity for the people of Ota to have a space where they can carry out their business ideas with ease having taken into consideration during the design stage our tropics, culture, and lifestyle to birth Bells Alumni Business Incubation Centre. The study used quantitative analysis for my research, further research can be done using a spreadsheet, simulations of buildings, and zero net buildings to broaden the knowledge of energy-efficient design strategies for commercial buildings.

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