Analysis of Artificial Lighting Design Fixture on the Indoor Night Time Illuminance

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Received:14.08.2022 **Accepted**: 05.12.2022 **Published**:06.12.2022

Abstract:
Human beings depend on a lighting system in their indoor environment for visual tasks and to function appropriately. With daylight absent during the night, artificial lighting becomes the only lighting source for illuminance. This study evaluated the effect of lighting design fixtures on the artificial lighting illuminance adequacy of students' private rooms. The illuminance level was measured using the Sunche model HS1010 digital luxmeter with a sampling frequency of 2 times per second and a high precision wide measurement range of 1 - 1200,000 lux at nine (9) grid points. Analysis of illuminance data obtained showed that the lamp capacities (5, 10, 50, 100, and 200 Watts) and the lighting fixtures array (single light point source (centred), double (opposite array) and quadruple (double opposite layout)) affect the adequacy of the indoor space illuminance. The wall paint colour (cream, pink and blue) did not affect the reflection ability of the illuminance as they were all emulsion paints. Analysis of the side effect of the lighting design fixtures showed that the lamp capacities, the lighting fixtures design, and the wall paint colour did not affect the thermal conditions of the indoor environment. Therefore, this study concluded that the higher the lamp capacities and the lighting fixtures array the better the nighttime artificial illuminance.

Keywords: Indoor space, Illuminance, Artificial lighting, Night, Sufficiency

1. Introduction

THE The history and existence of humanity are inevitably connected to natural light. Light is among the natural resources that have helped people to survive, being a source of energy that the earth needed as heat and illumination to support life. As civilization advances, artificial lighting systems were developed to enable the performance of daily tasks at night or in places that lack adequate natural light. Human beings have a dependency on the lighting in their indoor environment to do visual tasks and function properly. Artificial lighting replicates the daylight in terms of lighting value and colour scheme of the lighting fixtures [1]. Studies noted that despite this development, the preference for daylighting rather than artificial lighting is still among students for some reasons [2,3]. With daylight absence, at night seasons, artificial lighting becomes the only source of illuminance. An inadequate lighting system causes visual discomfort to indoor occupants while performing a concerned visual task such as reading.

The design properties of any building describe, among other things, the illuminance and lighting distribution of the indoor space. Lighting fixture design conforms to a set of quantitative values of illuminance quality for the visual need purposes of a work plane and avoidance of glare-free and visual conveniences [2]. This is measured in line with the expected specifics within the boundary of the minimum requirement for effective illumination level [4]. Najafabadi [5] stressed that it is important to pay significant attention to the students' hall of residence, particularly the design aspect. As a study noted that students spend a lot of time in the study tavern, and the intensity of the artificial light in the study hall through the design has to conform to the visual need for appropriate lighting level [6]. The optimal choice of artificial light can be significantly affected by the operation costs, maintenance, energy efficiency, and long lasting LED fixtures. Paying attention to the design fixtures of the room lighting system, regular cleaning of lamps, and switching off the burned lamps were recommended by Moradi et al. [7] for efficient illuminance. Lighting systems have relevant standards for the different types of artificial light for indoor and outdoor usage depending on the need [8]. The required standards are guided by some professional and regulatory bodies, such as Illuminating Engineering Society (IES) and the Chartered Institute of Building Services Engineers (CIBSE) [8-10].

Inappropriate illuminance and poor artificial light contribute to the development of various psychological diseases and negatively affect the physiology and productivity of the

students [7]. A study emphasized that among the factors that bring about the negative effect of artificial light is intensity [11]. Chepesiuk [12] study emphasized that over-illumination causes the growth of light pollution which conversely negatively influences well-being and human health through direct influence on the life cycle and disruption of human circadian rhythm [11-13]. Azodo [2] highlighted some side effects of under-lit and over-lit illuminance in an indoor environment. A well-planned and developed artificial lighting system reduces students' eye fatigue. Hence performance and productivity will grow, especially in the long-term perspective [6][7]. In case of poor light, even students with healthy eyes in a short time can feel diverse problems, from eyestrain and impaired vision to a headache and considerable physical fatigue [7]. It is crucial to pay more attention to the issue of artificial lighting and light pollution to minimize its negative impact on human health [12]. Artificial lighting, on the other hand, can negatively affect nighttime melatonin secretion, influence the human's psychological, cardiovascular and metabolic functions and increase a person's alertness and sleep onset latency [11]. Stevens et al. [14] noted that the disruption of the circadian circle of artificial lighting damages the physiologic and metabolic processes in the human body. The effects of good lighting extend much further than visual effects only to the biological effects. Meaning, that good lighting has a positive influence on health, well-being, alertness, and even sleep quality [15]. Thus, the artificial light quality should be good enough to guarantee efficient visual performance.

Hathaway et al. [16] observed that the type of artificial lighting system used directly affects the health and performance of the students. Song [17] emphasized that students' hall of residence is practically a second home for the students, as they spend a significant part of their daily lives in them, necessitating that particular attention to issues relating to lighting in the buildings [17]. Knowing that ninety per cent of the information humans obtain are through sight, it is necessary to mention that the use of high-quality artificial light can improve the comfort and the general well-being of indoor occupants [8][18]. Attempting to address the effect of inadequate lighting systems is costly and complicated. To maintain and enhance the visual safety of an indoor environment, an evaluation of the lighting system illuminance level is required. More so, maximizing the benefit of artificial lighting while minimizing the negative impacts, is possible through re-evaluation of the lighting system for alteration and development of a new approach and strategy to lighting in communal buildings. Therefore, this study evaluated the effect of lighting design fixtures on the artificial lighting illuminance adequacy of students' private rooms.

II. MATERIALS AND METHODS

A. Experimental design of the study

The experimental research design in this study is a scientific approach involving two sets of data variables, independent variables (lighting fixture, lamp capacity, and wall paint colour) and dependent variables (indoor illuminance). This study was conducted in a preoccupied students' private hall of residence in Wukari, Nigeria. Students' private rooms were considered as their usages are multi-purposes, including studies. The characteristics of the indoor environment and implemented appropriate design fixture orientation and arrangement assessed are presented in the figures below. Three lighting design fixtures evaluated were single light point source (centred) (Figure 1), double (opposite array) (Figure 2), and quadruple (double opposite layout) (Figure 3). The walls of the rooms assessed were painted with emulsion paint of the same texture but different in colour. Three paint colours considered were cream, pink, and blue. These were the regular wall paints in commercial and residential buildings in the Wukari metropolis. The lamp capacities for the lighting fixtures that produced the assessed illuminance were 5, 10, 50, 100, and 200 Watts of the same product. Other indoor environment physical characteristics assessed to determine if the lamp capacities affect the thermal condition of the room environment were relative humidity, air circulation, and ambient air temperature.

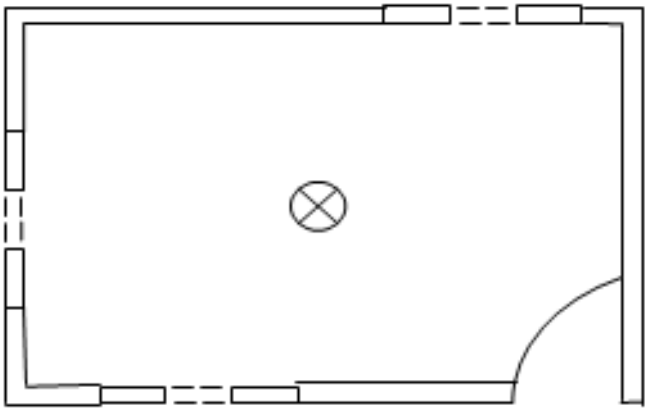

Fig. 1. Single light point source (centered) lighting design fixture orientation and array

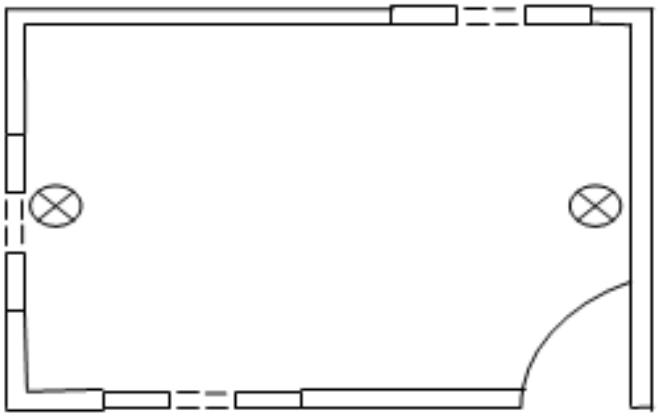

Fig. 2. Double point source (opposite arrangement) lighting design fixture orientation and array

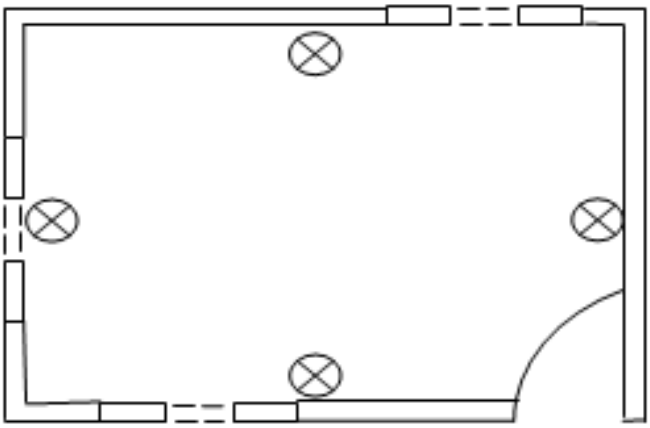

Fig. 3. Quadruple (at the center of each side of the rooms) lighting design fixture orientation and array

Data collection was between 8:00 – 10:00 pm behind a closed door to avoid interference from the outdoor environmental factors (light trespass, relative humidity, air circulation, and ambient air temperature). Thick fabrics were used as window blinds to avoid light trespass possibility from the outdoor environment. The illuminance measurement points were nine grids at 2m heights (Fig. 4).

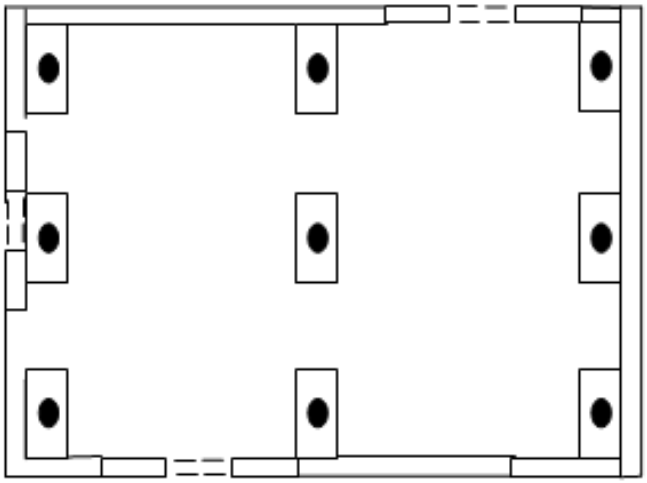

Fig. 4. Illuminance measurement points

B. Instrumentation design of the study

The following research tools were used for collecting data for this study. A digital luxmeter (Sunche model HS1010, Shanghai Industrial Co., Ltd, Shanghai) was used for illuminance measurement at the grids (Fig. 5)

Fig. 5. Sunche model HS1010 digital luxmeter

A generic 5m retractable measuring tape rule was used for measuring the grid point distances (Generic Manufacturing Corporation, Temecula California, USA) (Fig. 6).

Fig. 6. Mass band 5m retractable measuring tape

A digital anemometer (model GM816, Shenzhen Jumaoyuan Science and Technology Co., Ltd, Shenzhen) was used for the air circulation measurement (Fig. 7),

Fig. 7. Digital anemometer

Multi-functional digital LCD thermometer and hygrometer (takealot.com) measured relative humidity and environmental air temperature (Fig. 8).

Fig. 8. Digital LCD thermometer hygrometer

C. Estimation of illuminance uniformity (U_o)

The uniformity illuminance of the room (U_o) at a grid point of 2 m from the floor is defined as the ratio of the minimum

illuminance (*Emin*) to the average illuminance on the grid point (*Eaverage*) in a given moment (Eq. 1). The illuminance uniformity (U_o) ratio was analyzed on a scale of ≥ 0.3 by Illuminating Engineering Society (IES) and Chartered Institute of Building Services Engineers (CIBSE) for an acceptable value [9,10].

$$U_{o,average} = \frac{E_{min}}{E_{average}} \quad (1)$$

Where: Emin = the minimum value of illuminance at the measurement points
Eaverage = the average value of illuminance at the measurement points

D. *Statistical analysis of the study*

The data collected was analyzed using a Statistical Package for the Social Sciences (SPSS 20.0). The effect of the walls' paint colours and design fixture orientation and array on the illuminance level was analyzed using analysis of variance at a p-value of 0.05 for confidence level. Also, analysis of variance tests was carried out on relative humidity, air circulation, and environment air temperature data for the mean difference of their independent groups and whether they are significantly different. The summary of the data was presented in the form of tables

III. Results and Discussion

The results of the descriptive statistical analysis of the factors affecting indoor nighttime illuminance assessed in this study are presented in Table 1. From the result, it was found that the impact of lamp capacity on the illuminance of the indoor environment was highest when 200 Watts lamp was used (mean = 325.00 lux, SD = 195.01). The lowest illuminance was recorded when 5 Watts capacity lamp was used. Analysis carried out to determine the effect of the lighting fixture design on the illuminance level of the indoor environment of assessed rooms showed that quadruple light fixture design recorded the highest illuminance (mean = 114.76 lux, SD = 93.50), whereas the lowest illuminance level was recorded when single point source was used (mean = 53.31 lux, SD = 52.13). The effect of the wall paint colour on the illuminance level of the indoor environment of the rooms assessed showed that walls painted with pink colour recorded the highest illuminance with an average mean = 80.34 lux and SD = 75.53 (Table 1)

The values for the environmental factors assessed gave a temperature range of 28–30 °C, a relative humidity range of 69-73%, and the air circulation ranges from 0.0 - 0.1 m/s. There was no difference in each category of the assessment, the lamp capacities (5, 10, 50, 100, and 200 Watts) and the lighting fixtures design (single light point source (centred), double (opposite array) and quadruple (double opposite layout)), and the wall paint colour (cream, pink and blue). This result implies that the lamp capacities, the lighting fixtures design, and the wall paint colour do not affect the thermal conditions of the indoor environment. Table 2 presents the result of the illuminance uniformity ratio of the rooms for the nine grid points from which the measurement was taken in each of the rooms. This necessitates that the users may decide to place the reading or study table in any corner of the room. According to Azodo et al. [1], good visibility of a lighting system defines the adequacy of the amount of light present and the proper distribution of light which plays a role in the avoidance of visual stress and discomfort risk. Sufficient visual perception is requisite for safe task performance and the surrounding environment without eye-strain experiences. The overall uniformity ratio (U_o) analyzed under the recommended uniformity ratio of ≥ 0.3 for the perception to remain acceptable showed that the recommended uniformity ratio for lighting light distribution categories were insufficient when 5 Watts lamp capacity was used (Table 2).

TABLE I
DESCRIPTIVE STATISTICS OF THE FACTORS AFFECTING INDOOR NIGHT TIME ILLUMINANCE

Characteristics	Variables	Min	Max	Mean	Std deviation
Lamp capacity (Watts)	5	3.00	43.00	17.59	11.59
	10	14.00	81.00	35.90	18.31
	50	23.00	128.00	68.75	33.51
	100	28.00	134.00	77.16	33.25
	200	117.00	325.00	195.01	75.37
Light fixture design	Single	3.00	239.00	53.31	52.13
	Double	9.00	251.00	68.59	55.53
	Quadruple	21.00	325.00	114.76	93.50
Wall paint colour	Cream	3.00	325.00	79.01	77.07
	Pink	5.00	323.00	80.34	75.53
	Blue	3.00	321.00	77.30	70.40

TABLE 2
ILLUMINANCE UNIFORMITY RATIO (U_o) FOR THE NINE MEASUREMENT POINTS IN THE ROOMS

Lamp capacity (Watts)	Minimum	Maximum	Mean	STD	Overall uniformity
5	3.00	43.00	17.59	11.59	0.17
10	14.00	81.00	35.90	18.31	0.39
50	23.00	128.00	68.75	33.51	0.33
100	28.00	134.00	77.16	33.25	0.36
200	117.00	325.00	195.01	75.37	0.60

The lamp capacities, 5, 10, 50, 100, and 200 watts, were analyzed in the three categories of the lighting design fixture orientation and array in the three rooms' walls paint colours, cream, pink and blue. Analysis of variance test was used to identify the effect of lamp capacities, 5, 10, 50, 100, and 200 watts on the illuminance and to highlight the statistical significance of each lamp capacity effect obtained by comparing the mean square against an estimate of the experimental error. The result obtained for the illuminance for the five categories of lamp capacities had p-values less than 0.05, indicating that they are significantly different from zero at a confidence level of 95% (Table 3).

The analysis of variance for the effect of lighting fixture design on Illuminance showed a statistical F-value of 28.50. The means of the groups are significantly different as the p-

value is less than 0.05. This result implies that lighting fixture design orientation and arrangement affect the illuminance levels in the rooms (Table 4).

TABLE 3
ANALYSIS OF VARIANCE FOR THE EFFECT OF LAMP CAPACITY ON ILLUMINANCE

Representation	Sum of Squares	Df	Mean Square	*F*-value	*p*-value
Between Groups	1554839.82	4	388709.95	231.97	0.00
Within Groups	670285.73	400	1675.71		
Total	2225125.55	404			

a. Predictors: (Constant), lamp capacity
b. Dependent variable: Illuminance

TABLE 4
ANALYSIS OF VARIANCE FOR THE EFFECT OF LIGHTING FIXTURE DESIGN ON ILLUMINANCE

Representation	Sum of Squares	Df	Mean Square	*F*-value	*p*-value
Between Groups	276318.91	2	138159.45	28.50	0.00
Within Groups	1948806.64	402	4847.78		
Total	2225125.55	404			

a. Predictors: (Constant), lighting fixtures design
b. Dependent variable: Illuminance

The effect of wall paint colour on indoor Illuminance analysed using analysis of variance gave a very low *F*-value (0.06). The groups' means are not significantly different because the *p*-value is more than 0.05. This result implies that wall paint colour does not affect the illuminance level of the indoor environment. Consequent, they are all emulsion paints (Table 5).

TABLE 5
ANALYSIS OF VARIANCE FOR THE EFFECT OF WALL PAINT COLOUR ON ILLUMINANCE

Representation	Sum of Squares	Df	Mean Square	*F*-value	*p*-value
Between Groups	625.68	2	312.84	0.06	0.95
Within Groups	2224499.87	402	5533.58		
Total	2225125.55	404			

a. Predictors: (Constant), wall paint colour
b. Dependent variable: Illuminance

IV. CONCLUSION

Knowing that humans obtain most of the information they use by sight, it is important to have a lighting system that delivers the appropriate visual need while minimizing the non-visual effects of light. This study evaluated the effect of an artificial lighting system in a room at nighttime on the illuminance in a preoccupied students' hall of residence, and showed that the higher the capacity of the electric lamp, the better the illuminance as 200 Watts lamp capacity had the highest illuminance. The higher the lighting fixture array, the better the illuminance as quadruple light fixture design array had the best adequate illuminance uniformity in the room irrespective of the wall paint colour as the wall paint did not affect the illuminance of the rooms. Further study is recommended in this area of study which will cover different paint textures.

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