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On Lighting Design, Simulation, Analysis and Amelioration of a Computing Laboratory Area Using Dialux Software Simulation Techniques

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ABSTRACT

It is of significant academic and commercial interest to develop energy efficient lighting systems for different settings especially of indoor facilities following the requisite illuminance and lighting power density standards. In addition, it is imperative to analyze and ameliorate existing lighting systems in various spheres of humane activity in order to phase out inefficient lamps and replace the corresponding fixtures with energy efficient solid state or other forms of lighting. In the undertaken designing work, the existing lighting system of the Central Computing Laboratory, Electrical Engineering Department, Jadavpur University was analyzed and a DIALux simulation model was created to simulate and ameliorate upon it. Thereafter, an ameliorated DIALux simulation model was created using DIALux 4.12 and it was duly shown that it adheres to the recommendations and guidelines of the relevant Indian standards such as the IS – 3646 and Energy Conservation Building Code (ECBC) in terms of illuminance level and lighting power density respectively. It is recommended to redesign the lighting layout of the aforementioned laboratory following this ameliorated simulation model.

Keywords : Lighting Design, Illumination, Energy Efficient Lighting, Software Simulation, LED, DIALux.

I. INTRODUCTION

Modern lighting systems are increasingly becoming complex in nature and over the past two decades, software simulation techniques in the realm of illumination engineering have been utilized to model, visualize and analyze various indoor and outdoor lighting systems as per the requirements of various national and international codes of practice and standards. Modern lighting design process takes account of the required illumination levels for various activities, uniformity of distribution of light in the working space for illumination, colour of the light, correlated colour temperature (CCT) and colour rendering index (CRI) of the light sources in use, energy considerations etc. In addition, it is cardinal to consider the human responses to light [14] in order to reduce visual discomfort, avoid excessive glare and inculcate an aesthetic lighting design for optimization of visual stimulus and human performance [15]. Considering these, the existing lighting system of the Central Computing Laboratory, Electrical Engineering Department, Jadavpur University was analyzed and a DIALux model was made emulating the physical system. Thereafter, an ameliorated DIALux model was made following the IS – 3646 and ECBC (2007) guidelines to redesign the lighting plan.

II. LITERATURE REVIEW

For indoor lighting design in the Indian context, IS – 3646 (code of practice for interior illumination) [1] of the Bureau of Indian Standards is followed by and referred to for implementing any standard lighting design. The Energy Conservation Building Code (ECBC) of 2007 [2] was developed by the Govt. of India for commercial buildings and it sets minimum standards for power utilization for a connected load of 100 KW or more. It also tabulates recommended lighting power densities (LPD) for various workspaces as a function of building area or space. Kumar, Satish, Ravi Kapoor, Rajan Rawal, Sanjay Seth, and Archana Walia [3] expounded on development of energy conservation building codes and their implementation strategies in the Indian context. Mukherjee, Proneel [5] reviewed energy efficient lighting systems for an office building. Luoxi, Hu Guojian Hao [6] compared between lighting softwares DIALux and Agi 32. It was found that DIALux simulation techniques were more reliable and accurate. Vishwas, Moheet, and Prashant Kumar Soori [7] analyzed the day lighting and artificial lighting components for an office lighting system design. Thus, DIALux software simulation techniques were utilized in the lighting design, simulation and analysis of the aforementioned computing laboratory.

III. MATERIALS & METHODS

A. Hardware Components

A digital photometer, a laser distance meter, a chalk and a tape measure were utilized to carry out the light and distance measurements.

B. Software Components

DIALux, a software developed by DIAL GmbH of Germany for the purpose of lighting system planning and design utilizing its standard library of objects, was utilized for the lighting design and simulation. An associated software POV – Raytracer was used to render photorealistic images of the Dialux simulation models. Standard .ies files for TCS 306/236, TCS 306/136, FBH 100/113 and LTD Lithonia 2PM3N 12 cell 2x4 luminaires were utilized to plan the lighting system.

C. Methods

(1) *Distance Measurement*

In order to correctly model the laboratory, distance measurements were tabulated and assumed to proper truncation. The entire laboratory was differentiated into six workspaces with a total of twenty-six computer terminals. The length, width and height of workspaces, i.e. the tables and a row of adjacently placed worktops, were duly tabulated. A complete floor plan was drawn by sketching the room elements in their respective locations. The height of the room, i.e. the orthogonal distance from the ground to the ceiling was measured with the help of a laser range-finding meter. In a similar fashion, the heights of the different windows within the room were measured; also, distances of some workspaces from their adjacent walls were measured using the tape measure and also the laser range-finding distance meter, wherever the latter was necessary.

(2) *Illuminance Measurement*

A standard photometer, which could measure up to illuminance levels of 50000 lux with a minimal error margin, was utilized to calculate the illuminance levels of the different workspaces. To attain better approximations of the average illuminance levels, the different workspaces were sub – divided into grid systems with several grid points. First, the requisite distance measurements were tabulated and from the tabulated data, the imaginary grid systems were drawn by marking several points on the workspaces by a piece of white chalk. With the photometer, the illuminance levels on those points were measured and noted down in a tabular form. Necessary precautions were taken so as to avoid the shadows of the observer falling on the workspace or blocking the path of the light from the adjacently placed overhead luminaires. By following this procedure, the average illuminance levels of the different workspaces were duly calculated.

(3) *DIALux Simulation*

A new indoor project is initiated by clicking on “New Interior Project” of Fig. 1. After the initiation, the opening screen appears on the monitor. Objects and luminaire files are chosen from a list of available items. Utilizing various objects and luminaire files, a user may design a lighting system as per the required criterion. An illustrative design is shown herein:

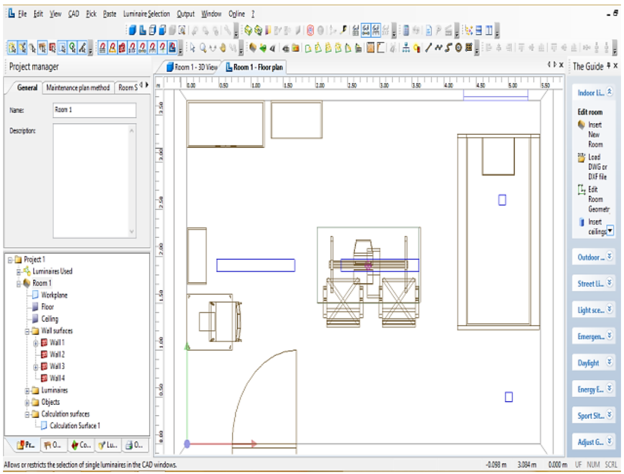

Figure 1. Illustrative Project Floor Plan

One shall arrive at the summarized photometric results, which may be appropriate for easy calculation of total luminous flux, electrical load, uniformity and lighting power density.

(4) *POV – Raytracer Rendition*

The POV – Raytracer software is utilized to create a photorealistic view of the simulation model and it uses its radiosity function to map the light distribution as it may be visually perceived by a normal human eye. It may also work as an anti – aliasing filter to smoothen up edges and improve the overall appearance of the model. An illustrative POV – Raytracer rendition in 3 – D is duly shown herein:

Figure 2. A Trial POV–Raytracer Rendition

IV. RESULTS

A. Floor Plan

The floor plan of the laboratory showing the working surfaces is duly shown herein:

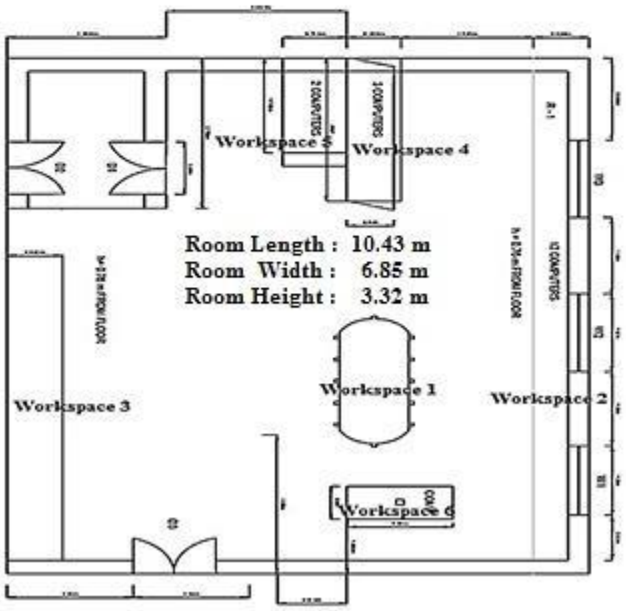

Figure 3. Laboratory Floor Plan

B. DIALux Floor and Luminaire Plan

The DIALux floor and luminaire plan of the existing system is duly shown herein:

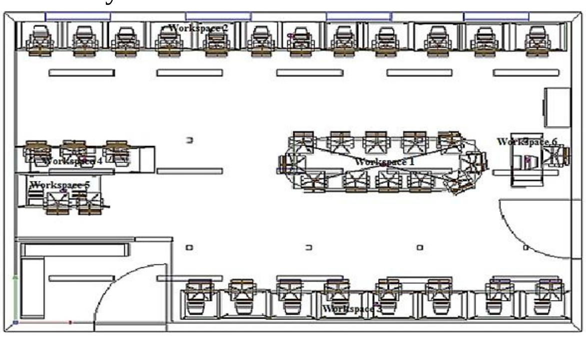

Figure 4. Lighting Plan of Existing System

The floor and luminaire plan of the proposed lighting system (the ameliorated DIALux model) is shown herein:

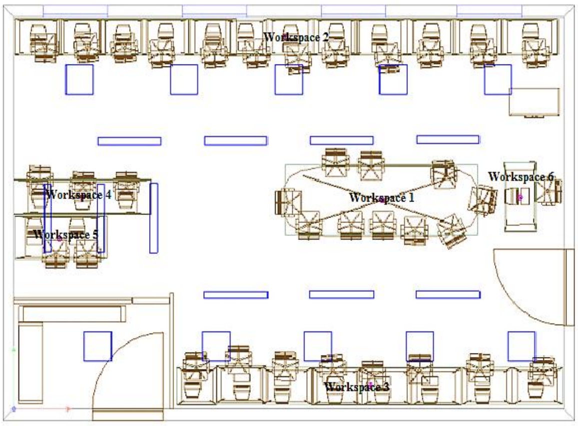

Figure 5. Lighting Plan of the Proposed System

C. The Reflected Ceiling Plan

The reflected ceiling plan of the original physical lighting system in the laboratory is duly shown herein:

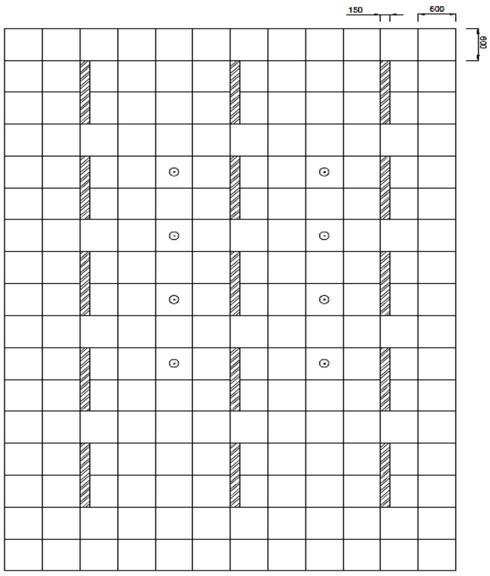

Figure 6. The Reflected Ceiling Plan

D. Measured Dimension of Workspaces

Table 1. Calculation Surface Dimensions

Name	Length (in m)	Width (in m)	Height (in m)
Workspace 1 (Centre Table)	3.66	1.22	0.76
Workspace 2 (12 Computers)	10.43	0.64	0.76
Workspace 3 (8 Computers)	7.30	0.64	0.76

Name	Length (in m)	Width (in m)	Height (in m)
Workspace 4 (3 Computers)	2.631	0.619	0.76
Workspace 5 (2 computers)	1.745	0.751	0.76
Workspace 6 (1 Computer)	1.22	0.60	0.76

E. Illuminance Levels

A table showing the measured illuminance levels of the laboratory, the illuminance levels of the DIALux model replicating the physical system and the proposed ameliorated DIALux model is duly shown herein:

Table 2. Illuminance Comparison

Parameter	Existing System	DIALux Model	Ameliorated DIALux Model
Illuminance Level (in lux)	Workspace 1: 488.89 Workspace 2: 314.80 Workspace 3: 320 Workspace 4: 283.33 Workspace 5: 232 Workspace 6: 357	Workspace 1: 485 Workspace 2: 257 Workspace 3: 264 Workspace 4: 233 Workspace 5: 211 Workspace 6: 408	Workspace 1: 716 Workspace 2: 419 Workspace 3: 462 Workspace 4: 415 Workspace 5: 417 Workspace 6: 426

F. POV – Raytracer Diagrams

(1) One POV – Raytracer diagram pertaining to the DIALux model emulating the physical existing lighting system is duly shown herein:

Figure 7. POV – Raytracer Model of Light Distribution of the Original DIALux Model

(2) One POV – Raytracer diagram of the ameliorated DIALux model of the laboratory demonstrating the subjective improvement in aesthetics and light distribution is duly shown herein:

Figure 8. POV – Raytracer Model of Light Distribution of the Proposed Ameliorated DIALux Model)

V. DISCUSSION

A. Calculation of Lighting Power Densities

(1) The surface area of the laboratory = length × breadth = (10.43 × 6.85) m^2 = 71.4455 m^2. For the existing lighting system, there are 26 (twenty-six) T12 fluorescent tubular lamps each of 40 W, 4 (four) T8 fluorescent tubular lamps each of 36 W and 8 (eight) of compact fluorescent lamps each of 18 W present and there are two lamps per luminaire for fluorescent tubular lamps.

Thus, the electrical power consumed = 26×40 + 4×36 + 8×18 = 1328 W.

Therefore, the lighting power density (LPD) = $\frac{1328}{71.4455} W/m^2 = 18.59$ W/m^2

(2) For the general DIALux model, there are 8 (eight) FBH 100/113 luminaires each of 17.3 W and 15 (fifteen) Philips TCS306/236 HF Normal luminaires each of 74 W having two lamps per luminaire.

Thus, the electrical power consumed can be calculated as = 8×17.3 +15×74=1248.4 W.

Therefore, the lighting power density (LPD) = $\frac{1248.4}{71.4455} W/m^2 = 17.47$ W/m^2

(3) For the ameliorated DIALux model, there are 6 (six) TCS 306/136 M1 luminaires each of 45.2 W, 4 (four) Philips TCS 306/236 HF Normal luminaires each of 74 W and 10 (ten) MLS CO., LTD Lithonia 2PM3N 12 Cell 2x4 Parabolic luminaires each of 37.3 W. Thus, the consumed electric power for the purpose of

lighting can be determined as = 6×45.2 + 4×74 + 10×37.3 = 940.2 W.

Therefore, the lighting power density (LPD) = $\frac{940.2}{71.4455} W/m^2$ = *13.16* W/m^2

B. Tabulated Comparison of Three Models

A tabulation of the three models with comparison parameters as number of luminaires utilized, total electrical power consumed, minimum average illuminance among the workspaces, maximum average illuminance among the workspaces, lighting power density and compliance with relevant standards is shown herein:

Table 3. Comparison of Parameters

Parameters	Existing Lighting System	DIALux Model	Ameliorated DIALux Model
Total No. of Luminaires	23	23	20
Total Electrical Power Consumed	1328 W	1248.4 W	940.2 W
Minimum Average Illuminance Among the Working Planes	232 lux Was observed in Workspace 5	211 lux Was observed in Workspace 5	415 lux Was observed in Workspace 4
Maximum Average Illuminance Among the Working Planes	488.89 lux Was observed in Workspace 1	485 lux Was observed in Workspace 1	716 lux Was observed in Workspace 1
Lighting Power Density	18.59 W/m^2	17.47 W/m^2	13.16 W/m^2
Compliance With IS – 3646	No	No	Yes
Compliance With ECBC 2007	No	No	Yes

The ameliorated DIALux model thus complies with the IS – 3646 (Part 1) of 1992 as it follows the 300 – 500 – 750 lux illuminance level recommendation and also the ECBC 2007 guidelines as the lighting power density for the laboratory is found to be 13.16 W/m^2 which is well below the highest recommended value of 15.10 W/m^2.

C. Limitations

Hereby, the study and analysis is dependent upon certain assumptions. First, the luminaires files utilized in the DIALux simulation model were assumed to be ideal sources of luminous flux and thus do not necessarily consider the lumen depreciation of the actual luminaires present in the laboratory. Then, the reflection factor of the ceiling was assumed to be 80%; that of the four walls to be 70%. Irregularities and roughness of the aforementioned surfaces were not considered. After that, various air circulating and air conditioning systems, such as air conditioners, wall mounted fans etc. were not considered and their 3D models were not imported to simulate the actual existing physical conditions of the laboratory. In addition, in the ameliorated model, these assumptions and exclusions limit the scope of this study and analysis and may require further iterations in order to attain higher accuracy in simulating and analyzing the lighting system.

VI. CONCLUSION

It can be inferred upon that the existing lighting system of the Central Computing Laboratory, Electrical Engineering Department, Jadavpur University does not necessarily adhere to the recommendations of the IS – 3646 (Part 1) of 1992 and the Energy Conservation Building Code (ECBC) of 2007. Two of the workspaces have average illuminance levels of 283.33 lux (workspace 4) and 232 lux (workspace 5) respectively and also the lighting power density (LPD) is more than 15.1 W/m^2 which is the recommended maximum LPD of a laboratory as per the table 7.3.2 (Interior Lighting Power – Space Function Method) of the ECBC. The DIALux simulation model of the existing system displays its LPD to be 17.47 W/m^2. In the ameliorated model, the involvement of the LTD Lithonia 2PM3N 12 cell 2x4 parabolic luminaires and complete elimination of compact fluorescent lamps (CFL) alongside lesser number of utilized fluorescent tubelights (FTL) substantially increased the light level of the workspaces. It follows the 300 – 500 – 750 lux illuminance level guidelines of the IS – 3646 (Part 1) of 1992 and the middle value is intended for five workspaces. Workspace 1 receives an average illuminance of 716 lux while workspaces 2 to 6, the computer workspaces, receive 419 lux, 462 lux, 415 lux, 417 lux and 426 lux respectively. It also follows the ECBC 2007 recommendations and has a lighting power density of

13.16 W/m^2 which is significantly lesser than the maximum recommendation level of 15.1 W/m^2. Thus, this model is an energy efficient one and produces more luminous flux (lm) per watt of consumed electric power. It can be thus concluded that the ameliorated model requires further iteration to enhance its plausibility, energy efficiency [11] and uniformity of light distribution among the workspaces. Nevertheless, this model shall be more energy efficient than the existing lighting system once physically implemented. The existing lighting system of the Central Computing Laboratory, therefore, may be improved upon by installing new fixtures for LED lamps [12], eliminating the existing compact fluorescent lamps and reducing the number of utilized fluorescent tubelights and this would essentially be an economically viable lighting design.

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