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Comparative Analysis Between Lumen Method Calculation and Dialux Simulation for Electrical Lighting Design.

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Abstract

This paper presents a comparative analysis between Lumen method and Dialux simulation for lighting design for an office block. The analysis is to determine which method gives the number of luminaires which produces the recommended photometric parameters by Illumination Engineering Society of North America (IESNA) standards for an office. The number of luminaires required for the office block was computed with Lumen method and Dialux Evo 9.2 using Spectral MIREFA luminaires specifications. Results was simulated on Dialux Evo 9.2 to determine the photometric parameters; illumination, uniformity of illumination and Unified Glare Rating (UGR). The Lumen method had one luminaire more than the Dialux simulation. Results from the photometric analysis showed that for a target value of 300lx, the Lumen Method achieved a better perpendicular illuminance of 367lx, 347lx and 314lx against 213, 248 and 241 from Dialux. Also, the Lumen method achieved better uniformity of illumination, having values of 0.034, 0.020 and 0.030 against 0.074, 0.002 and 0.024 gotten from Dialux design for the small, medium and large offices respectively, though both results were not up to the standard value recommended by IESNA as 0.4. The UGR results for Lumen method had points with stronger glare exceeding the standard of 19 set by IESNA, while Dialux had lower glare, making it the better design in terms of glare rating. Overall comparism shows that the Lumen method is better suited for lighting design calculations using Spectral MIREFA and Philips RC540B lighting fittings, while Dialux is suitable for lighting simulation and presentation.

1. Introduction

Lighting plays a very important role in regular human activities which is constantly available from the sun during the day time [1]. To cater for the night time, artificial lighting is required. Such artificial lighting should be as close as possible in replicating the natural lighting.

The lighting system is one of the major elements of the Electrical service design for buildings consisting of lighting fittings and their controls [2]. The lighting system should be designed such that it may; provide adequate illumination, provide light distribution all over the working plane as uniform as possible, provide light of suitable colour, avoid glare and hard shadows as much as possible, ensure low energy consumption and adhere strictly to standard [3]. In designing a lighting system for a building, there are some factors to consider such as; day lighting, physical dimensions of the room and the building as well as its location and position, the activities to be done in the room space, the power and luminous rating of the lighting fitting, the losses and maintenance factors and the budget for the project [4].

There are two methods of modelling a lighting system; manual method and the use of software. The manual method involves the use of mathematical calculations calculated manually in determining the number of lighting fittings and the spacing between them given the recommended illumination for the room according to IES (Illumination Engineering Society) standards. The manual method consist of three sub methods; point-to-point method, watts per square metre method and Lumen method. The Lumen method is the most widely used method of the three due to its simplicity and level of accuracy [5].

The lumen method, which is also called zonal cavity method, is an easy method to calculate the light level in a room. The method is a sequence of calculations that use horizontal illuminance criteria to create a uniform luminaire layout in a space. In its simplest form, the lumen method is merely the total number of lumens available in a room divided by the area of the room [6]. To perform this calculation, many factors, coefficients, lamp lumen data, and other quantities must be gathered. Despite the scientific impression of the lumen method equations, there are imprecisions and assumptions made into the method.

In light of technological advancement, lighting design softwares have been designed to handle complex lighting calculations and simulate the design in 3D display. Examples of these software include: AG132, Dialux, Relux, Ecotect, Radiance etc. [7]. Dialux software, Developed by DIAL GmbH is a widely used commercial package in lighting design, which is available for free through lighting manufacturers' websites. This program is customized for interior and road lighting. The program provides output in customized pdf format and additionally uses POV Ray to produce photorealistic images. It has an inbuilt calculation system that automatically generate the number of lighting fittings for a room space given the desired illumination.

This work aim to compare the two methods to determine which is best suited for lighting design.

2. Methodology

The comparative analysis carried out in this work are as follows:

- Calculation for the number of luminaires *Lumen method and Dialux Evo 9.2*
- Simulation of number luminaires result to determine lighting spacing and the photometric parameters using Dialux software.

2.1 Overview of architectural plan

The architectural plan is the office block of the Department of Electrical/Electronic Engineering, University of Benin. It comprises of 30 offices, one classroom, two toilets and a control room. The offices on the floor differ in dimension and presented accordingly:

a) **Small offices**: office whose area is 3.5m by 4.3m.
Office: 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 18, 19, 20, 22, 23, 24, 25 and Exam Office (21 offices).

b) **Medium offices**: office whose area is 5.4m by 4.3m.

Office: 1, 9, 16, 17, 26 (5 offices).

c) **Large offices:** office whose area is 7.1m by 4.3m
Office: 21, Graduate Assistants office, HOD's office, Conference room (4 offices)

2.2 Calculation for the Number of Luminaires

Specifications spectral MIREFA luminaires (25 Watts, 300 Lumen) was used for the luminaires computation.

a) The Lumen Method: this method was used to calculate the number of luminaire per office per recommended illuminance in lux by IESNA.

The Lumen method is given by the formula:

$$\textit{Number of lighting fixtures} = \frac{Lux \times A}{FL \times LLF \times Cu} \quad \textbf{(1)}$$

Where:

Lux = lighting requirement of the room or office (Lux)

A = area of the room or office (mm^2)

FL = luminous intensity of the lighting fixture (Lumen)

LLF = light loss factor

Cu = coefficient of utilization

The following values were used for the calculation (IESNA):

Lighting requirement of the room or office (Lux) = 300 Lux

Light loss factor (LLF) = 0.8

Coefficient of utilization (CU) = 0.75

b) Dialux Simulation: the architectural plan of the office floor (.dwg file) was imported into Dialux software and was simulated as presented in Figure 1. It generated the number of luminaires per office using the same assumed values for Lux, LLF and CU. Table 1 shows the results of the number of luminaires calculated using both methods

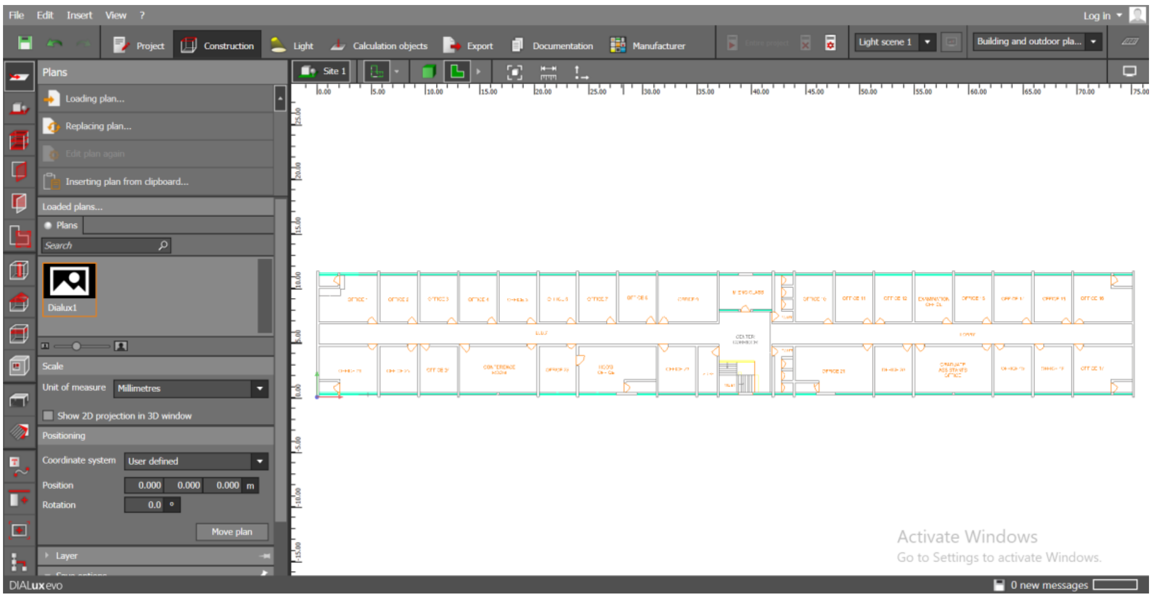


Figure 1: Importing of architectural plan from AutoCAD into Dialux

Table 1: Comparative analysis between the number of luminaires from Lumen method and Dialux simulation

OFFICE	**AREA (m^2)**	**FLUX (Lumen)**	**NUMBER OF LUMINAIRES**	
			Lumen Method	**Dialux Simulation**
Small Offices	14.74	3000	3 Nos	2 Nos
Medium Offices	22.98	3000	4 Nos	3 Nos
Large Offices	30.35	3000	5 Nos	4 Nos

It can be observed that the number of luminaires obtained using Lumen method is one luminaire more than that obtained using Dialux simulation for the same room size.

2.3 Photometric Parameters Generated from Dialux Simulation

For comparative analysis Dialux software was used to simulate the photometric parameters using results of the obtained for both methods. The project was simulated with the generated number of luminaires from Dialux for each office category, likewise the calculated number of luminaires using Lumen method. The outcome of the project simulation generates the photometric parameters for performance of the method and comparative analysis. The photometric parameters are as follows:

a. The perpendicular illuminance of the office work plane in Lux
b. The uniformity of illumination (g_1)
c. The Unified Glare Rating (UGR) of the selected calculation space in the room

a. Perpendicular illuminance: this is the vertical light hitting a horizontal surface. It is measured in Lux. The value of perpendicular illuminance must be greater than or equal to the recommended value of illuminance for the office by IESNA (300lx).

b. **Uniformity and non-uniformity of illuminance (g_1 & g_2):** is a quality issue that addresses how evenly the light spreads over a task area.

Uniformity of illuminance (**g_1**)**:** It can be calculated using the equation:

$$\boldsymbol{g_1 = \frac{E_{min}}{\bar{E}}} \quad \textbf{(2)}$$

Non-uniformity of illuminance (**g_2**) It is calculated by the formula:

$$\boldsymbol{g_2 = \frac{E_{min}}{E_{max}}} \quad \textbf{(3)}$$

Where,
E_{min} = minimum illuminance (lx)
$\bar{E}$ = work plane perpendicular illuminance (lx)
E_{max} = maximum illuminance (lx)

c. Unified Glare Rating (UGR): the glare caused by very bright luminance in the visual field. This causes discomfort and fatigue to the eyes. This glare can be mitigated by not exceeding the suggested light levels and by using lighting equipment designed to reduce glare. It is quantified by Unified Glare Rating (UGR) given by Equation 4.

$$\text{UGR} = 8\, log_{10} \frac{0.25}{L_b} \sum \frac{\omega L_s^2}{P^2} \quad (4)$$

Where,
L_b = Background illuminance (cd/m^2)
L_s = Luminance of the luminaire (cd/m^2)
w = Solid angle subtended at the observer's eye by the luminaire (Steradians)
p = Position index

The recommended value of UGR by IESNA for an office is 19 at any angle.

3.0 Results and Discussion

The lighting design of the office categories is simulated using Dialux Evo 9.2 and the photometric parameters are measured for the comparism of the design by Lumen method and Dialux software.

3.1 Simulation Results

Prequel to generating the parameters, the lighting spacing and layout is simulated, the following factors are considered for simulation:

- Reflection factor (Ceiling, Walls & Floor)
- Clearance Height
- Mounting Height

Table 2 presents the assumed values for the simulation on Dialux.

Table 2: Assumed Values for the simulation on Dialux

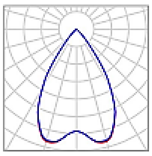
Office Category	Area (m^2)	Reflection Factor (%)			Clearance Height (m)	Mounting Height(m)
		Ceiling	Walls	Floor		
Small Office	14.74	70	50	20	2.670	2.670
Medium Office	22.98					
Large Office	30.35					

For this paper pictorial of simulation and results of the **medium office** would be presented, however results for comparative analysis of the three types of offices were presented.

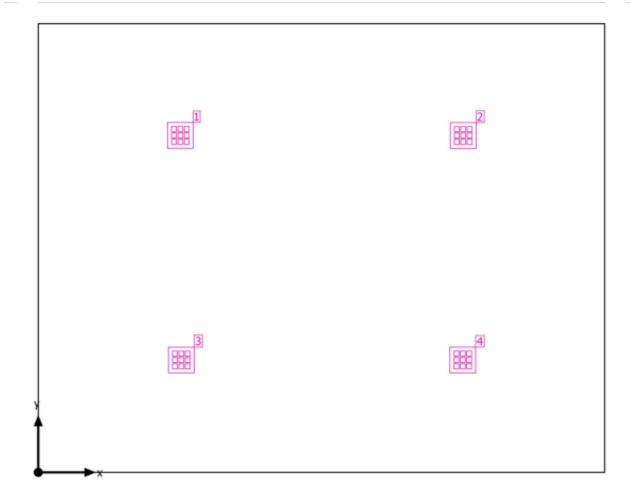
Figure 2 presents light spacing (x & y axis) and the luminaire layout plan of the of number of luminaires in the medium office obtained by using Dialux simulation while Figure 3 presents the light spacing and the luminaire layout plan of the luminaires in the same office, obtained from Lumen method. Figure 4 presents the 3-D rendition of the medium office from Dialux and Lumen method.

Luminaire layout plan

Spectral



Manufacturer	SPECTRAL	P	25.0 W
Article No.	SPG0330246AH	$\Phi_{Luminaire}$	3001 lm
Article name	MIREFA-ADQ-3x3 DAFWS840B0300		
Fitting	1x LED-M		



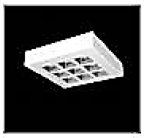
Individual luminaires

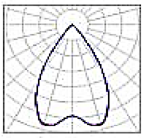
X	Y	Mounting height	Luminaire
1.351 m	3.206 m	2.670 m	1
4.040 m	3.205 m	2.670 m	2
1.360 m	1.069 m	2.670 m	3
4.035 m	1.070 m	2.670 m	4

Figure 2: the light spacing and plan layout of the luminaires in the medium office from Dialux software

Luminaire layout plan

Spectral





Manufacturer	SPECTRAL	P	25.0 W
Article No.	SPG0330246AH	$\Phi_{Luminaire}$	3001 lm
Article name	MIREFA-ADQ-3x3 DAFWS840B0300		
Fitting	1x LED-M		

3 x Spectral MIREFA-ADQ-3x3 DAFWS840B0300

Type	Field Arrangement
1st luminaire (X/Y/Z)	0.897 m / 2.134 m / 2.670 m
X-direction	3 pcs., Center - center, 1.795 m
Y-direction	1 pcs., Center - center, 4.268 m
Arrangement	A1

X	Y	Mounting height	Luminaire
0.897 m	2.134 m	2.670 m	1
2.692 m	2.134 m	2.670 m	2
4.487 m	2.134 m	2.670 m	3

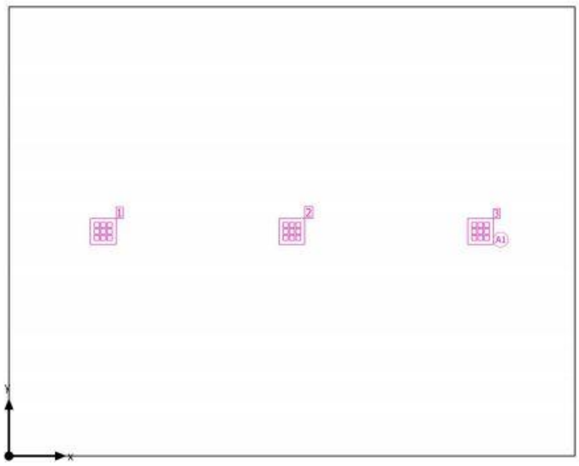


Figure 3: the light spacing and plan layout of the luminaires in the medium office from Lumen calculation

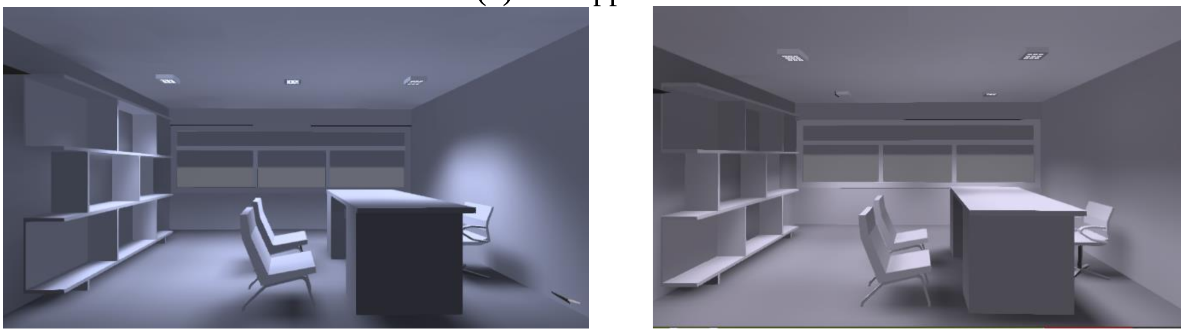


Figure 4: the 3-D rendition of the medium office from Dialux and Lumen Method respectively

The results of the photometric parameters from the simulation are presented below:

a. **Perpendicular illuminance**: Figure 5 presents the isoline diagram of the office, showing its illuminance for both methods. Figure 6 presents the calculation result for perpendicular illuminance due to the luminaire arrangement by Dialux. The perpendicular illuminance obtained was 248lx, which is lower than the recommended value (300 lux), hence the red bad sign. While the value of perpendicular illuminance due to the luminaire arrangement from Lumen calculation was 347lx which exceeds the recommended value as seen in Figure 7. Hence, the green tick sign is given.

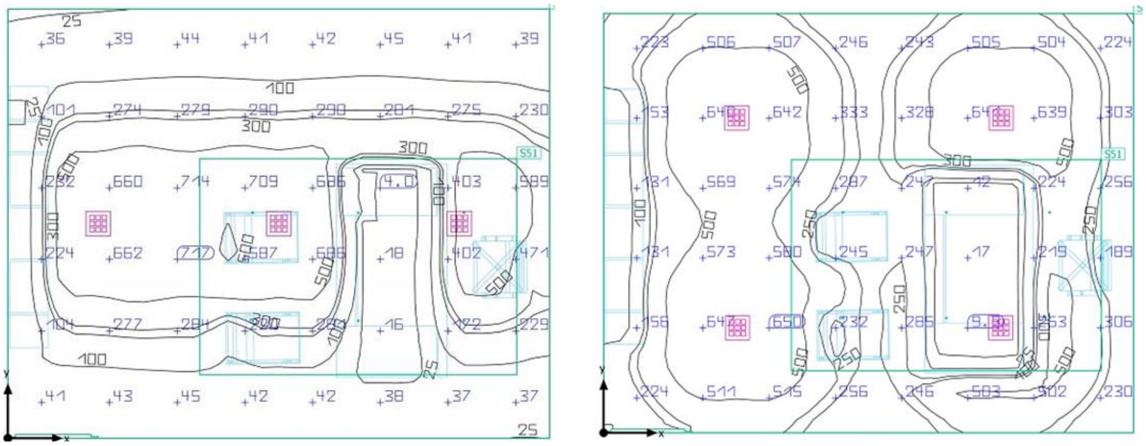


Figure 5: Isoline diagram of the office, showing its illuminance for Dialux simulation and Lumen calculation respectively

Calculation objects

Work planes

Properties	Ē (Target)	E_{min}	E_{max}	g_1	g_2	Index
Workplane (office 9) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	248 lx (≥ 300 lx) ✗	0.61 lx	741 lx	0.002	0.001	S79

Figure 6: Calculation results from large office using Dialux arrangement

Calculation objects

Work planes

Properties	Ē (Target)	E_{min}	E_{max}	g_1	g_2	Index
Workplane (office 9) Perpendicular illuminance (adaptive) Height: 0.800 m, Wall zone: 0.000 m	347 lx (≥ 300 lx) ✓	6.88 lx	671 lx	0.020	0.010	S79

Figure 7: Calculation results from large office using Lumen calculation arrangement

b. **Uniformity and non-uniformity of illuminance (g_1 & g_2):**
Figure 5 gives the values of the calculation objects performed by Dialux on the room space showing values of E_{min}, E, E_{max}, g1 and g2 obtained for the calculation space selected at a height of 0.80m, which is the height of the task area (Table) from the floor.
The value of $\mathbf{g_1}$ and $\mathbf{g_2}$ gotten from the arrangement by Dialux are **0.002** and **0.001** respectively, while the value of $\mathbf{g_1}$ and $\mathbf{g_2}$ from the arrangement by Lumen calculation are **0.02** and **0.01** respectively. These values are lower than the standard value of g1 for the workplane, given by IESNA as **0.4** but the values from Lumen method are closer compared to Dialux as seen in Figure 5 and 6 above. In general, the Lumen method has a higher Uniformity value compared to Dialux.

c. **Unified Glare Rating (UGR)**: The UGR for the office was calculated on the calculation space at a height of 1.2m, which is the height of the eye level from a sitting position obtained through measurement for a person **5 feet, 11 inches** tall. Other parameters selected are the viewing sector, which is the range of angle of rotation of the head when viewing, the step width is the smallest change in angle of rotation that can be made by the viewer taken as $\mathbf{15^0}$. The results are displayed in Figure 7. The maximum value of UGR in the office gotten from Dialux arrangement is **23.4** at an angle of $\mathbf{180^0}$, which is not suitable for good vision. While the maximum value of UGR gotten from Lumen calculation arrangement is **24.9**, at an angle of $\mathbf{105^o}$ which also exceeds the standard rating of 19 but is better off than the results from Dialux.

Six random points were selected on the calculation plane for the UGR calculation i.e. the glare effect of the beam of light from the luminaire installed in the office on six random positions at eye level height was calculated. The luminaire beam angle at the six random points on the calculation space for the two methods is shown in Figure 8. The Figure shows which of the points have the potential to give a glare effect on anyone who is sitting on that position at a particular viewing angle (indicated by the red lines). Hence, lighting equipment designed to reduce glare should be used.

Calculation objects

Calculation surface 4 (UGR)

Strongest glare at	180°
max	23.4
Target	≤19.0
Viewing sector	0° - 180°
Step width	15°
Height	1.200 m
Index	S84

Calculation objects

Calculation surface 11 (UGR)

Strongest glare at	105°
max	24.9
Target	≤19.0
Viewing sector	0° - 360°
Step width	15°
Height	1.200 m
Index	S51

Figure 7: UGR results of the medium office using Dialux arrangement and Lumen arrangement respectively

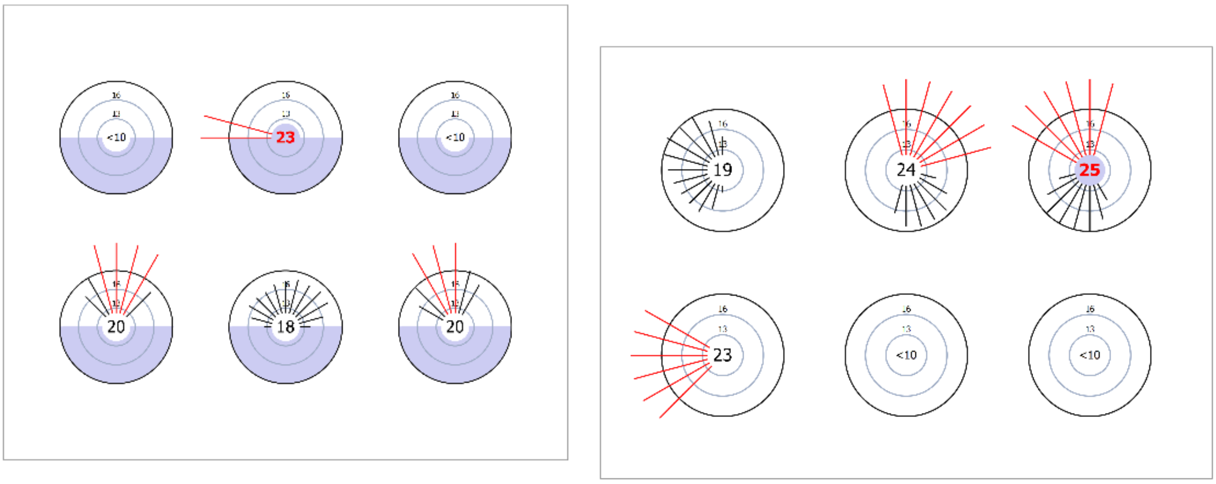


Figure 8: Luminaire beam angle at 6 random points on the workplane for Dialux arrangement and Lumen calculation arrangement respectively

3.2 *Comparative Analysis of Simulated Results between Lumen Method and Dialux*

The summary of the simulated results from the Lumen method and from Dialux for all the office categories is presented in Table 3. This would help in the comparison between the two methods to determine which of the methods gives the best result.

Table 3: Summary of simulated results from Lumen method and from Dialux

Office Category	Method	Perpendicular Illuminance (lx)	Uniformity of Illumination (g1)	Highest Unified Glare Rating (UGR)
Small Office	Dialux	213	0.074	18.3
	Lumen	367	0.034	27.4
Medium Office	Dialux	248	0.002	23.4
	Lumen	347	0.020	25.8
Large Office	Dialux	241	0.024	< 10
	Lumen	314	0.030	24.9

3.3 Discussion

From the analysis presented in Table 3, it is observed that, for all the office categories, the Lumen method achieved better perpendicular illuminance, having values above 300lx which is the standard for an office by IESNA. This is due to the effect of the extra lighting fixture the Lumen method had over Dialux calculation using the Spectral Mirefa's specifications.

In terms of Uniformity of illumination (g1), neither method met the standard given by IESNA as 0.4. Values of g1 closer to 0.4 or higher, denote better uniformity of illumination. However, for the small office, from Table 3, Dialux calculation gave a better uniformity of illumination due to its arrangement and light spacing while for the medium office and large office, the Lumen method performed better.

In terms of UGR results, the recommended value of UGR for an office by IESNA is 19. This means that values of UGR above 19 denote high glare and would result to strain on the eyes. For all the office categories, Lumen method had points with higher glare rating than Dialux software. This imply that the design done using Dialux calculation has a better glare rating and is more comfortable to the eyes.

4. Conclusion

From the observation, it is inferred that the automatically generated deign by Dialux has lower number of lighting fixtures than the Lumen method using the Spectral Mirefa luminaire which reduces energy consumption and cost, but the resultant illumination is not up to the recommended value. The Lumen method with one more Mirefa luminaire on the other hand meets the target value for illumination and thus becomes a better option for lighting design.

From the analysis done, though both the Lumen method and Dialux software are good for calculating the number of lighting fittings for a room space given the desired illumination, Lumen method gave better results and achieved the desired illumination compared to Dialux. It is therefore recommended that the Lumen method be used for lighting design. A software that uses the syntax of the Lumen method can be developed to automatically generate the number of lighting fittings given the desired illumination and all required parameters. Dialux software has proved to be a very good software for simulation and calculation of photometric parameters. Hence, the generated results gotten from Lumen method should be put into Dialux software for lighting design simulation.

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