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Evaluating Indoor Lighting Performance: A Comparative Study Using Dual Methods for Different Colour Schemes

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Abstract

Efficient lighting design is fundamental to creating comfortable, safe, and functional indoor workplace environments. An optimal lighting system not only ensures adequate illumination for visual tasks but also enhances occupant safety and visual comfort. In Malaysia, adhering to standard lighting recommendations is crucial and requires careful consideration of design elements, specifically the interaction between light sources and room surface colours. However, previous studies have largely focused on the efficacy of light sources in isolation, often overlooking the combined influence of light source type and room colour on illuminance distribution (lx). This study aims to bridge this gap by investigating the effects of different wall and floor colour schemes on light distribution using two distinct light source types. The methodology employs a dual approach: experimental testing via goniophotometer measurements and photometric simulation using DIALux software to ensure accurate illuminance results. The findings demonstrate that white colour schemes consistently yield significantly higher average lux values across both light source types compared to darker schemes. These results underscore the critical importance of integrating surface colour selection into lighting design strategies to maximize energy efficiency and visual performance in building interiors.

1. Introduction

Effective indoor lighting design is an element in creating functional, pleasant, and attractive environments. Previous studies have emphasized the importance of lighting in indoor spaces, highlighting its significant impact on visual comfort, safety, energy consumption, and the overall atmosphere (Dhayal & Jha, 2023). Illumination is the quantity of light that falls on a surface or unit area of the work surface, measured in lx units (Zumtobel, 2018). The Malaysian Standards Department and the Standard and Industrial Research Institute of Malaysia (SIRIM), through their Code of Practice for Upgrading of Interior Lighting with LED Lamps and Luminaire (2019), recommend an average lighting level for working interiors between 300 and 500 lx.

This aligns with the ISO CIE 8995-1 standard (ISO CIE 8995-1-2025 Light and Lighting- Lighting of Workplaces, 2025). Similarly, Katabaro & Yan (2019) follow these lighting levels, referencing the Chartered

Institution of Building Services Engineers (CIBSE) and the International Commission on Illumination (CIE). The choice of light source critically influences lighting quality. Historically, fluorescent lighting has been prominent in various applications due to its affordability, durability, and ease of use. However, the introduction of Light-Emitting Diode (LED) technology provides an energy-efficient and adaptable alternative designed to replace legacy sources. LEDs offer significant advantages, including energy savings of up to 50%, reduced maintenance costs, easier handling, and a longer life expectancy (Shaikh et al., 2018). Consequently, Gan et al. (2013) revealed that LED tubes have a high potential to replace traditional fluorescent lamps due to their superior energy efficiency.

Fluorescent and LED lamps both have their own characteristics, performing differently in electrical and photometric parameters. These differences are particularly evident in lighting distribution, luminous efficacy, luminous flux, luminous intensity distribution, power factor (PF) requirements, and colour rendering capabilities (Perdahci et al., 2018). Furthermore, a study by de Souza et al. (2019) found that lamps retrofitted with LEDs demonstrated a more uniform light intensity distribution compared to other luminaires. The interaction between light sources and room surface colours is another crucial, yet often overlooked, factor influencing indoor lighting performance. Research has shown that surface colours, especially on walls and floors, can affect distribution and light intensity (Selim et al., 2020). For instance, Bellia et al. (2017) revealed that surface colour influences illuminance values, with violet surfaces having lower lx values than white surfaces.

This demonstrates how surface colour interacts with light sources to modify the illumination distribution within an area. White walls typically reflect light more effectively, enhancing overall illumination, whereas darker colours absorb more light, reducing the luminous flux reaching the work surface. Therefore, understanding how different colour schemes influence lighting performance is essential for developing energy-efficient and effective lighting solutions. Despite the valuable findings provided by previous studies, research into the specific effects of various colour schemes on the comparative performance of fluorescent versus LED lighting remains limited.

The relationship between these specific light sources and different wall and floor colours is still underexplored. This study aims to fill this gap by examining how fluorescent and LED light sources perform with different interior colour schemes. This research focuses on two scenarios: Artificially White (AW) and Artificially Dark (AD). Through experimental and simulation methods using the goniophotometer and DIALux software, this study will address a gap in previous research. The findings aim to enhance the understanding of the relationship between light sources and interior colour schemes, contributing to more effective and sustainable lighting designs.

2. Methodology

This section is divided into two parts: (1) the photometric parameter measurement of different light sources using a goniophotometer and (2) illuminance measurement of the room using DIALux software. In the first stage, the electrical and photometric parameters of different light sources were measured, including voltage (V), lamp power (W), luminous flux of the luminaire (lm), luminaire efficiency (%), and luminaire efficacy (lm/W). The photometric data from the luminous intensity distribution curves (LIDC) measurement were used in the workplace modelling simulation in DIALux software. T8 fluorescent and LED luminaires were selected as the light source types, and black and white colours of the walls and floors were identified as variables affecting light distribution (lx) in the simulation design. Table 1 shows that "AW" refers to both white walls and floors, while "AD" refers to both dark walls and floors.

Table 1 *Colour scheme of the walls and floors*

Wall	Floor	Color Scheme
White	White	AW
Dark	Dark	AD

Figure 1 illustrates the flowchart of the study. The experimental process begins by identifying the light source and colour factors, such as the colour of the walls and floor. Next, measurements for the Light Intensity Distribution Curve (LIDC) parameters are carried out, and photometric data are recorded. The photometric data is then generated in the DIALux software for lighting simulation, and the lighting distribution values (lx) are recorded. If there is a need to test other light sources:

If there is a need to test other light sources:

- If (Yes), LIDC measurements and DIALux simulations will be performed using colour schemes and light sources other than those focused on in this study.
- If (No), the results will be compared between fluorescent lamps and LEDs.

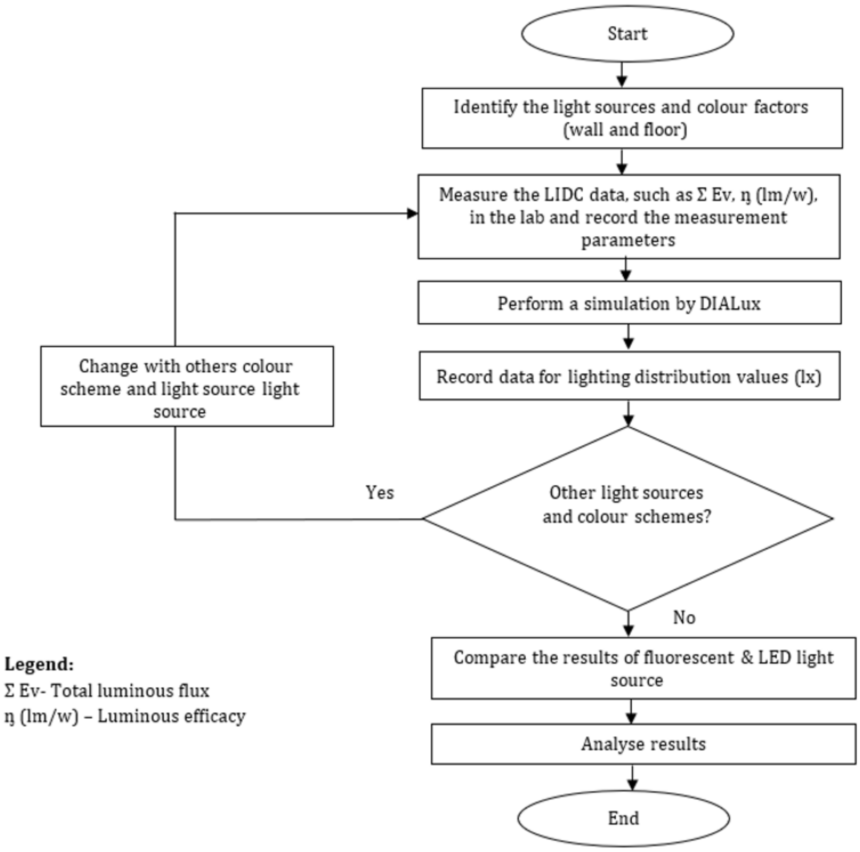

Fig. 1 *Flowchart of the project*

2.1 Photometrical Parameters Measurement

Luminaire Photometry Lab at CREaTE, also known as the dark room. The samples of indoor lighting luminaires were installed on the Rotating Luminaire Goniophotometer devices based on the C-γ coordinate system. Then, the goniophotometer will produce photometric data known as the Luminous Intensity Distribution Curve (LIDC) and convert it into an Illuminating Engineering Society (IES) file.

The dark room has dimensions of L: 9,500 mm, W: 2,220 mm, and H: 3,150 mm. The interior of the room is painted with a black matte coating to eliminate stray light sources. In the dark room, as shown in Fig. 2, two diaphragms with diameters of 1200 mm and 700 mm are positioned between the light source and the illuminance meter. The distance between the test sample mounted on the goniophotometer and the illuminance meter is 7,700 mm. The test is performed at an ambient temperature of 25 ± 2°C and relative air humidity of < 50%, following CIE 121:1996 (International Commission on Illumination, 1996) and CIE DIS S025:2015(Jamaludin et al., 2024).

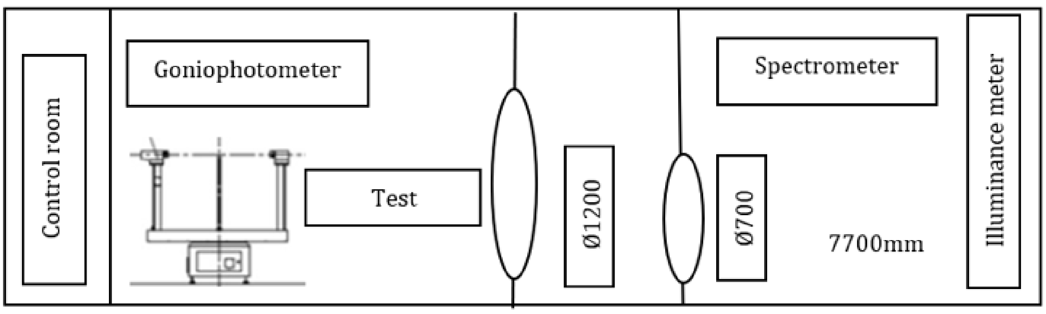

Fig. 2 *Illustration of a goniophotometer measurement setup*

Philips TLD 36W/865 fluorescent tubes, with 36 W and 20W Lumitec LED tubes, were used as light sources. Table 2 summarizes the specifications of two lighting systems that meet the quality of lighting comfort standards based on MS ISO 8995:2005 at the recommended average light levels for indoor lighting in workplaces.

Table 2 *Specification T8 lighting of fluorescent lamp and LED tubes*

Description	Fluorescent lamp	LED tube
Model	SAC 240/ W MOL	SAC 240/ W MOL
Tube Wattage	2 x 36W	2 x 20W
Total Luminous Flux	6140 lm	4000 lm
Colour Temperature	6500K	6500K

2.2 Illuminance Measurement Using DIALux Software

The second method focuses on lighting simulation using DIALux Evo software for validation, as it is the recognized industry standard for lighting design (Słomiński et al., 2025) . In this stage, the study examines how variations in wall and floor colours affect light diffusion from the light sources.

The simulation shown in Fig. 3 involves the following fundamental steps:

i. Setting up the Room:
Define the room's dimensions and layout, established as 10 by 6 meters. Include workspaces and other architectural elements and add selected lighting fixtures.

ii. Selecting luminaires:
Choose IES (Illuminating Engineering Society) files, which are derived from photometric measurements of actual light sources, to ensure accurate simulation data in DIALux.

iii. Arranging luminaires:
Placing the luminaires systematically inside the simulated setting to comply with the illumination design plan.

iv. Defining Calculation Points:
Identify specific locations within the room where illuminance levels will be measured.

v. Setting Parameters:
Set the lighting calculation parameters, including a desired illuminance of 300 lx based on (JKR, 2011).

vi. Running the calculation:
Use advanced algorithms to simulate how light interacts with surfaces and objects in the environment, considering reflection, refraction, and absorption.

vii. Analysing the Results:
After completing the calculation, evaluate the data based on the illuminance levels and visual representations of light distribution provided by the DIALux Evo. Evaluate the performance of the lighting design and identify areas that need to be improved to meet the required standards.

viii. Making Adjustments:
Adjust the luminaire arrangement or settings as needed to optimise the lighting design. Rerun the simulation to ensure that the improved design meets the standards that are required.

ix. Generating Reports:
Create comprehensive reports from DIALux Evo that summarise the lighting design results and performance.

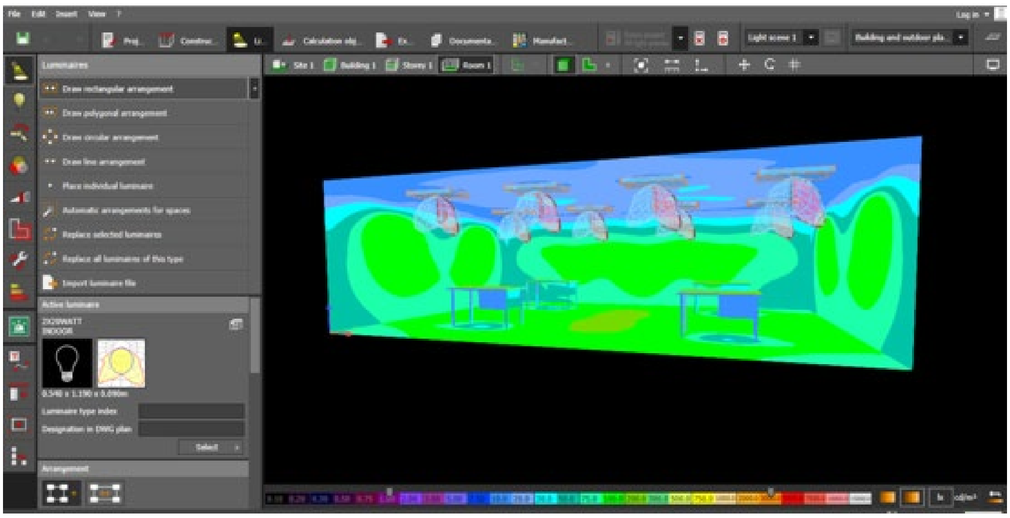

Fig. 3 *Workplace modelling by DIALux simulation*

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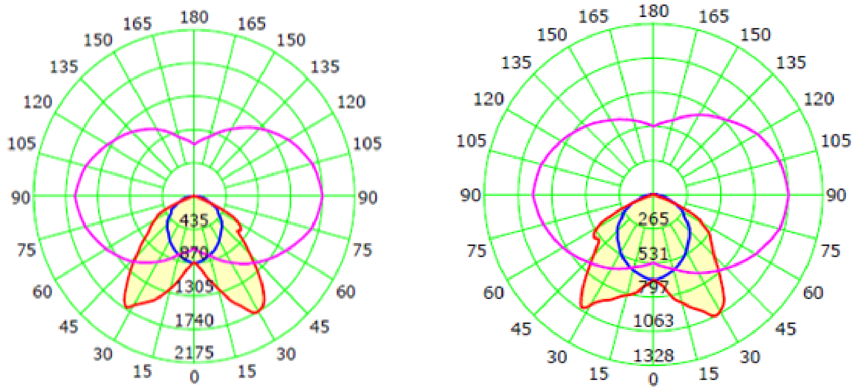
3.1 Air Quality Monitoring Instrument

Figure 4(a) shows the polar curve of the fluorescent lamp output facing downward. The differing shapes of the two curves result in asymmetrical light distribution due to the uneven spread of light across the area. The intensity of light in various directions is expressed in candelas (cd) and measured from the centre point of the light source. A plan view of a T8 fluorescent lamp is represented by the purple curve. The red curves represent the C90°–C270° plane, with a maximum intensity of 1740 cd at 30°. The blue curve represents the C0°–C180° plane and indicates a maximum intensity of 870 cd.

Figure 4(b) depicts the polar curve of the T8 LED lamp output facing downward. Due to its asymmetrical light distribution, the shapes of the two curves differ. The purple curve represents the plan view of the LED lamp. The red curves depict the C90°–C270° plane, with a maximum intensity of 1063 cd at 30°. The blue curve represents the C0°–C180° plane, with a maximum intensity reading of 664 cd.



(a) **(b)**

Fig. 4 *Luminous intensity distribution of (a) T8 fluorescent 2 x 36W; (b) T8 LED 2 x 20W*

Table 3 tabulates the photometric data for the T8 fluorescent lamp. The total rated lamp lumens are 6140 lm, and the amount of visible light emitted by a lamp is 3565.6 lm. The light output ratio (LOR) is 58.07%, which means 41.93% of the light is trapped inside the lighting fixture. Since the lamp fixture is facing down, the reading of the downward ratio is 57.8%, while the upward ratio shows 0.27% of light is coming from the lamp fixture.

Table 3 *Photometric data for T8 fluorescent*

Luminaire Parameters	Value	Luminaire Parameters	Value
Luminous Flux of the luminaire (lm)	3565.6	Total Rated Lamp Lumens (lm)	6140
Light Output Ratio (%)	58.07%	Luminaire Efficacy (lm/W)	43.74
Voltage (V)	241.2	Power of the Lamps (W)	81.51
Upward Ratio (%)	0.27%	CCT	6744 K
Downward Ratio (%)	57.80%	CRI	81

Table 4 depicts the photometric data for the LED lamp. The total rated lamp lumens are 4000 lm, and the amount of visible light emitted by a lamp is 2385.9 lm. The light output ratio (LOR) is 59.65%, which means 40.35% of the light is trapped inside the lighting fixture. Since the lamp fixture is facing down, the reading of the downward ratio is 95.91%, while the upward ratio shows 0.26% of light coming from the lamp fixture.

Table 4 *Photometric data for T8 LED*

Luminaire Parameters	Value	Luminaire Parameters	Value
Luminous Flux of the luminaire (lm)	2385.9	Total Rated Lamp Lumens (lm)	4000
Light Output Ratio (%)	59.65%	Luminaire Efficacy (lm/W)	65.53
Voltage (V)	240.7	Power of the Lamps (W)	36.41
Upward Ratio (%)	0.26%	CCT	6643 K
Downward Ratio (%)	95.91%	CRI	72

3.2 Photometry Comparison

According to the LIDC findings and Table 5, the T8 fluorescent lamp has a higher luminaire luminous flux (3565.6 lm) than the LED lamp (2385.9 lm), resulting in a 33% difference in light output between the two light sources. However, the LED lamp's power consumption is significantly lower, decreasing from 81.51W for the fluorescent lamp to 36.41W for the LED lamp. This represents a power reduction of approximately 55%, meaning the LED saves at least 45.1W compared to the fluorescent lamp's power consumption.

The results, supported by Ghisi et al. (2019), align with findings that LED luminaires can achieve adequate task illuminance even with considerably lower luminous flux compared to fluorescent sources, due to the LED's directional light beam, which improves light utilization efficiency. The LED’s downward ratio is 95.91%, while the fluorescent lamp’s downward ratio is 57.80%. This indicates that the LED’s initial output is more focused downward compared to the fluorescent light source. The difference in the Light Output Ratio (LOR) between the T8 LED and the fluorescent lamp is 2.6%, due to LED light sources emitting directional light, and fluorescent lights emitting omnidirectional (multi-directional) light.

The polar curves for both light sources appear similar due to the use of single-louvre satellite optical mirror reflectors. However, the distribution of luminous intensity in the LED curve is wider than that of the fluorescent lamp. Luminaire efficacy, which measures the efficiency of the entire lighting fixture, shows that the LED has an efficacy of 65.53 lm/W, which is significantly better than the fluorescent light source’s efficacy of 43.74 lm/W. Additionally, the Correlated Colour Temperature (CCT) for both fluorescent and LED light sources is in the cool white range (6744 K for the fluorescent and 6643 K for the LED). The Colour Rendering Index (CRI) indicates that both light sources provide good colour rendering, with 81 and 72, respectively.

Table 5 *Comparison of photometry between T8 fluorescent and LED*

Types of light sources	Luminous flux of the luminaire (lm)	Power of the lamps (W)	Downward ratio (%)	Light output ratio (%)	CCT	CRI
Fluorescent	3565.6	81.51	57.8%	58.07%	6744 K	81
LED	2385.9	36.41	95.91%	59.65%	6643 K	72

3.3 DIALux Simulation Result for AW of T8 Fluorescent

Figure 5(a) shows an office simulation in an AW (Artificially White) room with white walls and floors. According to DIALux's simulation, six T8 fluorescent fixtures are required to achieve the 300 lx lighting standard. The minimum illumination, Emin = 201 lx, and the highest illumination, Emax = 586 lx, of the measured light distribution were recorded at a distance of 1 meter from the working plane. The AW room had an average illumination value of 426 lx, which was 42% higher than the recommended lighting level. Similarly, the lighting distribution (lx) exceeds 550 lx, as indicated in the yellow area between the numbers of lamps in Fig.5 (b). The difference in illumination level (lx) between the Emax and Emin values is 65.70%. The distribution curve of the lighting intensity reveals a pronounced asymmetry across the room’s wall surfaces. This effect is likely caused by reflections from the lamp reflectors and the reflective properties of the white room colour, leading to uneven scattering of light across the floor. According toPeter Robert Boyce, (2014), the interaction of light with room surfaces, including reflective walls, can result in non-uniform lighting distribution.

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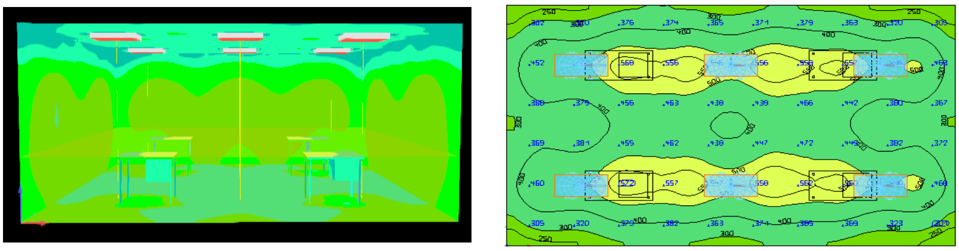
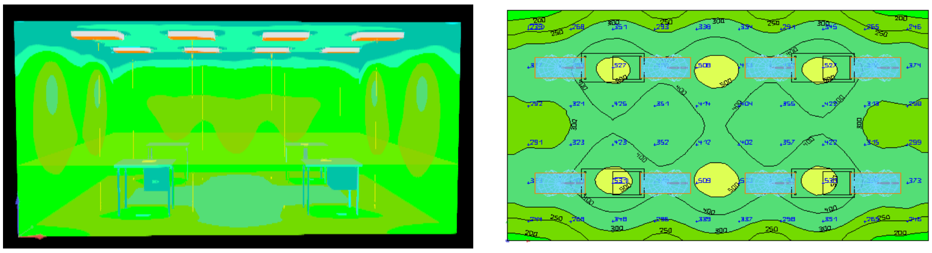


(a) (b)

Fig. 5 *DIALux Simulation Result for AW of T8 Fluorescent (a) The simulation of the light in AW room for T8 fluorescent; (b) Lighting distribution in AW room for T8 fluorescent*

3.4 DIALux Simulation Result for AW of T8 LED

Figure 6 (a) shows a minimum illumination, Emin = 179 lx, and a maximum illumination, Emax = 545 lx, both recorded at a distance of 1 meter from the working plane, as determined by DIALux results. The average illumination value in the AW room measured 364 lx, exceeding the recommended lighting level by 21.33%. Similarly, the lighting distribution (lx) exceeds 500 lx, as illustrated in Fig. 6 (b) by the yellow area representing the higher illuminance area. The difference in illumination levels (lx) between Emax and Emin is 67.16%. The distribution curve creates a sharp 'directional curve' on all sides of the room's wall surface and floor, due to the lamp's physical characteristics and the reflective properties of the room's white colour.

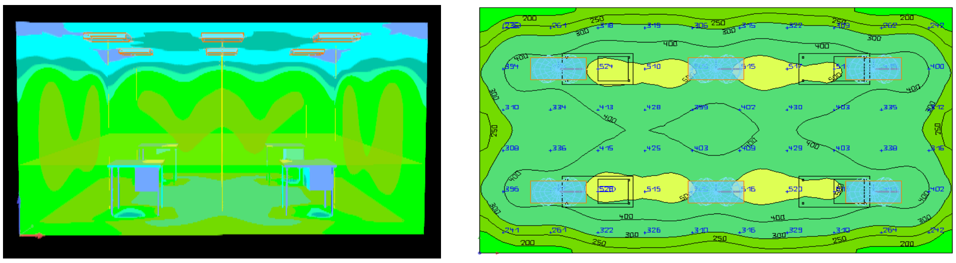


(a) (b)

Fig. 6 *Dialux simulation result for AW of T8 LED (a) The simulation of the light in AW room for T8 LED; (b) Lighting distribution in AW room for T8 LED*

3.5 DIALux Simulation Result for AD of T8 Fluorescent

Figure 7(a) shows that six T8 fluorescent fixtures are required to achieve the 300 lx lighting standard. The recorded values show a minimum illumination level, Emin = 141 lx, and a maximum illumination level, Emax = 544 lx. The average illumination in the AD room measured 376 lx, exceeding the recommended lighting level by 25.33%. Similarly, the lighting distribution (lx) exceeds 500 lx, as illustrated in Fig. 7(b) by the yellow area. The difference in illumination levels (lx) between Emax and Emin is 74%, signifying that the Min value is significantly distant from the lamp. Additionally, due to the room's dark colour, the lamp distribution curve on the walls and floor surface of the AD room is narrower compared to that of the AW room.

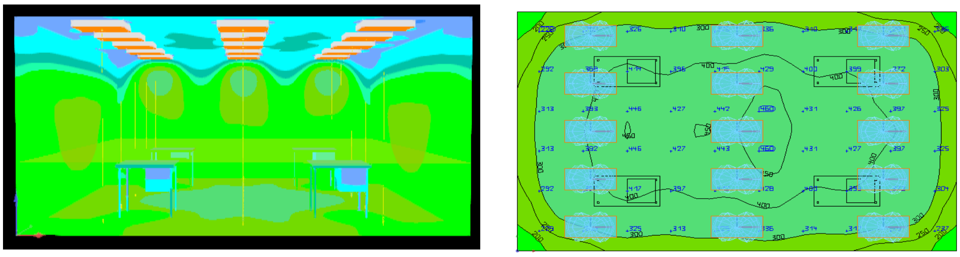


(a) (b)

Fig. 7 *DIALux Simulation Result for AD of T8 fluorescent (a) The simulation of the light in the AD room for T8 fluorescent; (b) Lighting distribution in the AD room for T8 fluorescent*

3.6 DIALux Simulation Result for AD of T8 LED

Figure 8 (a) shows an office simulation in an AD room with white walls and floors. The results indicate that 15 T8 LED fixtures are required to meet the 300 lx lighting standard, with a minimum of 161 lx and a maximum of 468 lx. In the AD room, the average illumination value measured 358 lx, which exceeded the recommended lighting level by 19.33%. Furthermore, as shown in Fig. 8 (b), there was no yellow area in the lighting distribution (lx) recorded in the AD room for the T8 LED. The difference in illumination levels (lx) between the Emax and Emin values is 65.60%. Meanwhile, due to the dark colour of the room, the lamp distribution curve on the wall and floor surfaces of the AD room is smaller than that of the AW room.



(a) **(b)**

Fig. 8 *Dialux simulation result for AD of T8 LED (a) The simulation of the light in the AD room for T8 LED; (b) Lighting distribution in the AD room for T8 LED*

3.7 DIALux Simulation Comparison

Table 6 and Fig.9 compare four different lighting systems, AW Fluorescent, AW LED, AD Fluorescent, and AD LED for T8 luminaires, in terms of average, minimum, and maximum illuminance. Among these, the AW Fluorescent system has the highest average illuminance (426 lx), with an illumination distributed from 201 lx at the dimmest point to 586 lx at the brightest. The AW LED follows with a slightly lower average of 364 lx, but maintains a reasonably balanced light distribution from 179 lx (Emin) to 545 lx (Emax). The AD Fluorescent and AD LED systems have lower average illuminance levels of 376 and 358 lx, respectively, with higher levels of light intensity, especially in the AD Fluorescent system, where the minimum drops to 141 lx. This suggests that the AW Fluorescent system provides the most consistent and bright illumination, which may be preferable in environments that require high visual clarity. LED options, slightly dimmer, provide benefits such as energy efficiency and a longer operational life. Overall, the graph demonstrates the trade-off between illuminance levels and potential energy savings when selecting an appropriate lighting system.

Table 6 *Lighting distribution for the light source colour scheme at 1m height of the working plane*

Colour scheme of the light source	No. lamp fixtures	Eav (lx)	Emin (lx)	Emax (lx)
AW Fluorescent	6	426	201	586
AW LED	8	364	179	545
AD Fluorescent	6	376	141	544
AD LED	15	358	161	468

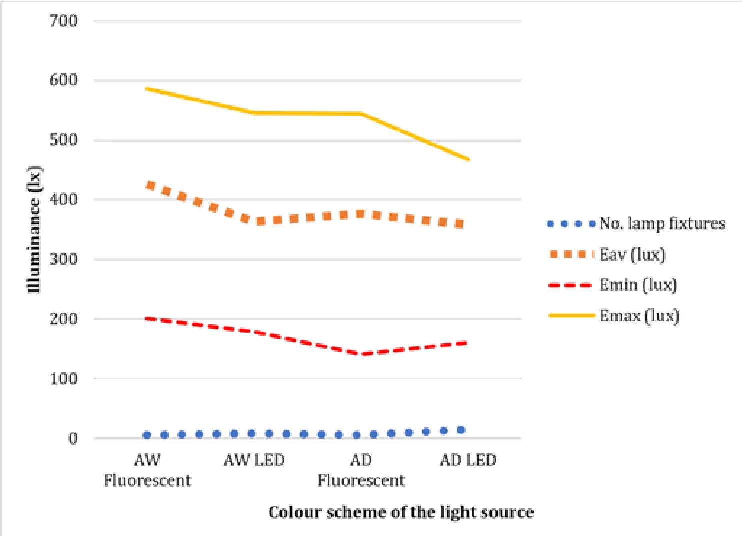


Fig. 9 *Difference in average illumination value for all colour schemes of the light source*

4. Conclusion

This study reveals that white colour schemes (AW) affect illumination levels compared to dark colour schemes (AD). T8 fluorescent lamps produced 62 lx (14.56%) higher than T8 LEDs in the AW scenario, with fluorescent lights offering more diffuse, scattered illumination, while LEDs provided focused, directional lighting. Although the T8 LED lights require more fixtures than T8 fluorescent lights, they are more energy-efficient, with a considerable reduction in power consumption, suggesting that LEDs are a prominent option for energy-efficient lighting designs. The DIALux simulations confirm that a white colour scenario contributes to improving light distribution and enhanced illumination. The software is also an excellent tool for precisely calculating the number of light fittings needed to achieve a desired illuminance level, making it invaluable for effective lighting design (Aikhoje P.Ta & Oriakhi O.M, 2022). Future research should focus on exploring energy-efficient building designs.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper titled "Evaluating Indoor Lighting Performance: A Comparative Study Using Dual Methods for Different Colour Schemes." The authors confirm that there has been no financial, professional, or personal relationship that could have influenced the work reported in this study. All authors have contributed to the research and manuscript preparation independently and objectively.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Norezmi Jamal, Shahriman Yunus, Hanif Jamaludin;* ***data collection:*** *Ain Bahror;* ***analysis and interpretation of results:*** *Ain Bahror, Noh Sarip, Hanif Jamaludin;* ***draft manuscript preparation:*** *Ain Bahror, Norezmi Jamal. All authors reviewed the results and approved the final version of the manuscript.*

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