International Journal of Business and Technology Management
e-ISSN: 2682-7646 | Vol. 7, No. 5, 491-506, 2025
https://asianscholarsnetwork.com/asnet-journals
SPECIAL ISSUE: International Virtual Go Green (iVGG) 2025

Simulation of Appropriate Daylighting Strategies for Higher Educational Institutions Buildings in Malaysia

Muhammad Anas Othman[1*], Mohd Fadzil Mat Yasin[1], Azizah Md Ajis[1], Adnin Syaza Jaafar[1], Yuhainis Abdul Talib[1]

[1] Department of Built Environment Studies and Technology, Faculty of Built Environment, Universiti Teknologi MARA, Perak Branch, Malaysia

*Corresponding Author: manas770@uitm.edu.my

Received: 23 May 2025 | Accepted: 23 July 2025 | Published: 1 October 2025

DOI: https://doi.org/10.55057/ijbtm.2025.7.5.43

Abstract: *Malaysia's higher education sector faces a significant challenge in balancing energy efficiency with budget constraints. The rising electricity bills, primarily driven by heating, air conditioning, and lighting loads, have become a substantial financial burden. Institutions are exploring various methods to control energy demand and reduce costs to address this issue. Building retrofitting using passive design strategies has emerged as a cost-effective. Therefore, this paper aims to investigate the appropriate daylighting strategies designed for building higher education institutions in Malaysia through simulation. This study employs simulation using Velux Daylight Visualizer software by displaying conditions of natural daylighting in generic models regarding illuminance level. Three case studies have been conducted by simulating using four daylighting strategies: (i) Window Base Case, (ii) Light Shelf (LS), (iii) Louvers (LO), and (iv) Overhang (OV). Data obtained from the Velux Daylight Visualizer provide analysis on illuminance level in false colour format by generating photo-realistic images based on detailed and physically accurate lighting simulations. The Comparison Simulation Daylighting Reading Table (CSDRT) is formulated by comparing the simulation illuminance readings with the recommended readings from three building guidelines: GBI for Interior Version 1.3, MS1525 2019 third revision, and CIBSE Lighting Guide 5: Lighting for Education. The CSDRT revealed that meeting all three guidelines simultaneously across every zone and time phase for all daylighting strategies is impractical. However, it is feasible to satisfy two guidelines, which can help determine the most effective daylighting strategy for specific zones. Key findings include the high effectiveness of louvers in Case Study A, promising results for the window base case strategy in Case Studies B and C, and varying performance of light shelves and overhangs. The research underscores the importance of aligning simulation studies with established guidelines for optimising daylighting and energy efficiency in educational buildings.*

Keywords: Simulation, Daylight Strategies, Velux Daylight Visualizer, Retrofitting

---

1. Introduction

Malaysia's higher education sector faces a significant challenge in balancing energy efficiency with budget constraints. The growing student population has led to increased electricity consumption in educational buildings, while government funding for public universities has been reduced by nearly 20% (Ministry of Finance Malaysia, 2016, 2017). This financial squeeze has made it imperative for Higher Education Institutions (HEIs) to find innovative solutions to manage their energy costs effectively.

The rising electricity bills, primarily driven by heating, air conditioning, and lighting loads, have become a substantial financial burden for HEIs (Sai et al., 2018). Institutions are exploring various methods to control energy demand and reduce costs to address this issue. Effective management of electricity distribution across campus sections and the implementation of energy-efficient technologies are becoming increasingly important (Jain and Jain, 2016).

Building retrofitting using passive design strategies has emerged as a cost-effective solution to lower electricity bills and enhance energy efficiency in educational buildings (Randjelovic et al., 2021). While previous research has focused on passive daylighting retrofitting for design studios, a more comprehensive approach is needed. By adopting integrated approaches to energy optimisation, as highlighted in Malaysia's 11th Plan Thrust 4, HEIs can work towards sustainability and resilience while managing their operational costs effectively (The Economic Planning Unit Prime Minister's Department Malaysia, 2015). Therefore, this paper aims to investigate the appropriate daylighting strategies designed for building higher education institutions in Malaysia through simulation.

2. Literature Review

2.1 Theory of Retrofitting Lighting

Retrofitting theory in the context of Higher Education Institutions (HEIs) involves modifying existing structures to enhance performance, increase functionality, and extend lifespan. This approach is particularly relevant to improving energy efficiency and sustainability in educational buildings. The theory encompasses updating infrastructure to meet current environmental standards and reduce resource consumption (Ghafoori and Motavalli, 2016), specifically focusing on enhancing daylighting strategies to minimise electricity usage in design studios.

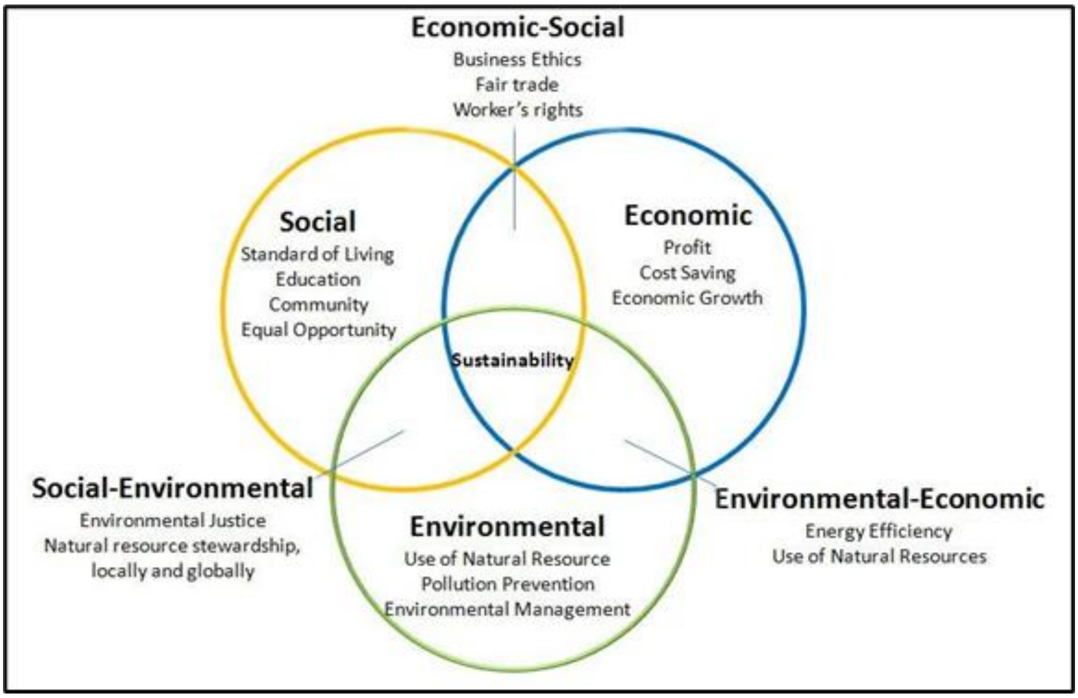

Figure 1: Three Sphere of Sustainability (Sustainability Paradigm)

The Three Spheres of Sustainability (refer Figure 1), also known as the Sustainability Paradigm theory, forms the fundamental theoretical framework for this research. This theory integrates Environmental, Social, and Economic aspects to achieve comprehensive sustainability. In the context of HEIs, the focus is primarily on the Environmental-Economic sphere, emphasising energy efficiency and the utilisation of natural resources like daylight (Cimiano-Prados et al., 2023). To implement successful retrofitting from this perspective, the Environmental Management System (EMS) Continual Improvement Cycle is employed (refer Figure 2). This cycle, often referred to as the Plan-Do-Check-Act (PDCA) model, is crucial in creating and maintaining sustainable buildings (Fet and Michelsen, 2023).

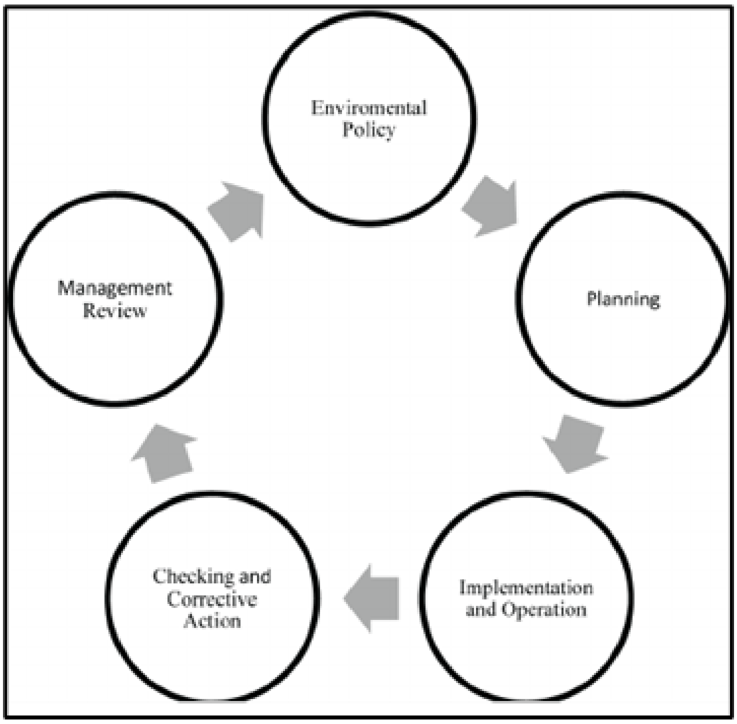

Figure 2: EMS Continual Improvement Cycle

The synergy between the EMS Continuous Improvement Cycle and the retrofitting approach lies in their shared goal of enhancing environmental performance in existing systems. Retrofitting, when implemented strategically within the EMS framework, can significantly improve energy efficiency and reduce the carbon footprint of educational buildings (Tawfik et al., 2023). This integrated approach contributes to the effectiveness of an organisation's environmental management system and aligns with broader sustainability goals, balancing economic considerations with environmental impact reduction.

2.2 Lighting – Illuminance

Lighting is composed of three main elements. They are (i) luminous, (ii) illuminance, and (iii) luminance. Illuminance is defined as the amount of light that falls on an object's surface, as shown in Figure 3 (Hiscocks, 2011; Li et al., 2014). Illuminance is measured in lux and used to determine the lighting level (Hiscocks, 2011). To acquire the appropriate illuminance level, the following formula is used:

$$E = \frac{F}{A}$$

E = illuminance of a surface (lm/m2 or lx)

F = luminous flux incident on the surface (lumen)

A = the area of the surface (m2).

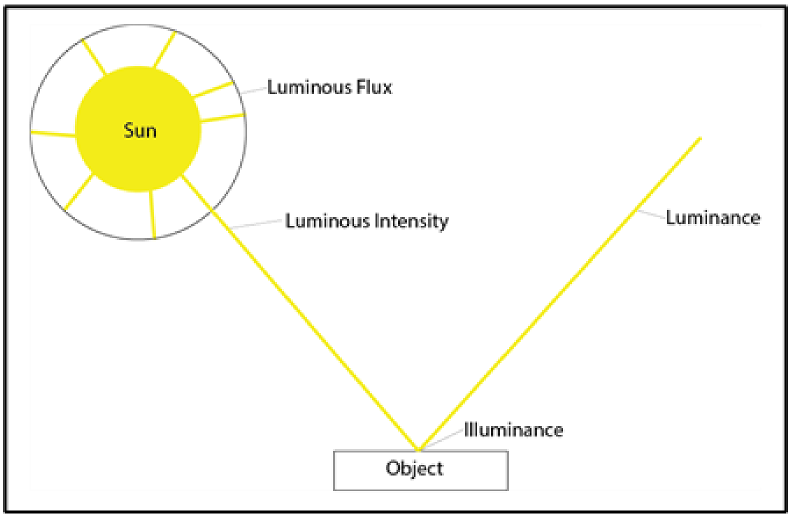

Figure 3: Components in Lighting

Adequate illumination throughout a studio is crucial. Designers often leverage daylight for interior lighting, reducing dependence on artificial sources (Li et al., 2005). Illuminance levels vary within a studio due to window proximity, sun position, and sky conditions (Kadir et al., 2016). However, excessive illuminance can lead to visual and thermal discomfort and disability glare (Nabil and Mardaljevic, 2005; Winterbottom and Wilkins, 2009).

Table 1 provides a comprehensive overview of illuminance standards for various spaces in educational and office environments, as recommended by different guidelines and institutions. The Green Building Index (GBI) for Interior Version 1.3 suggests a maximum illuminance of 2000 lux for standard offices. The Malaysian Standard (MS) MS1525: 2019 recommends 300-400 lux for general and drawing offices and 300-500 lux for classrooms and libraries. The Chartered Institution of Building Service Engineers (CIBSE) Lighting Guide 5 offers more specific recommendations, suggesting 750 lux for technical drawing rooms, 500 for conference and meeting rooms, and 300 for classrooms and tutorial rooms. These standards highlight the importance of appropriate lighting levels in different educational and workspaces, emphasising adequate illumination to support various activities while avoiding excessive brightness that could lead to discomfort or energy waste.

Table 1: Illuminance Standard Reading

No	Green Index Guideline	Space Types	Illuminance (Lux)
1	Green Building Index (GBI) for Interior Version 1.3	Standard Office	Below 2000 lux
2	Malaysian Standard (MS) MS1525: 2019	General Office	300-400 lux
		Drawing Office	300-400 lux
		Classroom/Library	300-500 lux
3	Chartered Institution of Building Service Engineers (CIBSE) Lighting Guide 5: Lighting for Education	Technical Drawing Rooms	750 lux
		Conference and Meeting Room	500 lux
		Classrooms and Tutorial Room	300 lux

Source: (CIBSE, 2011) (Malaysian Standard 1525, 2019) (GBI, 2023)

2.3 Daylight Strategies

Daylighting strategies are crucial in optimising natural light in buildings, particularly in educational settings. The most used strategies include windows, louvers, light shelves, skylights, and overhangs. These techniques are categorised based on their functions: penetration (windows and skylights), distribution (light shelves), protection (overhangs), and control (louvers). Each strategy uniquely enhances the quality and quantity of natural light within a space while addressing specific challenges such as glare, heat gain, and energy efficiency.

Windows are the primary method of introducing natural light into buildings. Windows not only allow daylight penetration but also provide views to the outside, contributing to occupant well-being (Dahlan and Eissa, 2015). However, it can lead to uneven light distribution, glare, and excessive heat gain. Window requires careful consideration to maximise its benefits while mitigating potential drawbacks.

Light shelves, louvers, and overhangs are designed to address the challenges associated with direct sunlight penetration. Light shelves reflect and redistribute daylight deeper into spaces, promoting even illumination (Costanzo et al., 2017). Louvers, consisting of adjustable slats, offer flexible control over light intake and can be integrated with automated systems for optimal performance (Idchabani et al., 2017). Overhangs act as passive shading devices, reducing heat gain and glare while maintaining exterior views (Yazhari Kermani et al., 2018)

3. Methodology

This study employs simulation through computers to generate data. Simulation studies help understand the behaviour of statistical methods by comparing the 'truth' (typically interest parameters) with the results from the generated data (Khanh Phuong et al., 2024). The simulation study was conducted using Velux Daylight Visualizer software. It offers an interactive and intuitive approach to daylighting in buildings during the schematic design phase (Keshavarzi et al., 2021).

Velux Daylight Visualizer software displays conditions of natural daylighting in generic models regarding illuminance level. The simulation has been evaluated for compliance with the European Standard for Daylight in Building EN17037. Additionally, the software has been validated in accordance with the CIE 171: 2006 test cases to assess the accuracy of lighting computer programs (Velux Group, 2024). Three case studies have been conducted by simulating using four daylighting strategies as presented in Figure 4: (i) Window Base Case, (ii) Light Shelf (LS), (iii) Louvers (LO), and (iv) Overhang (OV).

Data obtained from the Velux Daylight Visualizer provide analysis on illuminance level in false colour format by generating photo-realistic images based on detailed and physically accurate lighting simulations. This includes identifying which daylighting strategy has received the lightest intensity and which has received the least. Based on the data obtained, the Comparison Simulation Daylighting Reading Table (CSDRT) is formulated by comparing the simulation illuminance readings with the recommended readings from three building guidelines: GBI for Interior Version 1.3, MS1525 2019 third revision, and CIBSE Lighting Guide 5: Lighting for Education. This data will be presented in tabular form.

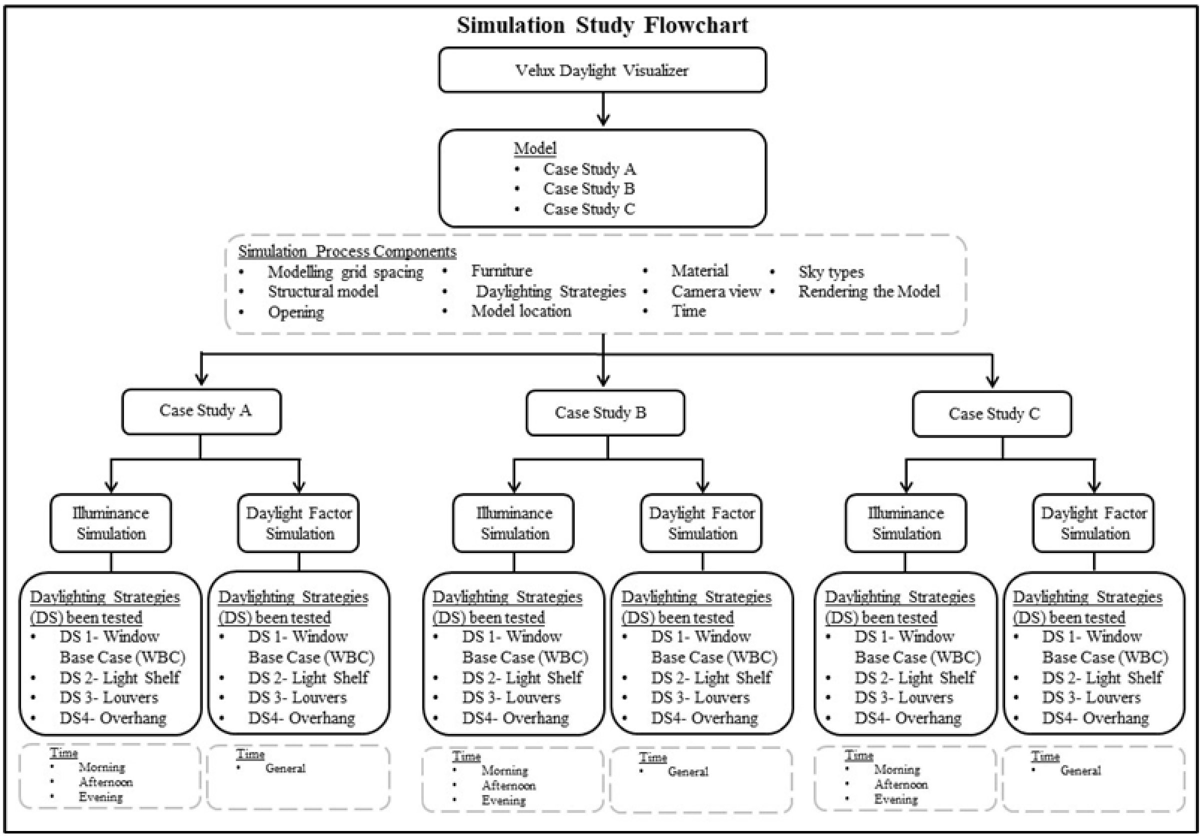

Figure 4: Simulation Study Flowchart

4. Findings and Discussions

This study investigates the appropriate daylighting strategies design for HEIs in Malaysia through simulation. The CSDRT compares simulation illumination results with the standard guidelines. The CSDRT helps determine whether daylighting strategies meet the standard illuminance readings. Comparing simulation studies with standard guidelines significantly enhances the quality and reliability of research findings. Pawel et al. (2023) and Xiao et al. (2022) emphasised that this approach ensures simulation transparency and replicability. Juhee and Hyunju (2020) found that this method improves research outcomes. Crawford (2018) noted that such comparisons ensure consistency and quality in research. Therefore, aligning simulation studies with established guidelines will boost the credibility of the findings and promote best practices across various fields.

Figure 5, Figure 6, and Figure 7 summarise the simulation results of the illuminance readings for the case studies. Each case study simulated four daylighting strategies: a window base case, a light shelf, louvres, and an overhang. The case studies were also simulated in Zone 1, Zone

2, and Zone 3 during the morning, afternoon, and evening. The results are presented in a false colour format, with each colour indicating the status of the illuminance level: blue for Perceptible, green for Acceptable, yellow for Tolerable, and red for Intolerable.

Each case study has its unique challenges. Case Study A has limited windows located on only one side of the studio. Case Study B, however, has many windows on both sides of the studio. Case Study C has a standard number of windows on both sides, but it has an issue with a non-functional window that's obscured by a partition.

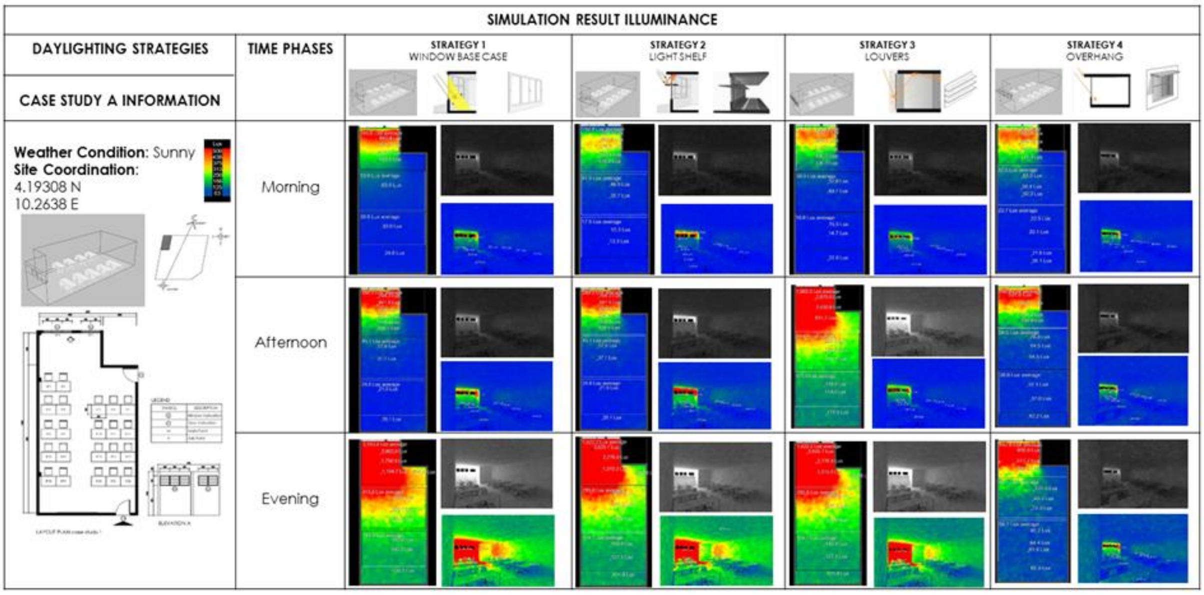

Figure 5: Simulation Result Illuminance Table (Case Study A)

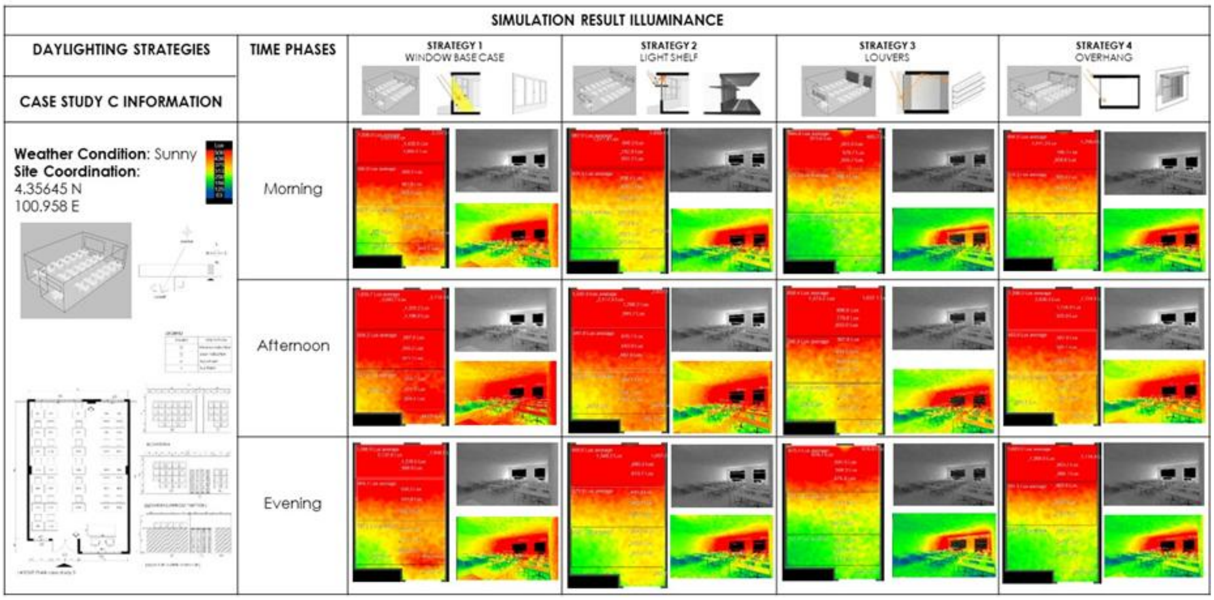

Figure 6: Simulation Result Illuminance Table (Case Study B)

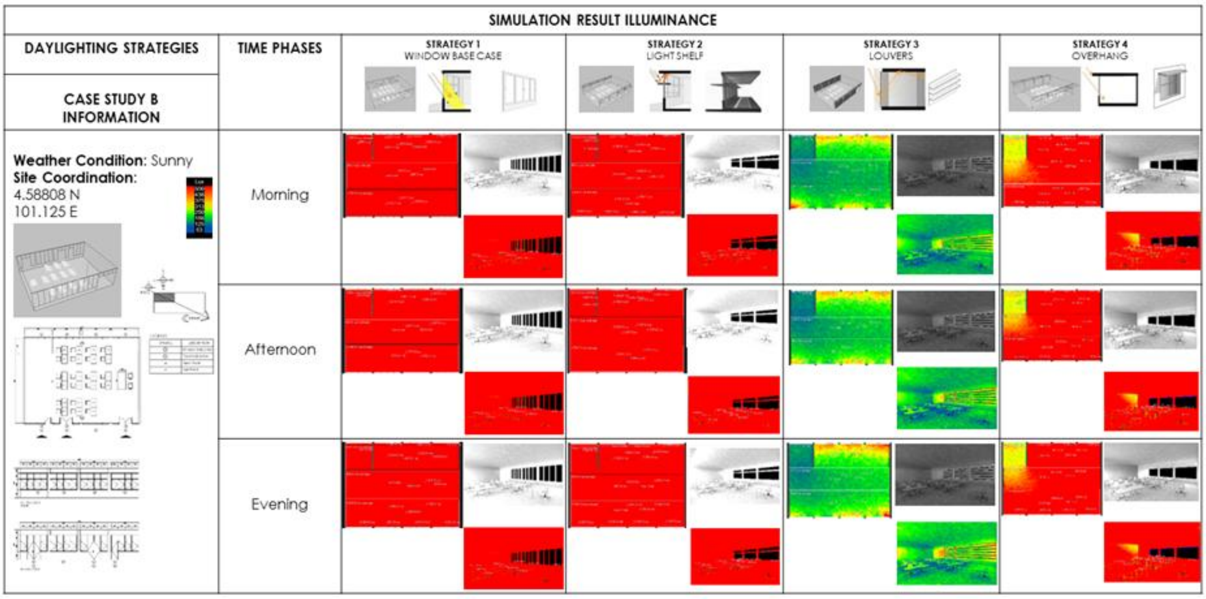

Figure 7: Simulation Result Illuminance Table (Case Study C)

Among the four daylighting strategies tested in Case Study A (refer Figure 5), louvres strategy achieves the maximum illuminance. It receives the highest illuminance reading in the evening among the three phases tested. This is because of only Zone 1 has a westward window. The louver daylighting strategy functions differently in this case study than the control daylighting strategy. This occurs because daylight penetration is reflected off the louvre fin and is subsequently distributed within the case study. Ahmad et al., (2021) and Alsukkar et al., (2022) stress that louvres can effectively reflect daylight penetration and enhance illuminance levels within a building. The illuminance level increases in the afternoon and continues into the evening. The second-highest illuminance is achieved with the window base case strategy in the evening, followed by the light shelf strategy, which also sees its highest illuminance during the evening phase. The overhang strategy records the least illuminance across all three time phases studied. This is evident in Zone 2 and Zone 3 in Case Study A, where the blue colour indicator is almost always present, demonstrating that the overhang strategy has reduced the illuminance level. Stevanovic, (2022) confirms that the overhang daylighting strategy can effectively control the amount of sunlight entering interior spaces, thus reducing daylight penetration into a building.

Figure 6 shows that the window base case and light shelf strategy provide the highest illuminance among the four daylighting strategies in Case Study B. This case study demonstrates abundant daylight penetration in Zone 1 (southeast-facing windows) and Zone 3 (northwest-facing windows). These zones receive the highest illuminance in all three time phases, as indicated by the red marker in the table, except when using the louver daylighting strategy. In this case study, the light shelf and overhang strategies are ineffective as shading devices, as 30% of the studio's total window area consists of large windows, allowing significant daylight penetration. However, the louver strategy performs well throughout the day, as shown by the green indicator signifying acceptable illuminance levels. The overhang strategy achieves the second-highest illuminance across all time phases, while the louver strategy receives less illuminance than other strategies but effectively balances light to achieve acceptable levels. He et al. (2021) emphasised that the louver daylighting strategy can effectively reduce excessive daylight penetration while optimising visual comfort and energy use. Al-shafaey et al. (2020) corroborated this, noting that integrating fixed horizontal louvers can improve daylighting performance, optimise visual comfort, and contribute to energy reduction.

Figure 7 shows that the Window base case strategy achieves the highest illuminance in Case Study C among the four daylighting strategies. The afternoon phase received the most illuminance in Zone 1, attributable to the functional southeast-facing window allowing daylight penetration in both morning and afternoon. However, Zone 3 received less daylight in the evening due to a non-functional northwest-facing window covered by a partition. The light shelf daylighting strategy ranks second in illuminance across all time phases, effectively distributing light during afternoon and evening. Though daylight penetration decreased slightly compared to the window base case, it still reached Zones 2 and 3. Light shelves are an effective strategy, distributing daylight deeper into spaces, reducing energy consumption, and enhancing visual comfort (Ambadi and Raphael, 2023; Sern et al., 2022). The overhang strategy received the third-highest illuminance, outperforming the louver strategy. However, acting as a shading device, the louvre strategy is superior to the overhang as it serves as a control strategy. Khidmat et al. (2022) confirmed that the louver strategy is more effective than the overhang in optimising daylighting and energy efficiency. He et al. (2021) further supported this, noting the louver strategy's dual function as a control strategy and shading device. This superiority is evident from comprehensive energy consumption data, highlighting improved energy efficiency.

Tables 2, 3 and 4 present a comprehensive summary of the illuminance readings obtained during the simulation study from Figures 5, 6 and 7. The data has been averaged by zone to evaluate the effectiveness of various daylighting strategies in providing sufficient daylight in accordance with recommended standard guidelines.

All case studies successfully met the standard illuminance reading set by the GBI Interior V1.3 guideline, which recommends illuminance levels below 2000 lux (Green Building Index, 2023). This standard was achieved across all zones and time phases. However, when assessed against the CIBSE Light Guide 5: Lighting for Education, which recommends a higher standard of 750 lux, none of the case studies met the requirement after simulating various daylighting strategies over three phases.

The MS1525 2019 guidelines yielded mixed results. Case Study A achieved standard illuminance in only one zone during the evening, with a reading of 314 lux using a window base case strategy. Case Study B failed to meet the standard in any zone. Notably, Case Study C demonstrated the most promising results, with all daylighting strategies meeting standard illuminance in specific zones and times:

i. Window base case strategy: Zone 3 met standards in the morning (323 lux) and evening (325 lux)
ii. Light shelf strategy: Zone 2 in the evening (379 lux), Zone 3 in the afternoon (358 lux)
iii. Louvers strategy: Zone 2 in the morning (324 lux), Zone 1 and 2 in the afternoon (358 lux and 397 lux, respectively)
iv. Overhang strategy: Met standards across all time phases (Zone 2: 379 lux in the morning, 381 lux in the evening; Zone 3: 322 lux in the afternoon)

International Journal of Business and Technology Management
e-ISSN: 2682-7646 | Vol. 7, No. 5, 491-506, 2025
https://asianscholarsnetwork.com/asnet-journals
SPECIAL ISSUE: International Virtual Go Green (iVGG) 2025

Table 2: Comparison Simulation Daylighting Reading Table (CSDRT) for Illuminance (Case Study A)

Case Study A						
Daylighting Strategy	Window Base Case (WBC)			Guideline		
Time/ Zone	Zone 1	Zone 2	Zone 3	GBI Interior V1.3	MS1525: 2019	CIBSE Lighting Guide 5: Lighting for Education
Morning	246 lux	53 lux	28 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	280 lux	45 lux	25 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	3154 lux	314 lux	150 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Light Shelf (LS)					
Morning	155 lux	41 lux	18 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	280 lux	45 lux	25 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1522 lux	286 lux	135 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Louvers (LO)					
Morning	185 lux	40 lux	19 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1982 lux	247 lux	122 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1522 lux	286 lux	135 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Overhang (OV)					
Morning	230 lux	52.6 lux	23.7 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	249 lux	55 lux	39 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	448 lux	100 lux	59 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable

Table 3: Comparison Simulation Daylighting Reading Table (CSDRT) for Illuminance (Case Study B)

Case Study B						
Daylighting Strategy	Window Base Case (WBC)			Guideline		
Time/ Zone	Zone 1	Zone 2	Zone 3	GBI Interior V1.3	MS1525: 2019	CIBSE Lighting Guide 5: Lighting for Education
Morning	1290 lux	800 lux	1234 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1404 lux	855 lux	1340 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1412 lux	894 lux	1359 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Light Shelf (LS)					
Morning	154 lux	965 lux	1416 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1812 lux	1111 lux	1710 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1557 lux	976 lux	1439 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Louvers (LO)					
Morning	195 lux	133 lux	179 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	196 lux	139 lux	184 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	217 lux	148 lux	193 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Overhang (OV)					
Morning	727 lux	494 lux	690 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	775 lux	526 lux	721 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	769 lux	521 lux	708 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable

Table 4: Comparison Simulation Daylighting Reading Table (CSDRT) for Illuminance Case Study C

Case Study C						
Daylighting Strategy	Window Base Case (WBC)			Guideline		
Time/ Zone	Zone 1	Zone 2	Zone 3	GBI Interior V1.3	MS1525: 2019	CIBSE Lighting Guide 5: Lighting for Education
Morning	1506 lux	505 lux	323 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1856 lux	606 lux	441 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1497 lux	494 lux	325 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Light Shelf (LS)			Guideline		
Morning	988 lux	405 lux	268 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1331 lux	541 lux	358 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	949 lux	379 lux	262 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Louvers (LO)			Guideline		
Morning	667 lux	324 lux	221 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	358 lux	397 lux	298 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: acceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	625 lux	284 lux	218 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Daylighting Strategy	Overhang (OV)			Guideline		
Morning	994 lux	379 lux	239 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Afternoon	1298 lux	483 lux	322 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: acceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable
Evening	1003 lux	381 lux	238 lux	Z1: acceptable Z2: acceptable Z3: acceptable	Z1: unacceptable Z2: acceptable Z3: unacceptable	Z1: unacceptable Z2: unacceptable Z3: unacceptable

The CSDRT revealed that meeting all three guidelines simultaneously across every zone and time phase for all daylighting strategies is impractical. However, it is feasible to satisfy two guidelines, which can help determine the most effective daylighting strategy for specific zones. Furthermore, the simulation results suggest that the medium-sized total window in Case Study C's existing conditions proves more efficient in achieving significant illuminance than the smaller windows in Case Study A and larger ones in Case Study B.

5. Conclusion

This study evaluates the effectiveness of various daylighting strategies in design studios of HEIs in Malaysia through comprehensive simulations and comparative analysis against established guidelines. The CSDRT revealed varying levels of effectiveness across different strategies, case studies, and time phases. Key findings include the high effectiveness of louvers in Case Study A, promising results for the window base case strategy in Case Studies B and C, and varying performance of light shelves and overhangs. While all case studies met the Green Building Index (GBI) guideline, none fully met the Chartered Institution of Building Services Engineers (CIBSE) standards, with certain strategies and zones meeting the MS1525: 2019 standard.

The research underscores the importance of aligning simulation studies with established guidelines for optimising daylighting and energy efficiency in educational buildings. However, limitations such as limited sample size and lack of consideration for seasonal variations were noted. Future studies could expand the sample size, conduct year-long simulations, incorporate post-occupancy evaluations, and integrate energy consumption data to address these. By addressing these aspects. Future research can provide more robust and applicable insights for optimising daylighting in educational spaces, contributing to both energy efficiency and improved learning environments in HEIs.

Acknowledgement
This research was not funded by any grant. We would like to express our sincere gratitude to the committee of the International Virtual Go Green (iVGG) 2025 for providing a platform that enables researchers to share knowledge and foster networking. Additionally, special thanks are extended to the Asian Scholars Network for publishing this article. Lastly, I would like to acknowledge the use of artificial intelligence tools, specifically ChatGPT by OpenAI and Notion AI, to assist in improving this manuscript's clarity, structure, and language. These tools were used to support the refinement of academic expression and formatting.

Conflict of Interest Statement
The authors declare that there is no conflict of interest regarding the publication of this research.

References

Ahmad, E., Yuehong, S., M. Alaa, M., & Omar, O. E. (2021). A novel automated louver with parametrically-angled reflective slats; design evaluation for better practicality and daylighting uniformity. Journal of Building Engineering, 42. https://doi.org/10.1016/j.jobe.2021.102438

Al-shafaey, N., Abdelkader, M., & Sabry, H. (2020). Double-Skin Facades in Healing Environments: An Approach for Enhancing Daylighting Performance In South-Oriented Patient Rooms in Cairo, Egypt. Engineering Research Journal, 165(March), 96–113. https://doi.org/10.21608/ERJ.2020.131829

Alsukkar, M., Hu, M., Eltaweel, A., & Su, Y. (2022). Daylighting performance improvements using of split louver with parametrically incremental slat angle control. Energy and Buildings, 274, 112444. https://doi.org/10.1016/j.enbuild.2022.112444

Ambadi, A. P., & Raphael, B. (2023). Experimental investigation on thermal performance of an actively cooled light shelf. Solar Energy, 263(March), 111932. https://doi.org/10.1016/j.solener.2023.111932

CIBSE. (1999). Daylighting and window design Lighting Guide LG10: 1991 (J. Wilson (Ed.)). Chartered Institution of Building Services Engineers. https://doi.org/278104

Cimiano-Prados, M., Pedreño-Rojas, M. A., Fořt, J., & Morales-Conde, M. J. (2023). Sustainable Retrofitting Criteria in Heritage Buildings: Case Study in Seville (Spain). Buildings, 13(7). https://doi.org/10.3390/buildings13071635

Costanzo, V., Evola, G., & Marletta, L. (2017). A Review of Daylighting Strategies in Schools: State of the Art and Expected Future Trends. Buildings, 7(2), 41. https://doi.org/10.3390/buildings7020041

Crawford, S. B. (2018). ASPiH standards for simulation-based education : process of consultation , design and implementation. BMJ Simul Technol Enhanc Learn, 4(3), 103–104. https://doi.org/10.1136/bmjstel-2018-000323

Dahlan, A. S., & Eissa, M. A. (2015). The Impact of Day Lighting in Classrooms on Students ' Performance. 6, 7–9.

Fet, A. M., & Michelsen, O. (2023). Environmental management systems. Business Transitions: A Path to Sustainability: The CapSEM Model, 67–75. https://doi.org/10.1007/978-3-031-22245-0_7

Ghafoori, E., & Motavalli, M. (2016). A retrofit theory to prevent fatigue crack initiation in aging riveted bridges using carbon fiber-reinforced polymer materials. Polymers, 8(8). https://doi.org/10.3390/polym8080308

Green Building Index. (2023). GBI Assessment Crieria forj Interiors. In GBI (Ed.), GBI Assessment Criteria For Non-Residential New Construction (NRNC) (Version 1., Issue April). GBI. www.greenbuildingindex.org %7C info@greenbuildingindex.org

He, Y., Lin, E. S., Tan, C. L., Yu, Z., Tan, P. Y., & Wong, N. H. (2021). Model development of Roof Thermal Transfer Value (RTTV) for green roof in tropical area: A case study in Singapore. Building and Environment, 203(June), 108101. https://doi.org/10.1016/j.buildenv.2021.108101

Hiscocks, P. D. (2011). Measuring Light. https://www.ee.ryerson.ca/~phiscock/astronomy/light-pollution/photometry.pdf

Idchabani, R., El Ganaoui, M., & Sick, F. (2017). Analysis of exterior shading by overhangs and fins in hot climate. Energy Procedia, 139, 379–384. https://doi.org/10.1016/j.egypro.2017.11.225

Jain, V., & Jain, N. (2016). Analysis of Maximum Demand of Educational Buildings and its Impact on Electricity Bills. International Research Journal of Engineering and Technology (IRJET), 3(1). https://www.irjet.net/archives/V3/i1/IRJET-V3I1145.pdf

Juhee, H., & Hyunju, P. (2020). Comparison of the Effects of Standardised Patient-based Simulation Education and Clinical Practice Education for Preoperative Nursing Care for High-risk Pregnant Women. Medico-Legal Update, 20(1), 1900–1906. https://doi.org/10.37506/v20/i1/2020/mlu/194581

Kadir, Aslila Abd, Ismail, L. H., Kasim, N., & Kaamin, M. (2016). Potential Of Light Pipes System In Malaysian Climate. IOP Conference Series: Materials Science and Engineering, 160, 012071. https://doi.org/10.1088/1757-899X/160/1/012071

Keshavarzi, M., Caldas, L., & Santos, L. (2021). RadVR: A 6DOF Virtual Reality Daylighting Analysis Tool. Automation in Construction, 125(0). https://doi.org/10.1016/j.autcon.2021.103623

Khanh Phuong, N. T., Chan, Y.-C., Do, C. T., Tuan, N. A., & Rinchumphu, D. (2024). A simulation-based workflow to calculate overall thermal transfer value when implementing daylighting-oriented shading control. Journal of Building Engineering, 84, 108616. https://doi.org/10.1016/j.jobe.2024.108616

Khidmat, Rendy Perdana, Fukuda, H., Paramita, B., Koerniawan, M. D., & Kustiani, K. (2022).

The optimisation of louvers shading devices and room orientation under three different sky conditions. Journal of Daylighting, 9(2), 137–149. https://doi.org/10.15627/jd.2022.11

La Forest, J.-P. (2014). Talking About Light, Luminous Flux, Luminous Intensity, Illuminance, Luminance, Brightness, Exposure, Exposure Value, And Light Stops – Photography Word Of The Week 2. Studio JPIC. http://www.studiojpic.com/luminance-brightness-photography-word-of-the-week-2/

Li, D. H. W, Lam, T. N. T., & Wu, T. K. K. (2014). Estimation of average daylight factor under obstructed CIE Standard General Skies. Lighting Research and Technology, 46, 187–197. https://doi.org/10.1177/1477153512453578

Li, Danny H.W., Lau, C. C. S., & Lam, J. C. (2005). Predicting daylight illuminance on inclined surfaces using sky luminance data. Energy, 30, 1649–1665. https://doi.org/10.1016/j.energy.2004.04.038

Malaysian Standard. (2019). Malaysian Standard (S. Berhad (Ed.); Third revi). Department of Standards Malaysia.

Ministry of Finance Malaysia. (2016). The 2016 Budget (Ministry of Finance Malaysia (Ed.)). Percetakan Nasional Malaysia Berhad. http://www.treasury.gov.my/pdf/budget/speech/bs16.pdf

Ministry of Finance Malaysia. (2017). 2017 Budget Report (Ministry of Finance Malaysia (Ed.)). Ministry of Finance Malaysia.

Nabil, A., & Mardaljevic, J. (2005). Useful daylight illuminances: a new paradigm for assessing daylight in building. Lighting Research and Technology, 37(1), 41–59. https://doi.org/10.1191/1365782805li128oa

Pawel, S., Kook, L., & Reeve, K. (2023). Pitfalls and Potentials in Simulation Studies Questionable research practices in comparative simulation studies allow for spurious claims of superiority of any method. Biometrical Journal, 66(1). https://doi.org/10.1002/bimj.202200091

Randjelovic, D., Vasov, M., Ignjatovic, M., Stojiljkovic, M., & Bogdanovic, V. (2021). Investigation of a passive design approach for a building facility: a case study. Energy Sources, Part A: Recovery, Utilisation and Environmental Effects, 00(00), 1–19. https://doi.org/10.1080/15567036.2021.1938761

Sai, S. G., Surya, P., & Gunalan, K. (2018). Smart Institutions Using Energy Management System. 2018 4th International Conference on Electrical Energy Systems (ICEES), 459–464. https://doi.org/10.1109/ICEES.2018.8442371

Sern, C. H. Y., Liou, L. T. K., & Fadzil, S. F. S. (2022). Daylighting Performance of Integrated Light Shelf with Horizontal Light Pipe System for Deep Plan High-Rise Office in Tropical Climate. Journal of Daylighting, 9(1), 83–96. https://doi.org/10.15627/jd.2022.6

Stevanovic, S. (2022). Overhang Design Methods. Springer Nature Singapore. https://doi.org/10.1007/978-981-19-3012-6

Tawfik, T., M. Khodeir, L., & Fathy, F. (2023). Identifying Retrofit Technology to Improve Building Energy Performance: A Review. Engineering Research Journal, 178(0), 174–200. https://doi.org/10.21608/erj.2023.302133

The Economic Planning Unit Prime Minister's Department Malaysia. (2015). 11th Malaysia Plan. https://www.epu.gov.my/en/economic-developments/development-plans/rmk/previous-plans

Velux Group. (2024). Daylight Visualizer. https://www.velux.com/what-we-do/digital-tools/daylight-visualizer

Winterbottom, M., & Wilkins, A. (2009). Lighting and discomfort in the classroom. Journal of

Environmental Psychology, 29(1), 63–75. https://doi.org/10.1016/j.jenvp.2008.11.007

Xiao, Y. L., Shiyan, Y., Yi, G., & Baoyan, L. (2022). Comparative analysis of the reporting guidelines on simulated acupuncture in randomised controlled trials of acupuncture. Acupuncture Research, 47(11), 103. https://doi.org/https://doi.org/10.13702/j.1000-0607.20210921

Yazhari Kermani, A., Nasrollahi, F., & Mahdavinejad, M. (2018). Investigation of the relationship between depth of overhang and amount of daylight indicators in office buildings of Kerman city. Environmental Health Engineering and Management, 5(3), 129–136. https://doi.org/10.15171/EHEM.2018.18