CHAPTER II

LITERATURE REVIEW

To establish and fortify the groundwork of this research, a thorough analysis of scientific articles sourced from reputable journals, conferences, and literature has been conducted and synthesized. The findings of this analysis are detailed in Table 2.1 below.

2.1 References List

For enhancement, several literature reviews are presented that discuss lighting systems designs and evaluations in various buildings, double skin facade impact as well as Net Zero Building principles, shown in Table 2.1 below.

Table 2.1 References List

Researcher (Year)	Research Purpose	Research Method	Result
Siti Zulaiha Ahmad Jasmi, Mohd Fairullazi Ayob, Srazali Aripin, and Faizul Azli Mohd Rahim (2019) [28]	Present a finding upon an investigation of energy efficiency on the lighting system in a university library.	Semi-structured face-to-face interviews were used by four respondents in charge of the lighting system for the library.	The lighting system used in the library is not energy efficient, causing high energy consumption. Thus, guidelines are proposed such as replacing fluorescent lamps with LED and giving awareness to occupants to optimize energy consumption.
Usaha Situmeang, David Setiawan, and Monice (2020) [29]	Evaluating the existing lighting system of the street within the University of Lancang Kuning.	Location selection into 4 parts, data collection using a lux meter (illuminance), and data processing for the lighting system using schemes and figures to help visualize the condition of the system.	The lighting system in the main road of Lancang Kuning University is not optimal with dark areas percentages of 48% and assuming repairment and/or reactivation, the dark area will be less than 30%. The recommendation is given by using a 500 W bulb or SON-T 250 W.

Mustafa Serhan Unluturk and Zehra Tugce Kazanasmaz (2024) [30]	Analyzing studies focuses on daylight performance on double skin facades.	Recent studies are collected and depicted in tabulated form along with graphics, methodologies, and daylight parameters findings.	The results of the review indicate that daylight parameters are a vital aspect to be considered by architects and designers to let optimum penetration of daylight, such as using double skin facade.
Vivianie Fortuna, Widyarko Widyarko, and Joice Sandra Sari (2022) [31]	Evaluating the lighting system in Medan's Buddhist Temple	Using correlational research method between illuminance measurement using lux meter (morning, noon, and late afternoon) as well as occupants' perception of visual comfort from survey/questionnaire. The collected data will be analyzed and compared using theories and SNI.	For the activities area, the illumination level is far below the requirements for visual comfort standards of 100 Lux except at Zone III in the East Mountain Temple (around 20-60 Lux). However, occupants are comfortable with the condition.
Meltem Erign (2019) [32]	Examine the effect of double skin facades of an office to daylight performance.	Designing of single skin facade and double skin facade using Relux in the same location and dimension for daylight performance comparison.	The effect of illuminance values for double skin facades decreases by 25-30% compared to single skin, however, it slightly raises the illuminance near the rear wall to support uniformity. It also provides 18 different setups on double skin facades based on several variables which shows that selection on very low or very high transmitted glazing type must be avoided, depth of cavity effect changes by changing length as well as layer orientation impact more for lower valued transmitted glazing materials.
Ahmet Afşin Küçük and Özlem Sümengen (2022) [33]	Serve as a basis for energy efficiency and lighting design based on comfort and cost in Turkey educational buildings.	Choosing location, collecting illuminance and area data as well as power consumption for lighting of types of lamps presented. The data is compared with BEP-TR, Turkey's standard for	Based on the collected and processed data, calculation methods regarding comfort level and cost considerations are given in tables as recommendations to improve the condition (based on initial investment, assembly, dismantling, and repair costs).

		energy efficiency on buildings.	In this case, the existing luminaires are not sufficient to provide a suitable illuminance level. Thus, using an improved proposal by changing the current lighting system with LED, a 62.356% reduction in annual energy consumption is obtained according to BEP-TR.
Aristakus Edi Manubawa, L.M.F Purwanto, and Antonius Ardiyanto (2020) [34]	Examine the performance of double skin facade in Henricus Constant building of Soegijapranata Catholic University along with the level of natural lighting in buildings.	Descriptive quantitative by assessing the level of the illuminance of natural lighting using a lux meter at 26 points and model simulations using Sketchup and Dialux.	Results show that the secondary skins create shade in the building's interior, however causing natural lighting to be 30 lux, far less than 350 lux for classroom standard (SNI).
Shaosen Wang, Jinjin Huang, and Xiaoqing Hong (2019) [35]	Present design strategies and energy performance of a net zero energy house which was built for Solar Decathlon China 2018 competition.	The design strategies considered architectural concepts, materials, and passive and active strategies along with energy simulation using Energyplus.	Using materials (wood, straw insulation, phase change material, bamboo, and low-e triple pane hollow glass), passive strategies (natural ventilation and lighting, thermal buffer as well as dynamic shading by skylight that can be opened/closed, etc.), and active strategies (BIPV, HVAC, and control system) shows annual consumption by 12,544.9 kWh in which 75.6% by PV.
Ghina Soraya, Popi Puspitasari, Khotijah Lahji (2022) [36]	Determine the height of the curtain so students can adjust the natural lighting and reduce artificial lighting usage.	Measuring illuminance by arranging each worktable 60 cm apart and recording the result within conditioned curtain height (30, 60, 90, and 120 cm).	The curtain height of 30 cm does not provide comfortable natural lighting whereas by 60-120 cm, the illuminance reaches the requirement of 750 lux around the window at 09.00-12.00 WIT. However, it causes glare with openings of 120 cm at more than 12.00-14.00 WIT.
Anita Białek, Luiza Dębska, and Natalia	Assess current thermal sensations and light intensity	Measure and collect data on illuminance by using a Testo meter. Then	The result of 430 lux has met the standard in which answers from respondents show that

Krawczyk (2022) [37]	in Kielce University at various classrooms.	descriptive data by questionnaire.	higher lighting levels cause higher productivity.
Khalid Abdul Mannan (2020) [38]	Examine the lighting condition of the fashion workshop room at the Jakarta Creative Hub which is compared to SNI.	Data collection using a lux meter three times a day from 10:00 until 17:00 at 9 points which then use Dialux to suggest better lighting system.	The results show a value of 40-380 lux in areas far from windows, below 500-1000 lux for workspaces according to SNI. Areas near the windows that produce 1500-3500 lux can be implemented with shading/curtains while areas with lower natural lighting need artificial light (proposed with 42 lamps of 2037 lumens each to produce evenly lit 596 lux in Dialux).
N. Kutlar and M.P. Mengüç (2019) [39]	Assessing current condition of daylight design and proposing solution for better energy efficient design on lighting.	Ozygein University's new signature building, AB4, is being studied at its design phase and using DesignBuilder and Revit to make the proposed design.	Results show that Option 5, which allows more daylight to penetrate offices at 117 and 120 levels, showing high value of sDA although 6% more ASE occurred, caused glare which can be anticipated using blind curtains.

Overall, the given literature reviews discuss about the designs and assessment of illuminance in library, universities, and temples along with elaboration for double skin facade impact, Net Zero Building principles, and. In correlation with this research, the novelty lies on the illuminance and light power density measurement based on the requirement for Greenship Net Zero and Healthy Building for buildings that integrated double skin facade which are the C and D tower in UMN.

2.2 Fundamental Theories

2.2.1 Lighting

Light is a form of energy (electromagnetic radiation) that can be seen by human eyes within certain range of wavelength (380 nm to 750 nm) with the speed that reaches 3.10^8 m/s [40]. This energy form (mostly from the sun) is important for human life since it is the main source of photosynthesis of plants [41], which will be the initial stage of the food chain and ecosystem. It is also important for maintaining the Earth's temperature through its radiation which will form the weather in the atmosphere [42]. The most important role is to provide visualization for the inhabitants of Earth, such as humans for their activities. Generally, lighting can be based on natural sources (sun, fire, stars, and even animals) and artificial sources (lamps) [42], [43]. Not everything can radiate light but for sure that light can be reflected and/or absorbed.

The use of lighting is essential for human activities. In this case, daylighting becomes the concept that is needed which will be followed and supported by an artificial lighting system to support the working performance. In this era, humans spend most of their time indoors, so it is inevitable to use daylighting as efficiently and comfortably as possible to give the most positive effect to occupants (such as minimizing circadian rhythms disruption and health problems) and supporting energy efficiency measures. Thus, good design for buildings that relieve effective natural lighting systems (completed with artificial lighting systems where needed) is important. Ensure the design of the building gives the best outputs in the lighting system, Measurements can be made to check and compare to a standard to know how the building works in giving visualization to occupants.

Several terms are used to describe and measure light. In physics, photometry to be precise, these include luminous flux (lumen), luminous intensity (candela or lumen/Steradian), illuminance (lux or lumen/m^2), luminance (candela/m^2), luminous energy (lm. s), and many more [44], [45]. The table 2.2 can better describe the unit of photometry.

Table 2.2 Photometric Units of Measurement [44], [45]

Quantity	Symbol	Unit (MKS)
Luminous energy	Q_v	lumen s
Luminous energy density	w_v	lumen s m^{-3}
Luminous flux	$\Phi_v = \frac{dQ_v}{dt}$	lumen
Illuminance (luminous flux) areal density	$E_v = \frac{d\Phi_v}{dA}$	lux or lumen m^{-2}
Luminous exitance	$M_v = \frac{d\Phi_v}{dA}$	lumen m^{-2}
Luminous intensity	$I_v = \frac{d\Phi_v}{d\omega}$	candela or cd or lumen sr^{-2}
Luminance	$I_v = \frac{d^2\Phi_v}{dA\, d\omega\, cos\theta}$	nit or cd m^{-2}
Luminous efficacy	$\frac{\Phi_v}{\Phi_{e-total}}$	lumen W^{-1}

In Indonesia, the comfort level of rooms in a building, including lighting, can be determined based on a standard called *Standar Nasional Indonesia* (SNI). This standard serves as the threshold that must be met by buildings starting from planning until developing to support the environment sustainability. In the case of lighting measurement, the SNI used are SNI 6197-2020 (Energy Conservation in Lighting System), SNI 7062-2019 (Lighting Intensity Measurement for Working Environment) as well as SNI 03-2396-2001 (Natural Lighting Designing Procedure in Buildings).

This research places significant emphasis on utilizing illuminance and light power density as crucial factors in assessing visual comfort. Data collection and measurement are employed to compare these metrics against the standards outlined in SNI 6197-2020. The resulting values, particularly tailored for office and educational environments, are presented in Table 2.3 and 2.4 below for reference.

Table 2.3 $E_{average}$ According to Type of Facilities and Rooms [22]

Room Function	**Minimum Average Lighting ($E_{average}$ in lux)**	**Room Function**	**Minimum Average Lighting ($E_{average}$ in lux)**
Office		**Education Institution**	
Receptionist Room	300	Classroom	350
Director Room	350	Library	350
Working Room	350	Laboratory	500
Computer Room	150	Computer Laboratory	500
Meeting Room	300	Language Laboratory	300
Drawing Room	750	Lecturer Room	300
Archive Storage	150	Exercise Room	300
Active Archive Storage	350	Drawing Room	750
Emergency Exit Room	100	Auditorium	300
Parking Lot	100	Lobby	100
		Stairs	100
		Canteen	200

Table 2.4 Maximum Light Power Density (Simplified Method for Building) [22]

Room Type	**Maximum Light Power Density (Watt/m^2)**
Office	
All rooms except parking lot, garages, stairs, and corridor	7.53
Working room ≤ 76.2 m^2, class, conference room, meeting room, training room, storage, and resting room	7.53
Working room ≥76.2 m^2 and toilet	7.53
Stairs, corridor, and parking garage	7.53
Education Institution	
All rooms except parking lot, garages, stairs, and corridor	7.53
Class, office, conference room, meeting room, library, storage, and resting room	7.53
Exercise room and cafetaria	7.53
Toilet	7.53
Parking garage	1.4

Aside from this research, several other aspects must be known such as the type of lamps to support the lighting system (within the energy efficiency scope). The types of lamps are halogen lamps, low-pressure lamps (such as fluorescent, mercury, and sodium lamps), high-pressure lamps (sodium and metalhilde lamps) as well as light emitting diode (LED) lamps [22]. The choice of lamp type should prioritize efficacy, ensuring optimal performance to support occupants' visual comfort within buildings.

2.2.2 Sick Building Syndrome

The World Health Organization specified the term "sick-building syndrome" to describe the symptoms encountered by building occupants. It is defined as a non-specific group of medical symptoms with unclear cause but with a possible relation to the indoor environment and a length of stay in a building [46], [47], [48], [49], [50]. It is associated with the environment (the presence of air conditioning, lighting, temperature, humidity, and dust), psychosocial, and personal factors. SBS symptoms usually are fatigue, heavy/lethargic feeling, headache, nausea, difficulty in concentration, itching, burning, hoarseness, dry throat, cough, dry or flushed skin, itching on the scalp of ears, or dry nutritional status.

Lighting, as mentioned, becomes one of the factors that contribute to the SBS of occupants. A study by [51] shows that the lighting in the Central Post Office in Bandung affects the appearance of SBS with a p-value of 0.002 and 0.015 for 1st and 2nd floor respectively which is less than 0.05, with symptoms such as eye fatigue and decrease of work performance. Another study by [52] shows a significant relationship between SBS symptoms with lighting in a hospital for a p-value of 0.001 and POR 40,000 CI = 95%, meaning that the risk is 40 times when inappropriate lighting is presented in the building. Therefore, this shows how important lighting is in a building for an occupant's health.

2.2.3 Net Zero Healthy

WorldGBC's Advancing Net Zero is a program that aims the decarbonization of the global scale by 2050 [6]. One of the sub-programs is called Net Zero Healthy in which a building is measured according to the design by considering its passive system (natural ventilation and lighting), active system (air conditioning, lighting, and other systems) as well as the environment (healthy and comfortable) that also includes renewable energy installation and usage [6]. This program has been executed in Indonesia in is launched and done by Green Building Council Indonesia to meet EUI, comfort, health, and renewable energy usage standards as well as using building automation systems for data purposes which also include carbon reduction. About lighting, the Net Zero Healthy program values good design for lighting especially when natural (dominantly) and artificial lighting are well carried out in the building part which can be appraised by its illuminance and light power density and comparing it to the standard, SNI 6197-2020 according to the Greenship criteria for visual comfort.

2.2.4 Environment Meter

Environment meter is a tool with 4 features, measuring relative humidity, temperature, noise, and light (illuminance) [53], [54]. In addition, this measuring instrument can be used as a calibration tool against other measuring instruments [54]. Several studies have used this tool to measure acoustic level, thermal comfort, humidity, and/or lighting in specific places such as laboratories, markets, and even airports [55], [56], [57]. In this research the environment meters used as shown in Figure 2.1 is DT-8820 with a size of 251mm x 63.8mm x 40 mm with a weight of 250g.

Figure 2.1 Environment Meter

2.2.5 Universitas Multimedia Nusantara (UMN)

Universitas Multimedia Nusantara (UMN) is a university in Gading Serpong that consists of several buildings which are the A, B, C, and D Tower. It is renowned for its commitment to green building principles, prominently highlighted in its New Media Tower (C) and PK Ojong Tower (D). This university boasts a plethora of amenities including classrooms, cafeterias, basements, laboratories, green spaces, libraries, and social areas. The architectural layout of UMN prioritizes longitudinal orientation from east to west, strategically situating rooms along the north and south axes to mitigate direct sunlight exposure. This design approach ensures that classrooms and laboratories receive ample daylight without excessive glare, fostering a more conducive learning and working environment. Moreover, UMN's buildings are extensively engineered with energy-efficient features such as natural ventilation and lighting systems, double-skin facades, and complementary facilities that align seamlessly with sustainable practices.

Double Skin facade (DSF) in general, is a three-layer design consisting of internal skin, intermediate area, and external skin that covers buildings [58]. The uniqueness of this design signifies the transparency with which daylight penetrates with a glare-free characteristic. It also boosts the aesthetic value of design. The benefits of DSF include environmental benefits (reduced energy consumption, ventilation, airflow regulation, thermal comfort enhancement, control of daylighting and glare, noise reduction) and economic benefits (decreasing cost in long term perspectives due to energy efficiency aspect and sustainability) [58], [59]. However, the disadvantages of DSF including investment cost and the risk of overheating on sunny days (needing to install a cooling system) must also not be overlooked [58]. The key components of a Double Skin Facade (DSF) primarily include the cavity gap, intermediate space, outer and inner glass layers, along with shading devices [59], [60]. In the case of UMN, the inner skin is made from m-system panels, concrete and plaster with 13 cm thickness for walls and clear glass up to 80% of the wall with 8 mm thickness. While the outer skin consists of hollow aluminum frames that are integrated by perforated aluminum plates. The intermediate spaces have various sizes, yet, can be accessed as a pathway. Notably, UMN's C and D towers DSF (illustrated in Figure 2.2) have effectively incorporated these elements, resulting in enhanced natural ventilation, acoustic insulation, optimized daylight utilization, reduced glare, lowered heat demand, and improved energy efficiency.

a) b)

Figure 2.2 Double Skin facade on UMN'S Building