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Field Assessment for Initial Preparation of Net Zero Building Certification for The Universitas Multimedia Nusantara (UMN) Building: A Case Study On Visual Comfort in C and D Tower

Nicholas Pranata, Muhammad Salehuddin
Engineering Physics, Universitas Multimedia Nusantara, Tangerang, Indonesia
nicholas.pranata@student.umn.ac.id, muh.salehuddin@umn.ac.id

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***Abstract*— Ensuring optimal physical comfort, the need for a comprehensive evaluation of the performance of building systems was established. This investigation endeavors to meticulously scrutinize illuminance and light power density metrics across distinct temporal segments (morning, noon, afternoon, and night), as well as the dynamism of daylighting and artificial lighting presence within Tower C and D of Universitas Multimedia Nusantara (UMN). Noteworthy for their incorporation of double skin facades, these edifices serve as focal points of inquiry. The empirical findings reveal that illuminance levels within classrooms and offices, irrespective of natural or artificial lighting, consistently fall short of the prescribed 350 lux threshold based on SNI across most floor levels. The efficacy of the double skin facade manifests in a discernible attenuation, diminishing illuminance ingress to the building by approximately 50%, and precipitously by up to 90% about window fixtures. Furthermore, the analysis of light power density underscores an energy efficiency quotient hovering around 60%. These empirical insights are intended to serve as a foundational resource for guiding the initiation of Net Zero Healthy Greenship certification endeavors.**

***Index Terms*— double skin facade SNI; illuminance; light power density; lighting systems; Net Zero Healthy.**

I. INTRODUCTION

The lighting system is one of the factors in the Net Zero Healthy program. The significance of lighting systems in a building design is correlated with health in many ways. Fundamentally, physical comfort based on thermal, humidity, and lighting as well as other aspects play an important role in ensuring the well-being of building occupants [1], [2], [3], [4]. For instance, the temperature designed based on the standard comfort methodologies does not comply with the preference of hospital patients based on the clothing insulation and activities inside the room [1]. For humidity, an imbalance of relative humidity greatly impacts the spread of viruses and bacteria indoors, causing health risks [2], [3]. Lighting systems show a similar concept in which the use of proper lighting will prevent sicknesses such as headache, blurred vision, and even stress, etc. [4].

With the current behavior of humans, which is spending time mostly in indoor environments, exposure to outdoor daylight is reduced and in contrast, light is exposed to occupants even in the hours of natural darkness [5]. Concerning comfort levels, there is a significant correlation with the phenomenon known as sick building syndrome (SBS), which refers to symptoms potentially induced by indoor environmental quality and the duration of time spent within a building [6], [7], [8], [9]. Symptoms of sick-building syndrome (SBS) appear in occupants such as nausea, eye irritation, olfactory disturbances, dry skin, sore throat, difficulty in concentrating, flu, and many others that greatly towards their performance [7], [10]. Hence, making the best designs, especially in lighting systems, will help in improving performance on visual tasks and avoid negative health impacts [11], [12], [13]. As an example, it is shown that symptoms of affective disorder and depression can be reduced by lighting therapy [14].

The Net Zero Healthy program delineates rigorous criteria for the integration of standardized lighting systems within building design. As stipulated by GBC Indonesia, the foundational requisites for ensuring the health and comfort of occupants encompass comprehensive considerations, encompassing not only air circulatory dynamics and thermal equilibrium but also the critical dimension of visual amenity. Specifically, adherence to the latest edition of SNI 03-6197 is mandated for illuminance levels by the Indoor Health and Comfort or IHC 5 New Building 2.0 framework [15].

In addition to illuminance standards, stringent compliance with prescribed light power density regulations, as outlined in the latest iteration of SNI 03-

6197, is imperative. These regulatory mandates are informed by a compendium of reference documents, including but not limited to SNI 03-2396 for natural lighting provisions, ISO 50015:2014 for the meticulous management of energy systems and the verification of organizational energy performance, as well as ANSI/ASHRAE/IES Standards 90.1-2019 delineating the Energy Standard for Buildings Except Low-Rise Residential Buildings [16]. The value of the standard for both variables is strongly adherent with room function, one such example like classroom criteria with 350 lux and 7.53 Watt/m^2 for illuminance and light power density respectively. Hence specific and careful measurements procedure for both cases must be well executed to get the expected result.

Following the measurement strategy, for lighting systems, another standard can be used, namely SNI 7062-2019 for the measurement of illuminance in the working environment. Whilst for light power density, technical data such as the room area, number of lamps, and the power consumed for the lighting is needed. With the measurement method provided, a determination of how good a lighting system in a building design can be made. Moreover, to the necessity for Indonesia's buildings to reach Net Zero Healthy, this research is conducted to contribute to support and reach a healthy environment in a building as well as become the basis and findings, especially in visual comfort, to promote energy efficiency and renewable energy implementation further. This research is conducted from February to May 2024 in UMN's C and D Tower by collecting pre-requisite data, location survey, administrative processing, measuring visual comfort based on illuminance and light power density, analyzing, and finally concluding and resulting in recommendations.

Currently, UMN’s D Tower is categorized as Net Zero Ready with the condition of as long as energy efficient measures are applied, and renewable energy is used at a minimum threshold [15]. Accordingly, this tower along with New Media Tower (C) had applied a unique design based on a double skin facade to help in building energy efficiency. In this case, the double skin facade has optimally helped in allowing natural lighting into the building while controlling overexposure to light and heat through its design filtering method. Double Skin facade (DSF) in general, is a three-layer design consisting of internal skin, intermediate area, and external skin that covers buildings [17]. The uniqueness of this design signifies the transparency with which daylight penetrates with a glare-free characteristic. 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) [17], [18]. 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 [17]. 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 [18], [19]. In the case of UMN, as seen in Fig. 1., 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 [20], [21]. 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.

a) b) c)

Fig. 1. Double Skin Facade View of UMN’s a) C, b) D Tower from Inside and c) Outside of Clasrooms

Thus, this helps in giving controlled natural lighting which will reduce the usage of artificial lighting that consumes energy, supporting energy efficiency. In addition, it also helps in regulating air flow and heat transfer between the outside and inside parts of the tower, giving sufficient fresh air and preferable temperature for occupants without having to avoid overdependence on mechanical air conditioning systems.

The effect of double skin facades in an office on daylight performance shows values for double skin facades decrease by 25-30% compared to single skin, however, it slightly raises the illuminance near the rear wall to support uniformity [22]. Another study examines the performance of the double skin facade in the Henricus Constant building of Soegijapranata Catholic University along with the level of natural lighting in buildings. 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) [23]. Thus, 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 [24].

Hence, this research is intended as a media for field assessment towards the readiness of UMN's building specifically in C and D towers that integrated double skin facade since the facilities fulfill the criteria for Net Zero Building are presented such as natural ventilation on the class corridor, natural lighting systems and so forth. The findings of this research are expected to contribute significantly to enhancing preparedness and serve as valuable scientific contributions. It is hoped that these insights will inspire further research in similar domains, thus fostering the advancement of Net Zero initiatives in Indonesia.

II. METHODS

In this study, quantitative descriptive methods are employed, encompassing data collection, processing, analysis, evaluation, and the formulation of recommendations regarding illuminance and light power density across various room types within UMN's C and D Towers. The research methodology's flow is delineated comprehensively through the following procedure in Fig. 2.

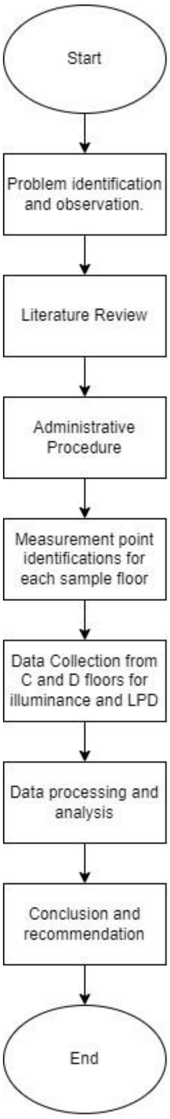


Fig. 2. Research Method Flow Chart

To provide a clearer understanding of data collection and data analysis, each variable for illuminance and light power density can be elaborated as follows:

A. Data Collections

a. Illuminance Data Collection

Illuminance measurements are done using DT-8820 Environment Meter which has been calibrated by comparing to other similar device such as lux meter to show the same result when positioned in the same spot. The measurements are made for both C and D tower which consist of classrooms, offices, storage, panel rooms, toilets, halls, and canteen as well as a parking area. Rooms within the C (New Media) and D (PK Ojong) Towers are appropriately categorized based on their designated functions and taken as sample as seen in Table I. Every floor will undergo comprehensive measures determined based on its area, classified in namely SNI 7062-2019 with the following method shown in Fig 3. This standard provides the methodology for illuminance measurement in working environments.

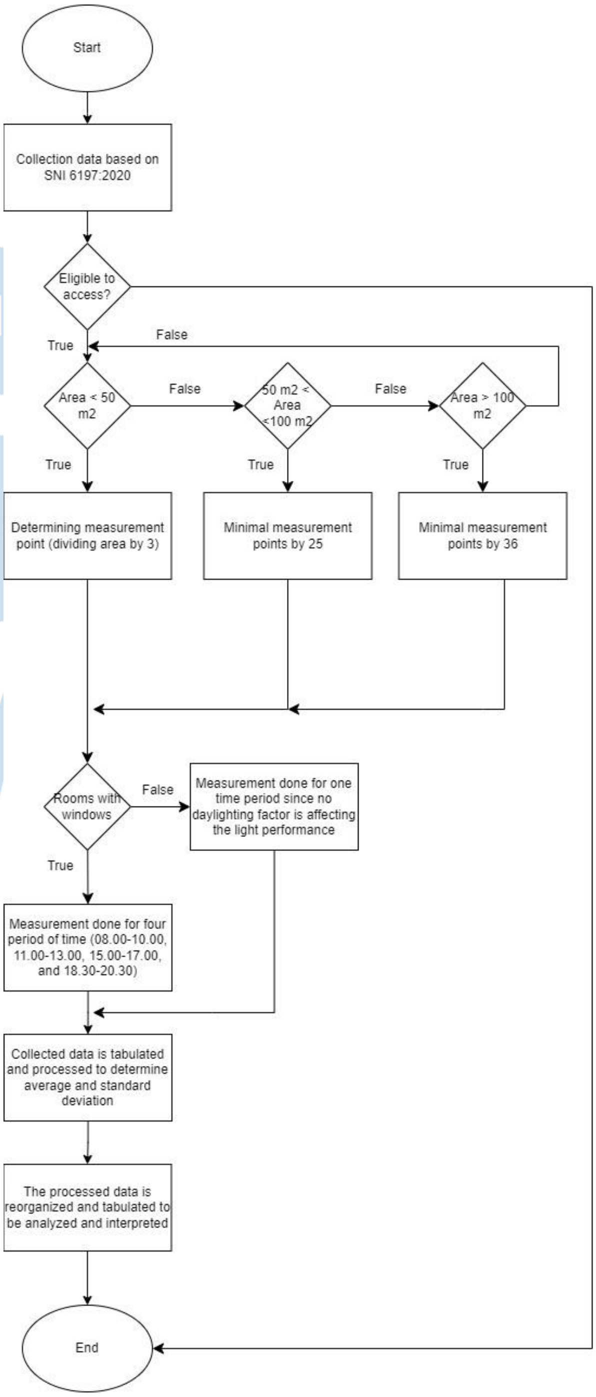


Fig. 3. Measurement Method Flow Chart

TABLE I. RULE BASE

Lamp/Fan	Cold	Warm	Hot
Dry	Bright/ Fast	Ideal/ Fast	Dim/ Fast
Medium	Bright/ Normal	Ideal/ Normal	Dim/ Normal
Moist	Bright/ Slow	Ideal/ Slow	Dim/ Slow

For clarity, as an example, the selected rooms are determined for their distributed measurement points, shown in Fig. 4. and 5.

Fig. 4. Tower C Seventh Floor for Laboratories Measurement Points

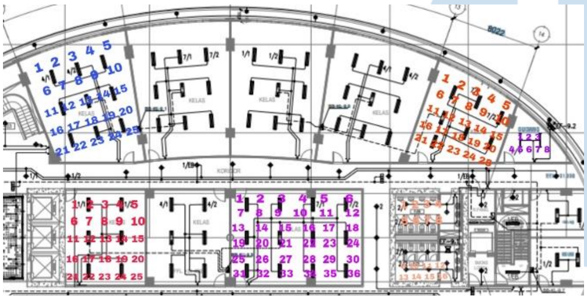


Fig. 5. Tower D's Classes, Laboratories, Architecture Studios, Toilets, and Storage Measurement Points

Fig 4. and 5. Shows C and D Tower in which the numbers in colors (black, blue, red, orange, and purple) shows the measurement points. Moreover, several factors must be considered such as repetition of 3 times for measurement with the height of 0.8 m from floor and the sensor being adjacent to the measured surface. Researchers must also position themselves to avoid light obstruction and should not wear reflective clothes. Further, this research uses the equation of illuminance from SNI 6197-2020 for comparison purpose which is shown in equation (1).

$$N = \frac{E\ average\ \times A}{F_i \times K_p \times K_d} \quad (1)$$

which can be reorganized to form equations (2) :

$$\frac{N}{A}(F_i \times UF \times MF) = E_{average} \quad (2)$$

To show the estimated E (illuminance) in each selected room by collecting the specification data of the lamp used such as the luminous flux or Fi (lumen), utilization factor UF or Kp by 0.5, maintenance factor MF or Kd by 0.6, area or A (m^2) and number of lamps or N. Both values of UF and MF will be utilized for all rooms illuminance calculation with the sense as an anticipation for the least optimum conditions for the current lighting system in both towers. In detail, as an example, with the given lamp specification of lamp specifications which are FL TL5 2700 lumen 28 W Philips for C Tower and LED tubes T8 1600 lumen 16 W for D Tower, the illuminance can be calculated by multiplying the number of lamps with its luminous flux along with the UF and MF value which then divided by the area for each floor. The lamps vary in which for C Tower, ranging from 10-24 while for D Tower by 12-18 for most of the typical rooms although several larger and/or smaller rooms have different numbers of lamps. While the areas vary from 50-110 m^2 and 60-100 m^2 for C and D Towers respectively.

The data processing is facilitated by Microsoft Excel in which tables of number of measurement points with 5 repetitions each are made to find the average and standard deviation. The illuminance obtained (E), both from manual measurements (average value as mentioned) and calculations, are compared to SNI 6197-2020 standards based on room function for visualization.

b. Light Power Density (LPD) Data Collection

The measurement method for light power density involves the need for technical data which is the lamp specification mention priorly. Then another data that must be obtained includes details such as the quantity of lamps used for illumination during activities as well as areas for each room that have also been explained. Thus, the given data can produce the calculation for LPD by multiplying the number of lamps by its power and then dividing by the room area. This data was gathered based on the specific conditions of each room, organized into tables, and then compared against the standards outlined in SNI 6197-2020. Finally, efficiency for this variable can be made by subtracting maximum values in SNI to the obtained LPD and then divided again by the SNI value to obtain the efficiency or saving percentages.

B. Data Analysis Technique

The collected and organized data undergoes analysis. This process involves comparing the measured results with the standards specified in SNI 6197-2020 for illuminance and light power density, as detailed in Table II. This standard, namely Energy Conservation for Lighting System, provides the values and specifications for the minimum and maximum values for illuminance, LPD, as well as other parameters including luminance, etc. that acts as a baseline to limits the utilization of lighting systems for energy conservation purposes.

TABLE II. ILLUMINANCE AND LIGHT POWER DENSITY STANDARD ACCORDING TO SNI 6197:2020 [16]

Type of Room	Illuminance (Lux)	Light Power Density (W/m^2)
Office		
Working Room	350	7.53
Meeting Room	300	7.53
Drawing Room	750	7.53
Parking Lot	100	7.53
Archive Storage	150	7.53
Education Institute		
Classroom	350	7.53
Laboratory	500	7.53
Computer Laboratory	500	7.53
Exhibition	300	7.53
Canteen	200	7.53
Parking Lot	100	1.4
Restaurant		
Fine Dining Room	30	8.61
Lounge	100	8.61
Cleaning Room	100	8.61
Toilet	200	8.61
Hotel		
Receptionist Room	200	6.03
Kitchen	300	6.03
Eating Room (Restaurant)	250	6.03
Multipurpose Room	250	6.03

The results of this research are derived from the analysis of three sets of measurement data encompassing illuminance, measured through both instrumentation and manual calculation, across four distinct periods (morning, noon, afternoon, and night), with and without daylight presence, alongside light power density. Certain conditions were established throughout the measurement process as follows:

1. Measurements are conducted in accessible rooms.
2. Measurements are conducted in four distinct periods: morning, noon, and afternoon. During each of these periods, measurements are taken twice under conditions with (C1) and without (C2) artificial lighting. For nighttime measurements, conditions without daylighting (C3) are used. Special considerations are made for areas such as the parking lot, where artificial lighting remains active at all times, and the canteen, where artificial lighting is adjusted based on situational requirements across all periods.
3. Illuminance measurements are conducted once in rooms without windows due to the absence of daylighting factors. Measurements are limited to accessible rooms only.

III. RESULT AND ANALYSIS

A. Illuminance Measurement Result

Measurements conducted during time periods—morning, noon, and afternoon—reveal a decrease in illuminance values in the absence of artificial lighting, predominantly ranging from 300-400 lux, which then drops to 150-250 lux for classrooms and laboratories, and 140-240 lux to 30-60 lux for offices. These variations are observed distinctly by floor level, indicating the unsuccessfulness to fulfill with the standards. Other types of rooms such as meeting rooms remain under 300 lux except for morning cases. While basement, storage and toilets do not comply with the requirements of 100 lux, 150 lux, and 200 lux. In the case of night period, all rooms show illuminance that are not reaching the standard.

Based on the preceding results, pertinent information can be extracted to serve as a reference for informing recommendations in preparation for Greenship Net Zero & Healthy Building Certification at Tower C as shown in Fig. 6. Specific to this scenario, the term “Not Appropriate” or NA and OK are used to represent the appropriateness percentage towards the standard (SNI 6197 2020). The data processing involves comparison for all measurement types C1, C2, and C3 at all periods to the standards and then counting the total that lies on the NA and OK categories. The results for each room are summed up and averaged to show the percentage per floor. The method of determining the percentage is based on the calculation for all illuminance measurement condition C1, C2, and C3 that do not adhere to the standard for each rooms in each floors. As an example, the second floor of D Tower, consisting of 9 rooms, each has 7 conditions (each C1 and C2 for morning, noon, and afternoon with addition of one C3 condition for nighttime). The illuminance results for those 7 conditions when compared to values from Table II do not reach the minimum of 350 lux for classrooms, confirming as NA. Therefore, the percentage of fulfillment can be shown by comparing the numbers of conditions that lie in NA aspect with the total of conditions which in the previous case resulting by 0%. Further analysis for floors with certain fulfillment can be made by adding each C1 and C2 conditions separately for each period to show the percentage between the NA or the non-fulfillment with the OK or the fulfillment.

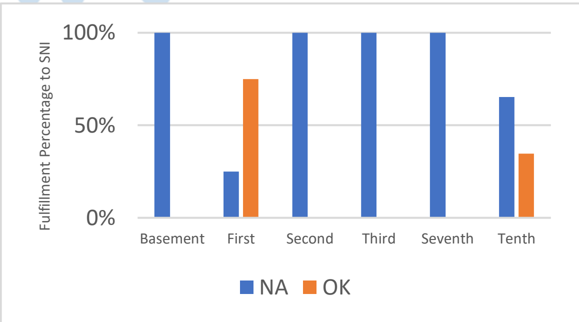
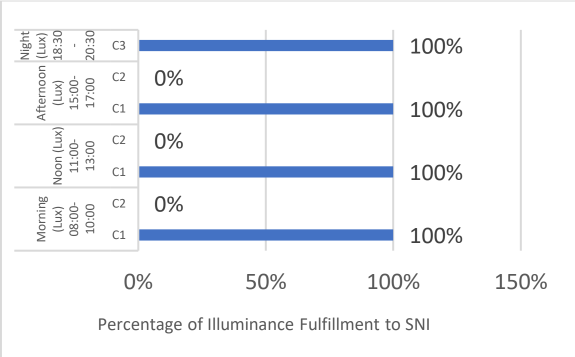
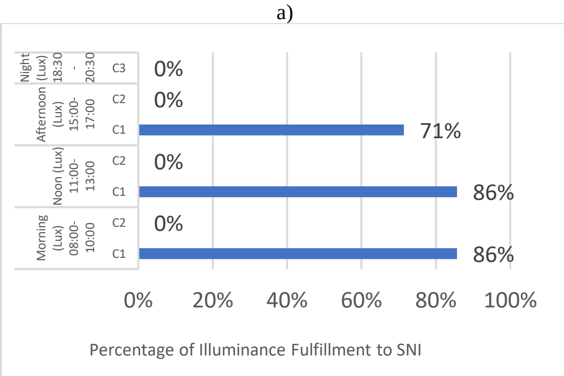


Fig. 6. Illuminance Satisfaction (%) of C Tower to SNI 6197 2020

Fig. 6. shows that all sampled floor results are not complying with the standards, except for first and tenth floor with 75% and 35% compliance respectively. For the Tenth floor especially, it can be further detailed, shown in Fig. 7. below.



a)



b)

Fig. 7. Condition of Illuminance at a) First Floor and b) Tenth Floor for Classes

From Fig. 6. and 7. can be seen that all rooms should immediately be adjusted to meet the standards. Cases in C2 show that the absence of artificial lighting can greatly affect the illuminance measurements since none complies with the standards, concluding that the rooms are always conditioned with artificial lighting all the time. Whilst in C3 cases where none complies with the standards, significant action must be taken such as changing the lamp type by having higher lumens up to 6500 lumens if assessed based on the calculations explained in illuminance calculation section. This includes the assumption for UF and MF by 0.5 and 0.6 along with the number of lamps, their luminous flux as well as the areas. By changing the luminous flux up to 6500 lumens, all rooms should reach the standard such as for classrooms by minimum of 350 lux for all period. This value itself is obtained by computing the current existing calculation in the illuminance calculation table with trial and error to see the maximum luminous flux than is applicable for all rooms for both C and Towers. It should be noted that for laboratories, additional lamps must be added with the recommended lumens from 22 to 27 and 24 to 30 lamps to reach around 500 lux based on the calculation method. This is recommended to counter the scenarios in which occupants use rooms without a daylighting presence at all.

Based on C1 measurements for all floors, the change of lamps mentioned priorly can help in fulfilling the gap between the existing illuminance and the required standard although the tenth floor has fulfilled to a certain extent which shows the correlation with time and height since daylighting and artificial lighting are presented as well as more amounts of light that reach the area for it being nearer to the sun. This is also supported by the fact that less shading and other factors occurred.

For Tower D data, across all types of rooms also indicate a decrease in illuminance values in the absence of artificial lighting, primarily ranging from 300-500 lux decreases to 120-300 lux for classrooms and laboratories, 170-210 lux to 30 lux for studios, and 150-390 to 15-250 lux for hotel faculty rooms. Moreover, the meeting rooms in the first and fifteenth floor do not adhere with the standard by 300 lux. Basement, storage and toilets in this tower are also not fulfilling the requirements of 100 lux, 150 lux, and 200 lux. Similarly, within C Tower, the case of night period for all rooms show inadequate result of illuminance. Significant information can be selected from the preceding results to provide highlights for recommendations in preparation for Greenship Net Zero & Healthy Building Certification at Tower D as shown in Fig. 8. below.

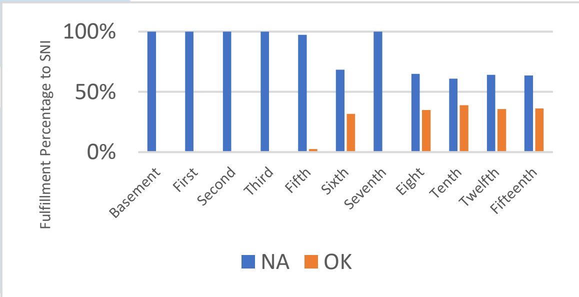
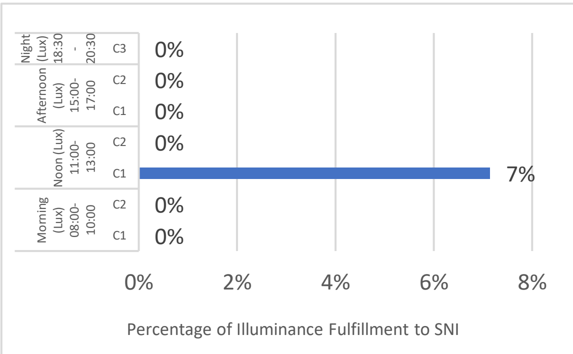
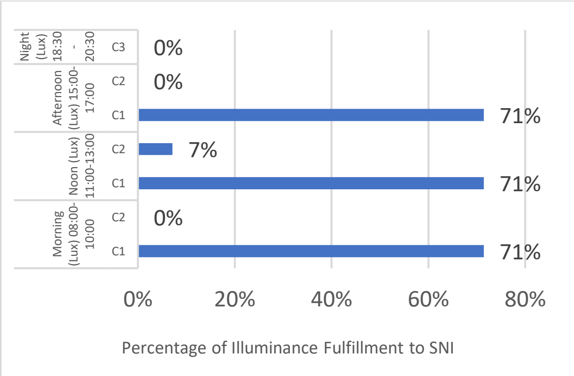


Fig. 8. Illuminance Satisfaction (%) of D Tower to SNI 6197 2020

Fig. 8. shows that all sampled floor results do not reach standards with lower levels to the third floor, and the seventh floor having 100% inappropriateness. These several floors starting from the fifth to the fifteenth can be further detailed in Fig. 9. below.



a)



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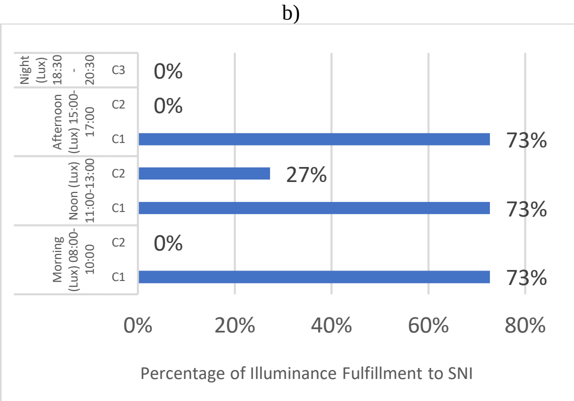

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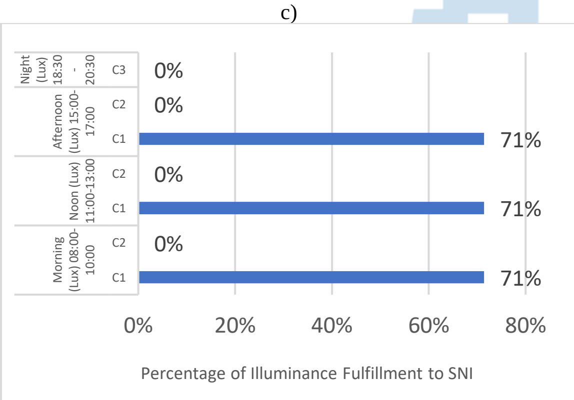

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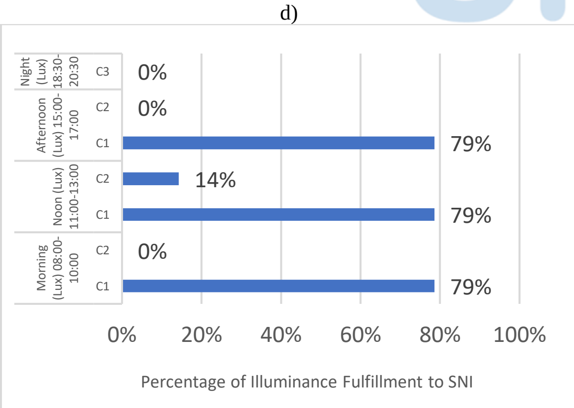
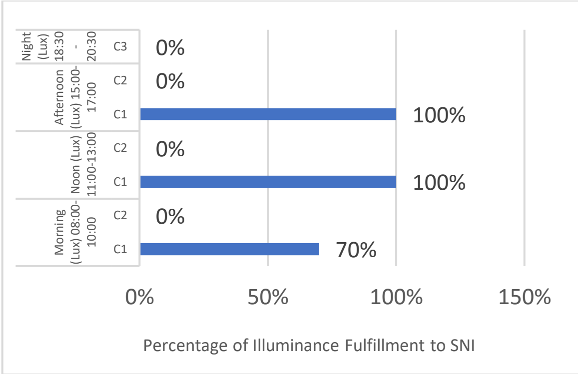


e)



f)

Fig. 9. Illuminance Condition in Classes for a) Fifth b) Sixth c) Eight d) Tenth e) Twelfth f) Fifteenth

From Fig. 9., it is highlighted that all rooms should also immediately be adjusted to meet the standards. Comparably with C Tower results, C2 measurements had shown rooms are not encouraged to be conditioned without artificial lighting to reach the standards. C3 cases also show that significant action must be taken, i.e. changing the lamp type by having higher lumens of up to 6500 lumens if assessed based on the assumptions in calculations (discussed in the next section) with laboratories on fifth floors must be added up to 25 lamps except for smaller areas should be added up to 17 lamps for the same lumens. C1 measurements for all floors also show the need to change the lamps mentioned previously in helping to reach the gap between the standards. Fig. 9. points out that C1 measurements for the fifth to fifteenth floors (except the seventh's) do satisfy the standard of 70% above which shows that height and time also correspond to the illuminance results. The same reasoning to C Tower's tenth floor, daylighting on the higher floor gives more amounts of light to the rooms which complies with the measurements results with the standards.

It should be noted that based on the findings, highlighted information can be given to show illuminance variation factors as follows:

- Orientation = The UMN building is oriented towards the northeast, strategically positioned to leverage sunlight from the east during sunrise, illuminating the southeast portion of UMN Tower C and D, primarily comprising corridors and lower-level classrooms. Conversely, during sunset in the west, direct sunlight bathes the northwest part of the building, reaching several upper-level rooms. This solar trajectory and its effects on illuminance are illustrated in Fig. 10. As sunlight angles change throughout the day, various rooms experience fluctuations in illuminance, contingent upon the building's design features facilitating light penetration. This trend is evident in Tower C, where higher floor levels exhibit higher illuminance levels, as exemplified by the tenth-floor surpassing 350 lux, while lower levels often remain below 300 lux. Similarly, Tower D showcases a notable disparity between higher (tenth to fifteenth) and lower floor levels, with illuminance levels hovering around 400-500 lux or higher on upper floors, particularly noticeable during the noon period. This difference can be attributed to the angle of direct sunlight reaching each area, emphasizing the influence of floor level height on illuminance results.

Fig. 10. Sunlight Direction Towards UMN

- Height = The variation in floor level height contributes significant differences. The variation in floor level height contributes significantly to the differences observed in illuminance values. Typically, higher floor levels experience increased illuminance due to reduced shading obstruction and a higher influx of sunlight.
- Shading = Shading, in this context, refers to the exterior elements of the building that cast shadows on lower floor levels, including Tower C and D up to the second floor. These shadows are caused by surrounding objects such as vegetation, other buildings, or adjacent UMN Towers, as well as internal factors like computer installations that obstruct natural light in computer laboratories.
- Reflection = Reflection is caused by external buildings.
- Weather Condition, Daylight Cycle, as well as Presence of Daylighting and/or Artificial Lighting.

B. *Illuminance Calculation Result*

For all the rooms, the area, number of lamps, and the specification of the lamp data are collected. Using the assumption for utilization factor as 0.5 and maintenance factor as 0.6, the result of the minimum E (illuminance) is based on the standard shown in Fig. 11 for Tower C and Fig. 12 for Tower D.

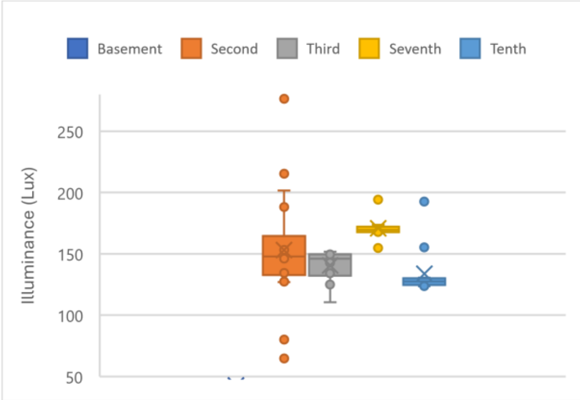


Fig. 11. Box Whisker Plot for C Tower Illuminance Calculation Results

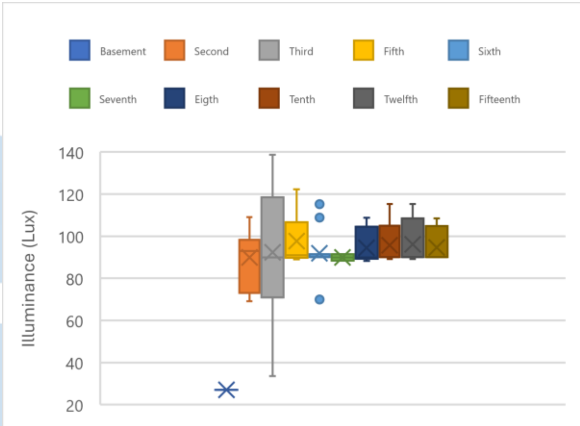


Fig. 12. Box Whisker Plot for D Tower Illuminance Calculation Results

The illuminance calculation data indicates that in Tower C, all types of rooms with known lamp data (number and luminous flux) and room area did not meet the minimum standard. This is evident in the parking lot, which measures only 42.7 lux instead of the required 100 lux. Similarly, offices mostly range around 40-150 lux while classes on the third and tenth floor lie about 120-150 lux. Laboratories on the seventh floor are also shown to be 150-190 lux. The same goes for toilets, storage, and meeting rooms. Whereas the illuminance calculation data for Tower D depicts the same trend by not meeting the minimum standard. Thus, it is recommended, as mentioned in the previous section, to change lamps to 6500 lumen types for each to reach the corresponding values in the standard also with additional lamps for laboratories according to Tower C and D existing lamps.

C. *Light Power Density Measurement Result*

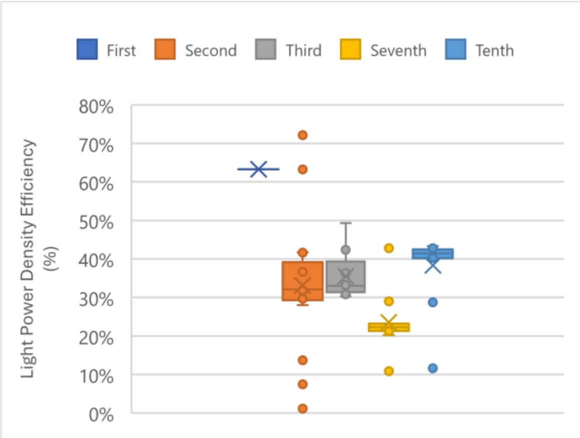


Fig. 13. Box and Whisker Plot for Light Power Density Efficiency Ranges of C Tower

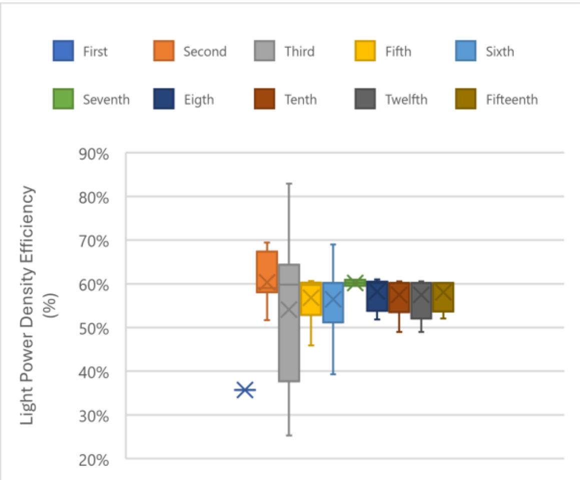


Fig. 14. Box and Whisker Plot for Light Power Density Efficiency Ranges of D Tower

Based on Fig. 13, the light power density (LPD) results for Tower C generally remain within 7.53 W/m², below the maximum standard. This indicates the energy efficiency applied throughout the tower, with the exception of the parking lot, which records an LPD of 1.47 W/m², slightly exceeding the standard of 1.4 W/m². LPD values for offices, classrooms, laboratories, and meeting rooms range from 4-5 W/m². Canteen's LPD reaches 2.77 W/m², factoring in the lamp type and wattage specified in the technical data. Efficiency calculations relative to the standard LPD (7.53 W/m²) indicate a 63.27% efficiency rate. For Tower D, the LPD results can be seen in Fig. 13.

Then based on Fig. 14., the light power density (LPD) results for Tower D generally align with or fall below the maximum standard of 7.53 W/m², as well as the educational institute standard and other standards for Hotel and Restaurant, serving as references. This indicates that energy efficiency measures have been effectively implemented across the tower. Specifically, the LPD for the parking lot, which measures 0.9 W/m² (compared to the standard of 1.4 W/m²), achieves an efficiency of 35.7%. LPD values for classes, laboratories, offices, and meeting rooms range from 2-4 W/m².

D. *Double Skin Facade Impact*

Tower C and Tower D, characterized by a distinctive continuous pattern on each floor level, comprehensive measurements of the Double Skin Facade's (DSF) aperture area, number of apertures, and window-to-wall ratio (WWR) per floor are imperative. This is further discussed as follows.

a) b)

Fig. 15. Double Skin Facade Tower C a) Pane Design and b) Measurement Result

Depicted in Fig. 15. for Tower C, each pane typically contains around 29 to 13 holes, totaling approximately 377 holes, each with a diameter of 2 cm. On the third floor, with a WWR of roughly 0.588 and 1.5 panes occupying the windows, the illuminance measurements reveal 9700 lux without the facade, 600 lux with the facade, and 388 lux with both windows and facade. The facade effectively filters about 94% of direct sunlight, with additional windows further reducing direct sunlight by 96%. However, these variations may also stem from factors such as sunlight angle and surrounding object shading.

Similarly, on the seventh floor with a WWR of about 0.61 and 2 panes vertically occupying the windows, illuminance measurements show up to 12550 lux without the facade, 5210 lux with the facade, and 730 lux with both facade and windows. This indicates a filtration of about 58.4% by the facade alone, with an additional decrease of 94.1% due to the presence of windows. On the tenth floor, with a WWR of approximately 0.48 and 1.5 panes vertically occupying the windows, illuminance readings are 5890 lux without the facade, 3240 lux with the facade, and 1031 lux with additional windows. This translates to a reduction of 44.9% with the facade and 82% with additional windows. These findings can be extrapolated to other orientations on the same floor based on concise measurement tests. The results indicate that the facade significantly reduces daylight illuminance in Tower C, with a decrease of more than 40%, while the inclusion of windows leads to a reduction of around 80-90%.

For Tower D, the facade design, as illustrated in Fig. 16., features circular apertures of varying sizes, with the smaller ones measuring approximately 2.5 cm and the larger ones around 25 cm. Across all floors, the window-to-wall ratio ranges from 16.5% to 24%, contributing to the filtration of light entering the rooms by the windows. Under optimal conditions, with 120 small circular holes and 45 large circular holes per room, the penetration of daylight is reduced by 31% with the facade alone and by 67% with the addition of windows.

a) b)

Fig. 16. Double Skin Facade for Tower D a) Design and b) Measurement Results

An example of this reduction is observed in the east corridor measurement during maximum direct sunlight (afternoon) on the fifteenth floor under favorable weather conditions, with illuminance levels decreasing from 16270 lux without a facade to 11230 lux with a facade and 5360 lux with additional windows. Similar reductions are seen across other floors, including the third, fifth, sixth, eighth, tenth, and twelfth levels, with reductions ranging from 30% to 40% with the facade and 70% to 90% with additional windows, under similar conditions.

Regarding the impact of the double skin facade on illuminance reduction, measurements conducted in the corridor corner reveal a significant decrease in direct daylight reaching the rooms, with a maximum reduction of 90%. While this reduction is beneficial for upper-level areas, lower-floor levels may experience insufficient daylighting, resulting in illuminance levels that do not meet the standard requirements. As an example, the third floor in C Tower suffers by lower illuminance in the noon, around 320 lux with daylighting and artificial lighting presented in which compared to the tenth floor with higher values by approximately 420 lux although shading factors also presented around the lower floors. The same goes for D Tower in which the fifth floors measurement results show illuminance value by around 300 lux whereas the twelfth floors reach above 420 lux. This clearly shows that the double skin facade affects the visual comfort in the room along with the priorly mentioned factors. Not to mention that laboratories in C and D Tower are relatively positioned vertically at the middle of the tower, illuminance results tend to not reach the minimum standard of 500 lux. Therefore, careful consideration of the double skin facade design is necessary, particularly for lower floor levels, along with consideration of other factors such as shading from surrounding objects that can further diminish sunlight intensity before it reaches the rooms.

IV. Conclusion

As the preparation for Net Zero Building's Certification, this research is conducted to assess the lighting systems for Universitas Multimedia Nusantara's Tower C and D in various periods (morning, noon, afternoon, and night) as well as the presence variation for daylighting and artificial lighting. The current condition of the lighting systems mostly did not comply with the standard. Areas that do not comply with the standard for the morning until afternoon period (C1 and C2) in Tower C are the basement (85-86 lux), second floor (130-240 lux for offices), third floor (300 lux for classes and above 190 lux for meeting rooms), and seventh floor (300-350 lux for laboratories). While for Tower D which are the basement (69-70 lux), meeting room (198 lux), second floor (above 179 lux for classes), third floor (150-200 lux for classes and laboratories), and fifth floor (280-434 lux for laboratories). Toilets and storage measurements also do not comply with the standard (below 200 and 150 lux respectively). For nighttime measurements (C3), which only rely on artificial lighting, none suffice the standard for all room cases. With proper adjustment for artificial lighting, it can support visual comfort and fill the gap to the standards. In this case, a change of lamps to 6500 lumens type can enrich the illuminance results to fulfill the standards, with important notes to add several lamps to laboratories case in which for C tower from 22 to 27 and 24 to 30 as well as D tower from 14 to 17 and 18 to 25 lamps corresponding to the number of existing lamps.

Illumination levels vary significantly among rooms within Towers C and D, with several floors falling below SNI standards from morning until afternoon. Notably, specific areas, including basements, meeting rooms, storages, classes, offices and laboratories did not meet these standards, with some areas even lacking the required illuminance by up to 500 lux (for laboratories intended) compared to reference values. Moreover, nighttime measurements across all room types on each floor also fall short of minimum standards. Despite focusing solely on artificial lighting system calculations, adjustments to factors such as utilization and maintenance may marginally improve results. However, both measured and calculated values still did not meet the SNI standards. While power efficiency remains high across room types shown by light power density outcomes, it's crucial to prioritize occupant comfort by ensuring adequate illuminance levels, even if it means sacrificing some efficiency.

The passive design, which is a double skin facade for both towers, does support the visual comfort criteria satisfaction however to some extent, as discussed on the findings earlier. In this case, several areas, especially on lower floor levels, suffer from low illuminance value since daylight is filtered not only by the double skin facade and the windows but also by surrounding objects that cause shading. Specifically, for Tower C, the sunlight is filtered above 90% on the third floor, and the seventh floor, 80% on the tenth floor. Whilst for Tower D, the sunlight is filtered by about 30-40% by the facade and up to 90% with windows addition. Future research can elaborate more on the double skin facade effect such as cavity and supported by simulations analysis for recommendations implementation as well as conducting surveys to analyze the correlation between the comfort levels felt by occupants with the existing lighting systems performance to see how far the adjustments must be done.

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