International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# Daylighting Simulation for Sustainable Certified Building - Tokyo Global Square, Minato City, Japan

**Muhamad Syariz Niza Bin Salehhuddin[1], Mohd Hafiz Bin Muhammad Zin[2]**

[1]Mr, School of Architecture, College Of Built Environment, University of Technology MARA Puncak Alam, Malaysia
[2]Dr, School of Architecture, College Of Built Environment, University of Technology MARA Puncak Alam, Malaysia

**Abstract**

According to the World Green Building Council, Sustainable Building or Green building refers to a building that, in its design, construction, or operation, minimises or eliminates negative impacts on the climate and natural environment while also creating positive impacts and improving our quality of life. It aims to conserve natural resources. This study focuses on assessing the effectiveness of daylighting in enhancing the overall efficiency of an office building. The selected office building, Tokyo Toranomon Global Square, located in Minato City, Tokyo, Japan, is certified by LEED and has received sustainable ratings. LightStanza has been utilised as a daylighting simulation tool for this study. The findings reveal that several factors influence the efficiency of the space, including building orientation, window type, glass type, facade materials, and room depth. Through computer simulations, it has been determined that the average illuminance level of daylight entering the building meets the ideal illuminance values specified by specific organisations that provide criteria for optimal lighting in office working spaces, namely as the Japanese Industrial Standard, (JIS Z 9110, 2010 – General rules of recommended Lighting Levels).

**Keywords:** Sustainable Building, Daylighting Simulation, Working Space

## 1. Introduction

Daylighting plays a crucial role in providing numerous benefits to the occupant as well as to achieve the sustainable building design standard [1]. Efficient daylighting strategy through the building design potentially provides a significant positive impact especially in reducing the carbon footprint to the environment [2]. As part of the passive sustainable design, daylighting will reduce the building energy consumption via various efficient design strategies [3]. Quality of daylighting in the building space potentially will enhance the occupants's health and their comfortability [4]. On the other hand, indoor and outdoor building's performance play a major role in influencing human wellbeing [5]. Daylighting also helps to minimise the reliance on artificial lighting, thereby reducing electricity costs and lowering the expenses associated with High Volatility Organic Compounds (HVOC) [6]. By utilising daylight, environmental quality is improved, and energy efficiency is enhanced by reducing the need for artificial lighting [7]. Daylight not only contributes to energy conservation but also has a positive impact on various aspects, such as human performance, workplace productivity, human health, and financial return on investment [8].

It is worth noting that light can influence the human circadian system, and the light intensities and spectra required to activate the circadian system differ from those needed for visual perception. Insufficient exposure to bright light during the day can disrupt the circadian system, leading to feelings of depression, poor sleep quality, lethargy, and even illness [9]. This highlights the importance of daylight in our daily lives, even within our own houses. Overall, daylighting offers significant advantages in terms of sustainability, cost savings, environmental well-being, and human health and productivity. Therefore, incorporating effective daylighting strategies in architectural design is crucial for creating sustainable and healthy built environments.

## 2. Literature Review

Sustainable office building that has been certified by LEED that was selected from Japan is Tokyo Toranomon Global Square, located in Minato City as shown below (Figure 1.0). This office building was awarded the Gold Award with the rating system LEED BD+C: Core and Shellv3 - LEED 2009 in August 2020. Tokyo Toranomon Global Square was developed as part of an urban redevelopment project, resulting in a multi-purpose office building comprising 24 above-ground stories and 3 basement levels. The gross floor area of the building is 47,261 sqm, in accordance with Japanese Building Standards. The project was initiated in 2012, aiming to address issues such as deteriorating buildings in the area and congestion at Toranomon Station on the Tokyo Metro Ginza Line. Construction commenced in January 2018 following the establishment of an area development partnership and the authorization of property right exchanges, concluding in June 2020.

**Figure 1.0: Tokyo Toranomon Global Square, Minato City, Japan.**
**Source: Nomura Real Estate Co, 2023.**

The Toranomon area has experienced a rapid increase in its working population in recent years. As a result, the area aims to transform into an advanced international business hub through the redevelopment of office buildings. Toranomon Station faced structural limitations as the first underground railway station in Japan on the Ginza Line. The project significantly improved the transportation functionality of the Toranomon area, which has been experiencing a population surge. This was achieved by expanding the platform into a private site for the first time, resulting in an additional 600 sqm underground, as well as the creation of 800 sqm public plazas above ground adjacent to the platform.The project site is highly regarded and has received approval in the LEED Sustainable Sites category due to its excellent access to public transportation.

The project building achieved the highest rank of 3 in the Tokyo Green Building Program, with a 20.39% reduction in building envelope performance (PAL*) and a 27.53% reduction in building energy performance (ERR) based on the 2014 standard. It also obtained an S-rank in the CASBEE self-assessment check system, in addition to LEED Gold certification. Notable efforts contributing to these evaluations include the implementation of highly efficient LED lighting fixtures throughout the building, the use of auto-dimming and motion sensor lighting control systems, lighting power reduction in non-occupied areas, and rainwater reuse.

Energy savings in air conditioning were achieved by adopting a separated sensitive and latent heat air conditioning system on the office floors. This system controls the temperature and humidity separately, allowing for high-latent heat air conditioning operation for cooling purposes. The spaces provide 30% increased outdoor air compared to the ASHRAE 62.1-2007 standard, considering energy conservation through free cooling based on outdoor weather conditions and demand-controlled CO2 concentration. As a result of the aforementioned energy optimizations, the project building achieved a 30.3% reduction in energy costs compared to the ASHRAE 90.1-2007 baseline building in its entirety.

Referring to the LEED score table (Figure 1.1), it can be observed that this office building has successfully obtained credits in several categories, including sustainable sites, water efficiency, energy and atmosphere, innovation, and regional priority. However, it is worth noting that the assessment does not specifically consider the presence of direct sunlight and its effect on the well-being of the workers within the building. The daylighting issues can be classified into three factors, such as selection of material, orientation of the building and the lack of application of passive and active methods.

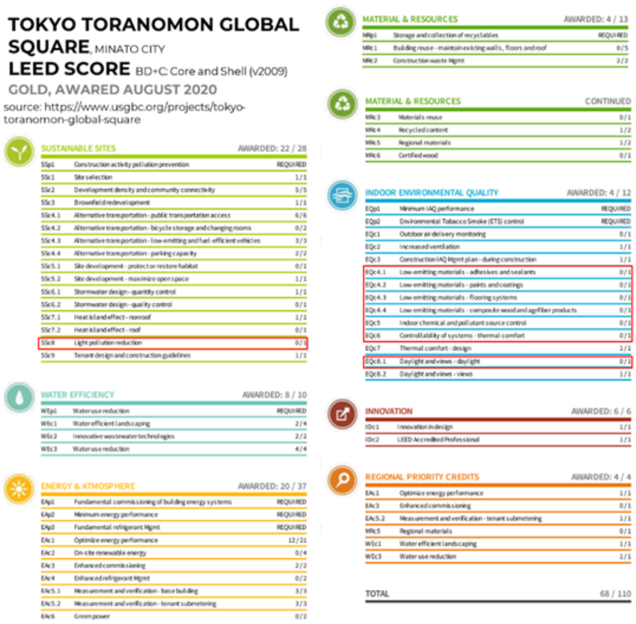



**Figure 1.1: LEED scorecard for Tokyo Toranomon Global Square, Minato City, Tokyo, Japan. Source: LEED rating system, U.S. Green Building Council, 2020.**

Every sustainable design should take into account strategies based on the United Nations' Sustainable Development Goals (SDGs). These goals encompass 17 components that represent different aspects of sustainability, and they can be effectively implemented in this project. By aligning with these goals, the design ensures a thoughtful response to the site and the well-being of the people involved as per (Figure 1.2).

**Figure 1.2: Component of Sustainable Development Goal (SDGs).**
**Source: United Nation, 2023.**

### 3. Research Methodology

This investigation relies on data collected primarily from online sources, journals, and books. The research study consists of three main stages: 1. Case Study, 2. 3D Modelling, and 3. Daylight Simulation. Additionally, an analysis of existing data has been conducted.

#### A) Case Study

The official website of USGBC LEED provides information confirming that the building falls under the category of office buildings, with each floor ranging in size from 1000-4000 sqm. This particular project has been awarded the prestigious Gold certification in the LEED Sustainable Sites category, primarily due to its exceptional accessibility to public transportation. The size of the typical floor area is 1935.52 sqm as shown on (Figure 1.3) . The data collection process for this study focuses on various factors that influence daylighting simulation, encompassing aspects such as climate, building typology, building orientation, window and glass types, room depth, sky condition and the utilisation of daylight rating tools. The primary objective of this study is to evaluate and conduct thorough daylighting simulation tests on both buildings. The aim is to examine the factors that impact the amount of daylight entering the buildings and calculate the illuminance value to compare it with the ideal threshold. Additionally, this paper seeks to investigate the design aspects that significantly influence daylighting and establish a comprehensive understanding of the relationship between daylighting and room depth.

However, efficient utilisation of passive lighting can yield favourable results in terms of a building's energy performance and overall energy consumption. The building's structure, characteristics, and external weather conditions collectively contribute to its energy performance. Hence, it is imperative to carefully consider and incorporate appropriate design strategies.


JIS
JAPANESE
INDUSTRIAL
STANDARD

JIS Z 9110
(IEIJ/JSA)
General rules of recommended
lighting levels

**Figure 2.0: Japanese Industrial Standard (JIS Z 9110, 2010 – General rules of recommended Lighting Levels).**
**Source: Japanese Industrial Standards Committee, 2010.**

Finally, the objective of this research is to explore and propose the most suitable solution that aligns with both the Sustainable Development Goals (SDGs) set by the United Nations and the Japanese Industrial Standard (JIS Z 9110, 2010 – General rules of recommended Lighting Levels) (Figure 1.3). These guidelines will serve as the basis for developing a new building proposal that effectively addresses the issue of direct sunlight penetration into the building.
By considering the SDGs and Lux standard by the JIS Z 9110 (Figure 1.4), which encompass various aspects of sustainability, the proposed solution aims to contribute to global sustainable development targets. Additionally, adhering to the Japanese Industrial Standard ensures compliance with recommended lighting levels, providing a framework for optimising daylighting while maintaining appropriate illumination within the building.

| Activity | Illuminance (lx, lumen/m²) |
|---|---|
| Areas with traffic and corridors - stairways, escalators - lifts - storage spaces | 100 |
| Working areas where visual tasks are only occasionally performed | 100 - 150 |
| Warehouses, archives, loading bays | 150 |
| Coffee break room, technical facilities, ball-mill areas, pulp plants, waiting rooms | 200 |
| Easy office work | 250 |
| Normal office work, PC work, show rooms, laboratories, check-out areas, kitchens, auditoriums | 500 |
| Mechanical workshops, office landscapes | 750 |
| Normal drawing work, detailed mechanical workshops, operation theaters | 1000 |
| Detailed drawing work, very detailed mechanical works, electronic workshops, testing and adjustments | 1500 - 2000 |
| Performance of visual tasks of low contrast and very small size for prolonged periods of time | 2000 - 5000 |
| Performance of very prolonged and exacting visual tasks | 5000 - 10000 |

**Figure 2.1: Table of standard light level for work spaces by the Japanese Industrial Standard (JIS Z 9110, 2010 – General rules of recommended Lighting Levels).**
**Source: Japanese Industrial Standards Committee, 2010.**

The research will carefully analyse the requirements and recommendations outlined in these guidelines to develop a comprehensive proposal. The proposed solution will take into account factors such as building design, orientation, window and glass types, shading systems, and other relevant design aspects. The goal is to strike a balance between maximising the benefits of natural daylight while minimising potential issues associated with excessive glare, heat gain, or energy inefficiency.

By integrating the principles of sustainability and the lighting standards outlined in the Japanese Industrial Standard, the new building proposal will aim to create a harmonious and optimised environment that ensures the well-being of occupants, enhances energy efficiency, and aligns with the global sustainability agenda outlined by the United Nations.

Overall, the research will culminate in a comprehensive proposal that provides an effective and sustainable solution for managing direct sunlight within the building while adhering to the guidelines set by the Sustainable Development Goals and the Japanese Industrial Standard.\

**B) Computer Simulation Steps**

**3D Modelling**

The office building's floor plan was found on the official websites. The Autodesk Revit 2020 has imported the plan picture. The image has been scaled in accordance with the scale indicated in the sketch to ensure that it is almost exactly the right size and that the north point corresponds to the context of the site and to Google Maps as a reference. Only one story of the structure has been modelled in Revit, and it consists of the grid, walls, windows, and doors elements. Once the existing building model was done, the final checking for the model needed to be made to make sure there were no gaps or other obstructions that could have affected the data collection error.

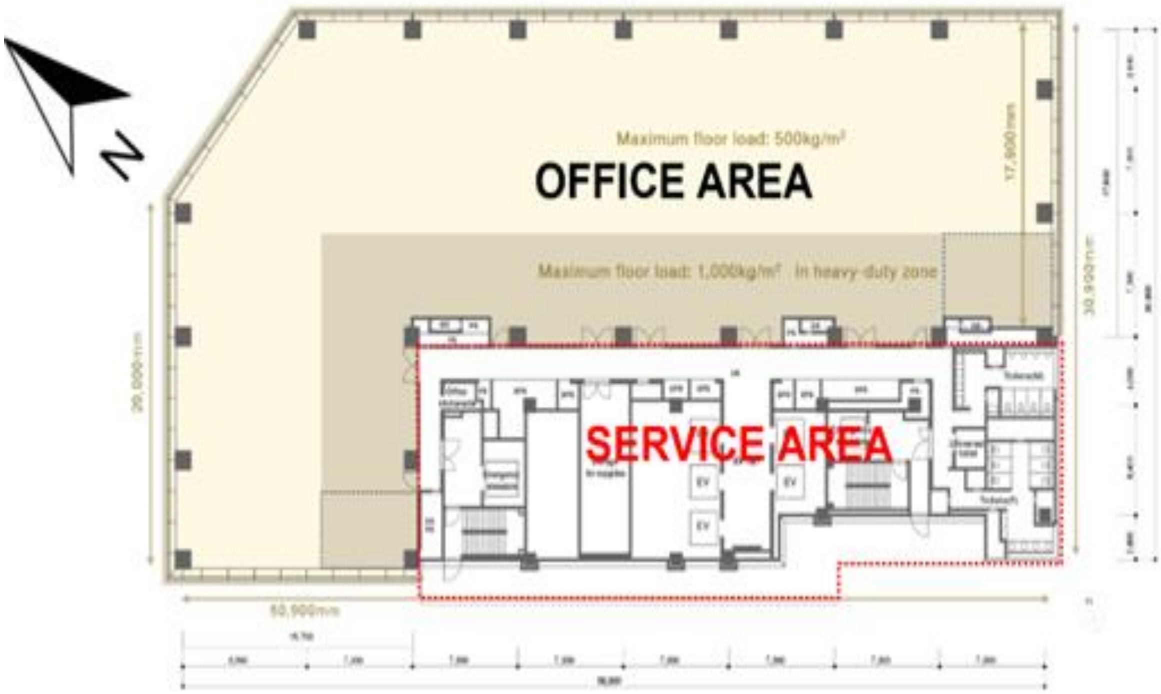



**Figure 2.2: Typical floor plan for Tokyo Toranomon Global Square.**

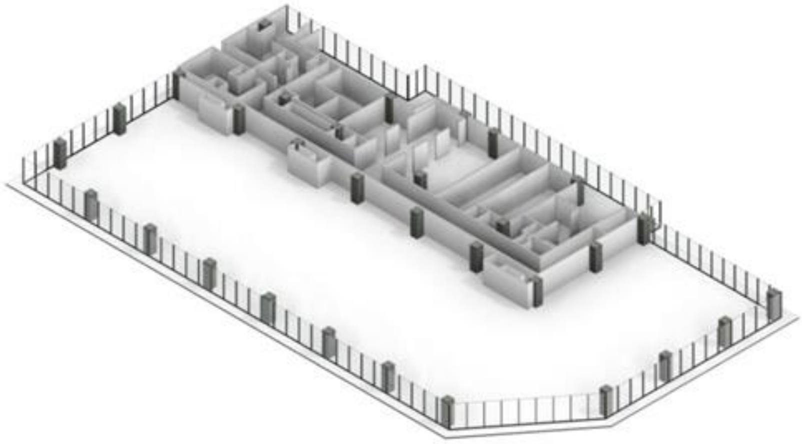


**Figure 2.3: Isometric 3D for existing Tokyo Toranomon Global Square.**

Next, from the existing model, create a new model as Figure 2.4 that proposes a new type of design to improve the daylighting into the building such as shading device and design façade.

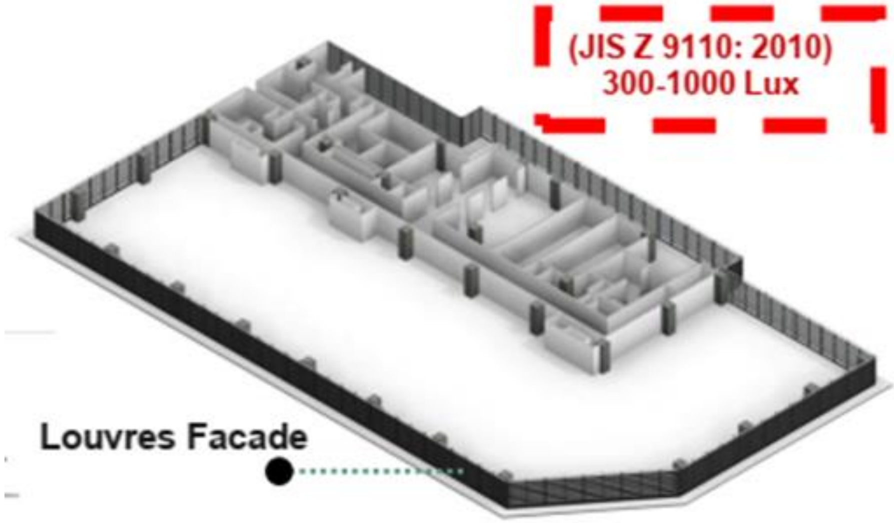



**Figure 2.4: Isometric 3D for design proposal Tokyo Toranomon Global Square.**

**Daylighting Simulation**

The powerful daylight analysis simulation programme that can be connected with Revit software, LightStanza, is the most compatible. Its capacity to supplement other software tools, such as Revit, is undeniable. By enabling the direct upload of studied models to the platform, users can obtain unmatched insights into how natural light interacts with model space. A simulation of both buildings' daylighting is necessary in order to analyse how well each building performs in this regard. To guarantee that operations are carried out in an orderly timetable and that accurate results may be acquired, a number of procedures have been outlined in the simulation process. The steps of the process are as follows:

**Step 1:** Generate chosen building in 3D model and building dimension with live sync that easily connects from the Revit 2020 to LightStanza by using plugin as shown in Figure 2.4.

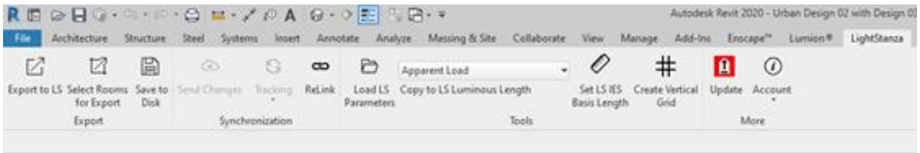



**Figure 2.4: Plug in for LightStaza for Revit 2020.**
**Source: Autodesk Revit 2020**

**Step 2:** Set location base (North point) on the coordinate as per Google Maps, set the sky condition as clear sky and set the date on 21 March 2023, hourly for 12 hours (8.00am – 7.00pm).
**Step 3:** Choose and set the building material according to the existing building. The originality of the material makes the data collection more precise and accurate for the daylighting simulation.
**Step 4:** Run the simulation by selecting the grid of daylighting for calculation of illuminance into the model.
**Step 5:** The results and data of the existing building in format of an Excel sheet that used to graph the outcomes and information gathered from all simulations (12 hours). The chart and figures are looked at, discussed, and a conclusion is drawn. Based on the graph and tabulated information, it will be determined whether or not the selected building performs well in the daylight.
**Step 6:** The results of the data collection showed the existing model does not meet the requirement according to the Japanese Industrial Standard, (JIS Z 9110,2010 – General rules of recommended Lighting Levels). Used the existing model then created the proposal design that makes the design more comfortable for working space, which uses louvres as shading devices.
**Step 7:** Repeat the simulation by referring to step 2 to step 5 and analysing the data collection between both model make the comparison by using average of illumination level and time taken as the main objectives that meet the guideline according to the the Japanese Industrial Standard, (JIS Z 9110,2010 – General rules of recommended Lighting Levels).
**Step 8:** Do the comparison and the overall conclusion for both model designs.

### Analysing an Existing Model

The data that have been collect from the daylight simulation will be analysing by using table and graph that compare to the ideal requirement. According to the Japanese Industrial Standard, (JIS Z 9110,2010 – General rules of recommended Lighting Levels), Lighting of workplaces - Indoor work places, the light level recommended for office work is the range 300 -1000 lux. For precision and detailed works the light level may even approach 1500 - 2000 lux.

## 4. Result & Discussion

In order to analysing the data collection from the LighStanza that according the Japanese Industrial Standard, (JIS Z 9110,2010 – General rules of recommended Lighting Levels), 3D model of existing building has been run the simulation to see the current illumination level of daylight toward the comfort level for working activities of the office building. The LightStanza have been running the simulation to study the daylighting performance of the existing model and proposal model that have been set on 21 March 2023 with clear sky conditions. The outcomes of the acquired daylighting simulation, however, have been tallied and are displayed in Tables 1.0 for the existing model and Table 2.0 for the proposed model. The table depicts the relationship between the depth of the room and the various daylight penetration timings, which affects the illuminance rating that the LightStanza provides.

**07 COMPARISON OF LUX TO ROOM DEPTH ANALYSIS**

**EXISTING**

| DEPTH ROOM (m) | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | Average Lux / Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPENING | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 2500 | 2500 | 1500 | 0 | 2541.67 |
| 4 | 2500 | 2500 | 2500 | 2500 | 3000 | 2500 | 2500 | 2500 | 2000 | 1500 | 1000 | 0 | 2083.33 |
| 8 | 2000 | 2000 | 2000 | 2500 | 2500 | 2500 | 2000 | 2000 | 1500 | 1000 | 500 | 0 | 1708.33 |
| 12 | 1500 | 1500 | 2000 | 2000 | 2000 | 1500 | 1500 | 1500 | 1000 | 500 | 0 | 0 | 1250.00 |
| 16 | 1000 | 1000 | 1500 | 1500 | 1500 | 1500 | 1500 | 1000 | 500 | 0 | 0 | 0 | 916.67 |
| 20 | 500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 500 | 0 | 0 | 0 | 0 | 583.33 |
| 24 | 0 | 500 | 500 | 500 | 500 | 500 | 500 | 0 | 0 | 0 | 0 | 0 | 250.00 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| Average Lux | 1166.67 | 1277.78 | 1388.89 | 1444.44 | 1500.00 | 1388.89 | 1333.33 | 1166.67 | 833.33 | 611.11 | 333.33 | 0 | |

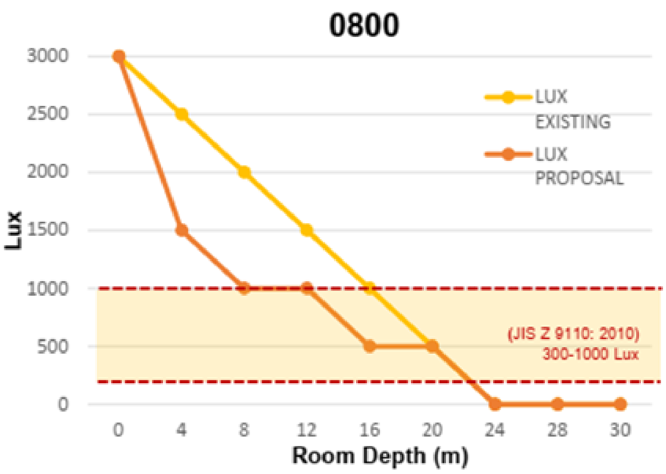
**Table 1.0: The existing double glazed glass wall for illuminance room depth analysis.**

**PROPOSAL**

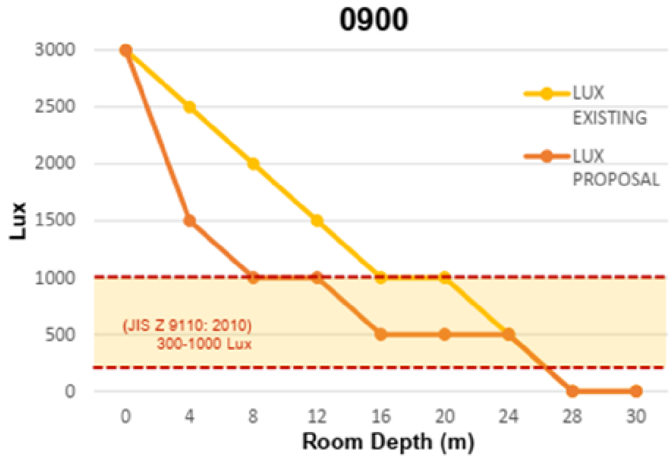
| DEPTH ROOM (m) | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | Average Lux / Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPENING | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 2500 | 2500 | 1500 | 0 | 2541.67 |
| 4 | 1500 | 1500 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 1000 | 1000 | 1000 | 0 | 1500.00 |
| 8 | 1000 | 1000 | 2000 | 2000 | 2000 | 1000 | 1000 | 1000 | 1000 | 500 | 500 | 0 | 1083.33 |
| 12 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 500 | 500 | 0 | 0 | 833.33 |
| 16 | 500 | 500 | 1000 | 1000 | 1000 | 1000 | 1000 | 500 | 500 | 0 | 0 | 0 | 583.33 |
| 20 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 0 | 0 | 0 | 0 | 333.33 |
| 24 | 0 | 500 | 500 | 500 | 500 | 500 | 500 | 0 | 0 | 0 | 0 | 0 | 250.00 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| Average Lux | 833.33 | 888.89 | 1111.11 | 1111.11 | 1222.22 | 1000.00 | 1000.00 | 888.89 | 611.11 | 500.00 | 333.33 | 0 | |

**Table 2.0: The proposal for an additional external louvres façade for illuminance room depth analysis.**

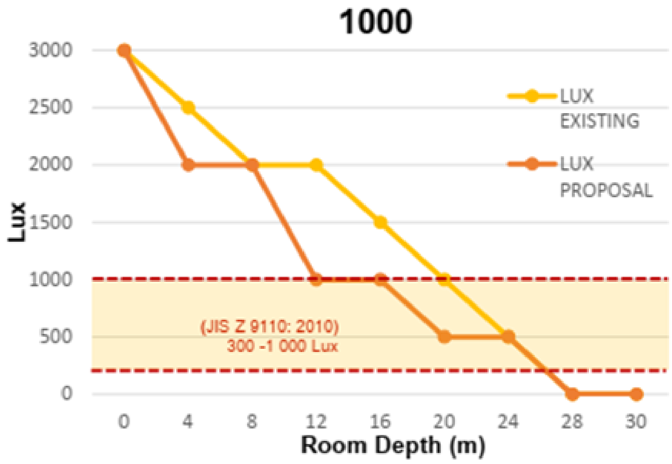
The measurements from Table 1 and Table 2 are graphed to offer clear comparison between the design building. The Graph 1 until graph 13 show the illumination level of the existing building with double glazed glass wall and the proposal of an additional external louvres façade at the same hour.



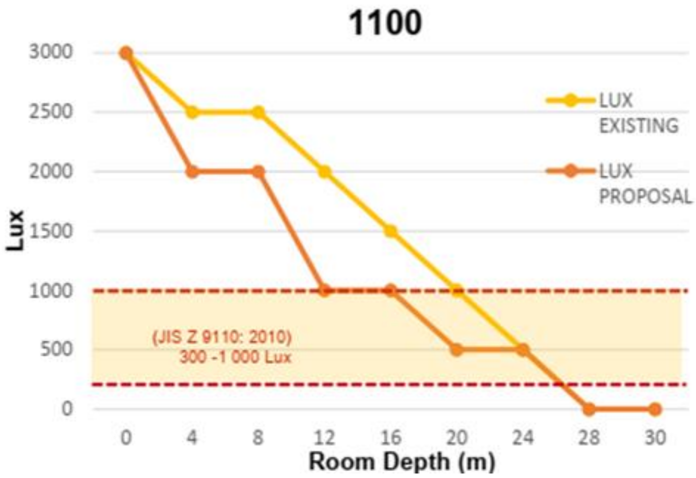

**Graph 1.0 The existing double glazed glass wall achieved optimum illumination at 16m to 20m depth while proposal additional external louvres achieved optimum illumination at 8m to 12m depth at 8.00 a.m., 21st March 2023.**



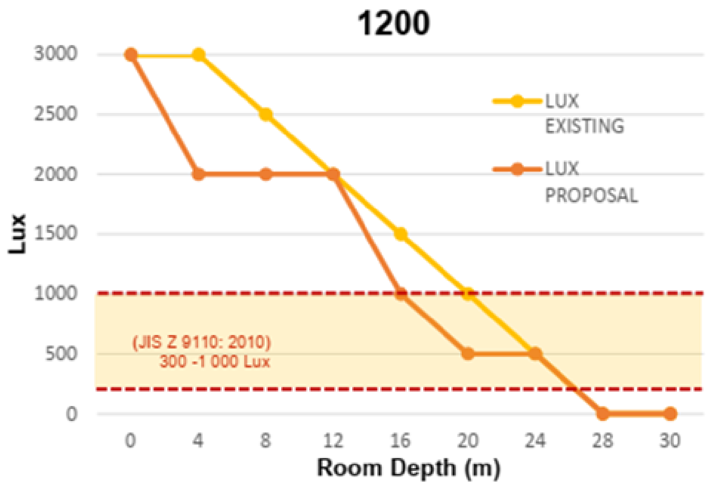

**Graph 2.0 The existing double glazed glass wall achieved optimum illumination at 16m to 24m depth while proposal additional external louvres achieved optimum illumination at 8m to 24m depth at 9.00 a.m., 21st March 2023.**



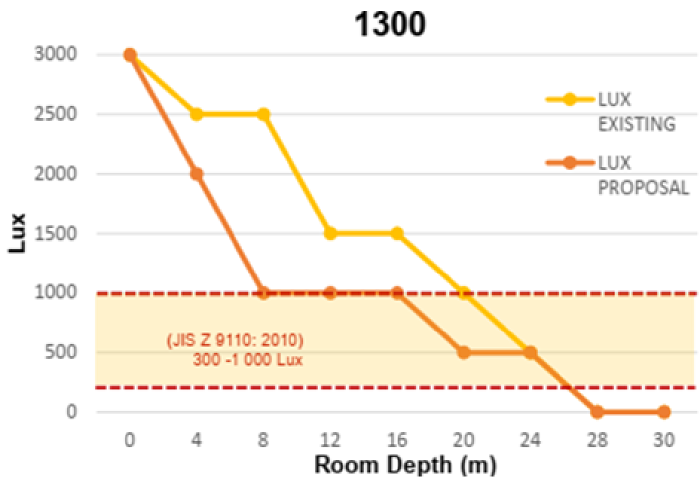

**Graph 3.0 The existing double glazed glass wall achieved optimum illumination at 20m to 24m depth while proposal additional external louvres achieved optimum illumination at 12m to 24m depth at 10.00 a.m., 21st March 2023.**



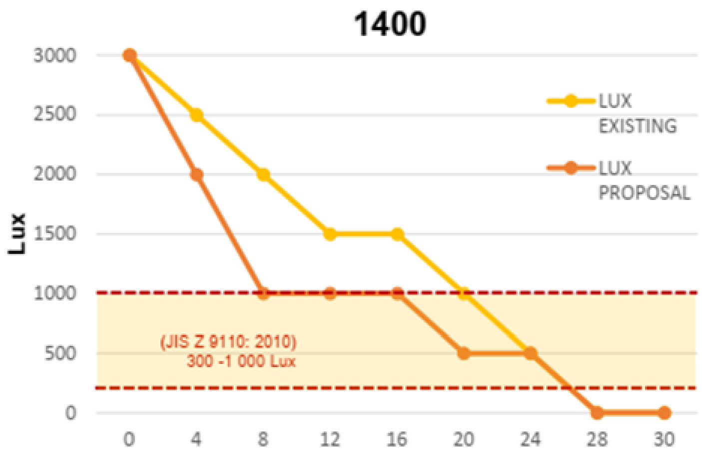

**Graph 4.0 The existing double glazed glass wall achieved optimum illumination at 20m to 24m depth while proposal additional external louvres achieved optimum illumination at 12m to 24m depth at 11.00 a.m., 21st March 2023.**



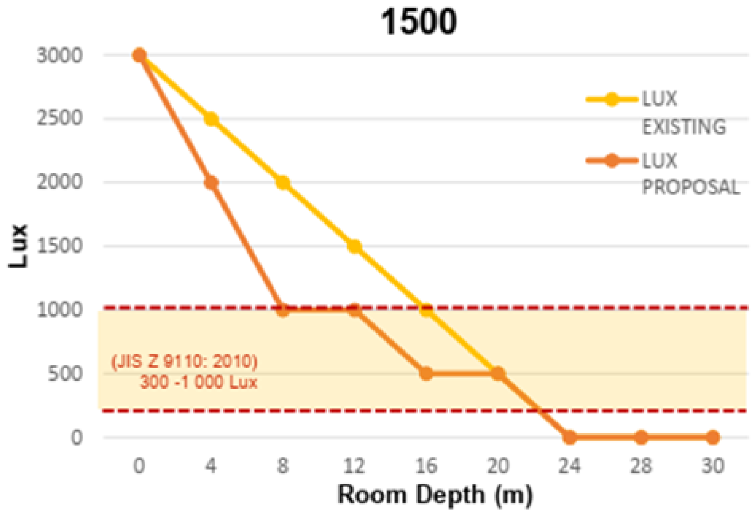

**Graph 5.0 Shows the existing double glazed glass wall achieved optimum illumination at 20m to 24m depth while proposal additional external louvres achieved optimum illumination at 16m to 24m depth at 12.00 p.m., 21st March 2023.**



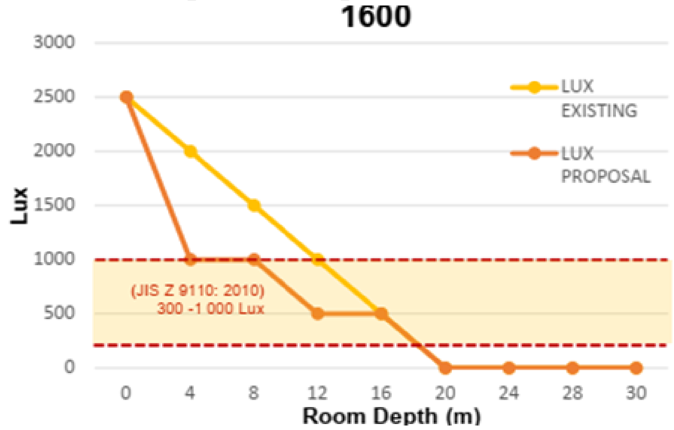

**Graph 6.0 Shows the existing double glazed glass wall achieved optimum illumination at 20m to 24m depth while proposal additional external louvres achieved optimum illumination at 16m to 24m depth at 1.00 p.m., 21st March 2023.**



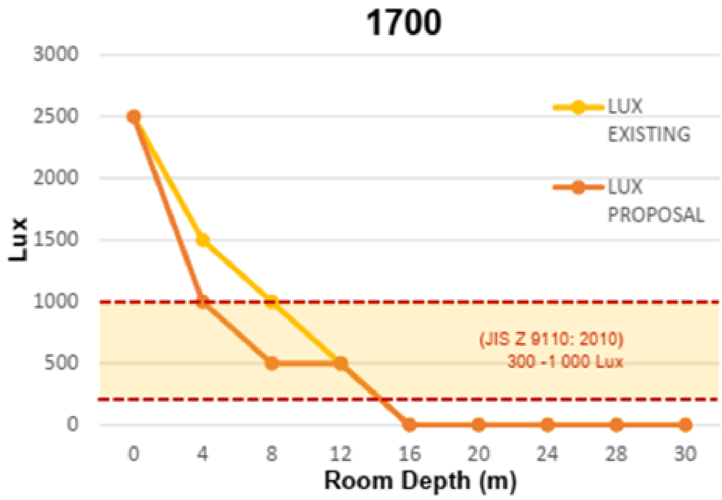

**Graph 7.0 Shows the existing double glazed glass wall achieved optimum illumination at 20m to24m depth while proposal additional external louvres achieved optimum illumination at 8m to 24m depth at 2.00 p.m., 21st March 2023.**



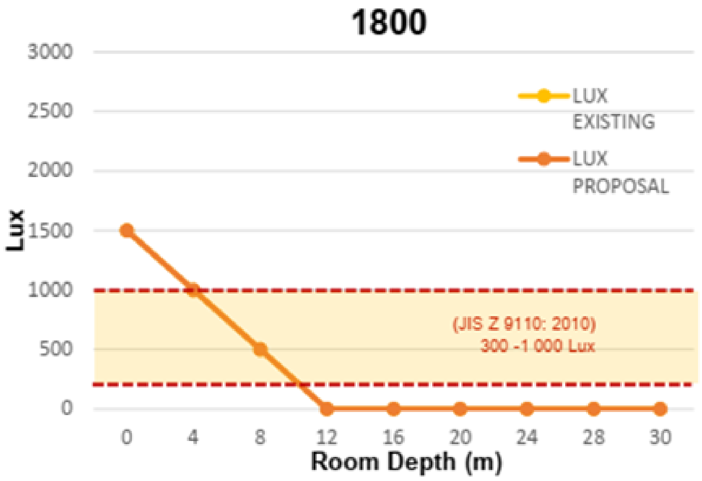

**Graph 8.0 Shows the existing double glazed glass wall achieved optimum illumination at 16m to 20m depth while proposal additional external louvres achieved optimum illumination at 8m to 20m depth at 3.00 p.m., 21st March 2023.**



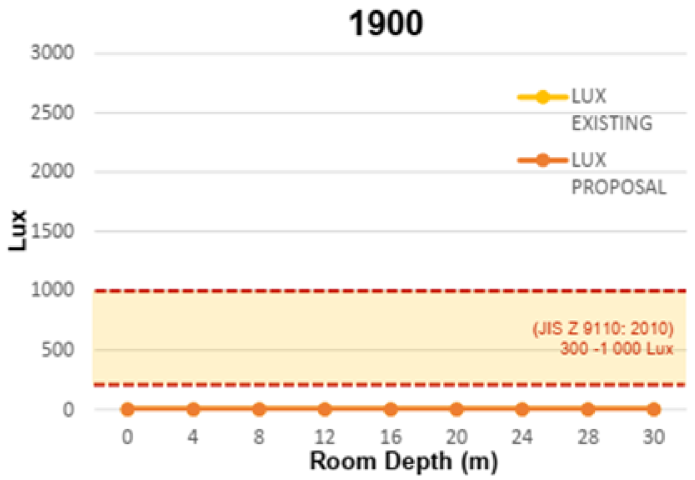

**Graph 9.0 Shows the existing double glazed glass wall achieved optimum illumination at 12m to 16m depth while proposal additional external louvres achieved optimum illumination at 8m to 16m depth at 4.00 p.m., 21st March 2023.**



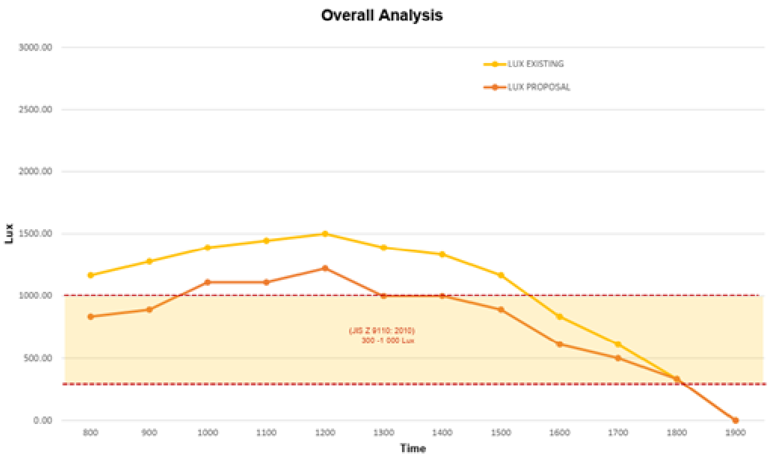

**Graph 10.0 Shows the existing double glazed glass wall achieved optimum illumination at 8m to 12m depth while proposal additional external louvres achieved optimum illumination at 4m to 12m depth at 5.00 p.m., 21st March 2023.**




**Graph 11.0 Shows the similarity of data existing double glazed glass wall achieved optimum illumination at 4m to 8m depth while proposal additional external louvres achieved optimum illumination at 4m to 8m depth at 6.00 p.m., 21st March 2023.**




**Graph 12.0 Shows the existing double glazed glass wall and proposal for additional external louvres did not achieve optimum illumination at 7.00 p.m., 21st March 2023.**



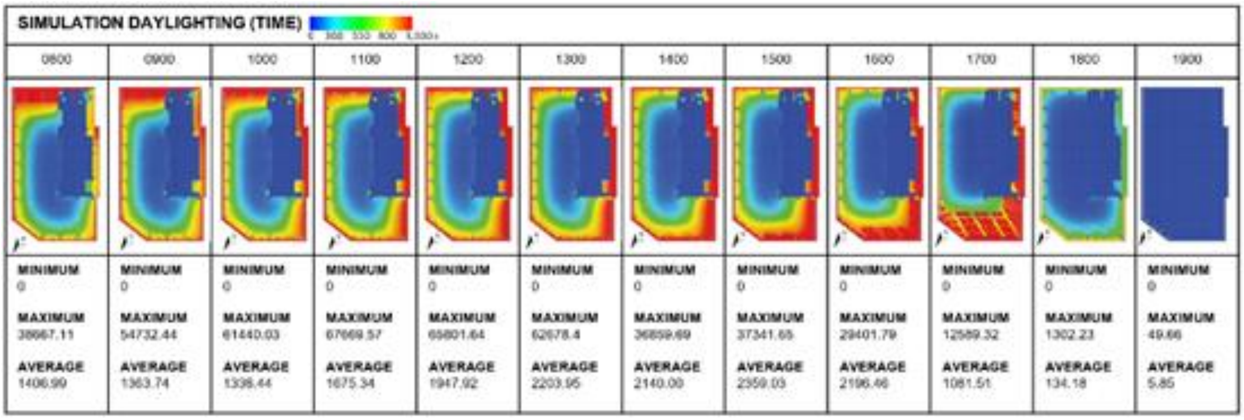

**Graph 13.0 Shows the existing double glazed glass wall achieved optimum illumination at 1600 (4.00p.m) to 1800 (6.00p.m) depth while proposal additional external louvres achieved optimum illumination at 0800 (8.00a.m) to 0900 (9.00a.m) and 1300 (1.00p.m) to 1800 (6.00p.m) depth from 8.00a.m to 7.00p.m (11 hours)., 21st March 2023.**

In general, from the findings shown in graphs 1 through 12, it shows both buildings receive enough daylight to penetrate the residential building except from 6:00 until 7:00 pm. From the graph above we can see that every data indicated below from ideal illumination requirements need to be supported with artificial light in a way to increase performance of the room and give good quality of comfort level interim of lighting. Meanwhile, every data that indicates above from the ideal illumination requirement need to add daylighting control strategy through roller blind, plant tree, louvres, tinted glass etc. to reduce glare. From Graph 1-13, the simulation result is simplified in Table 3 and 4 for both buildings. Tabulation of data in Table 3 and 4 shows the significant or major changes that can be seen in simulation of daylighting;

a) result of simulation on 3D model;

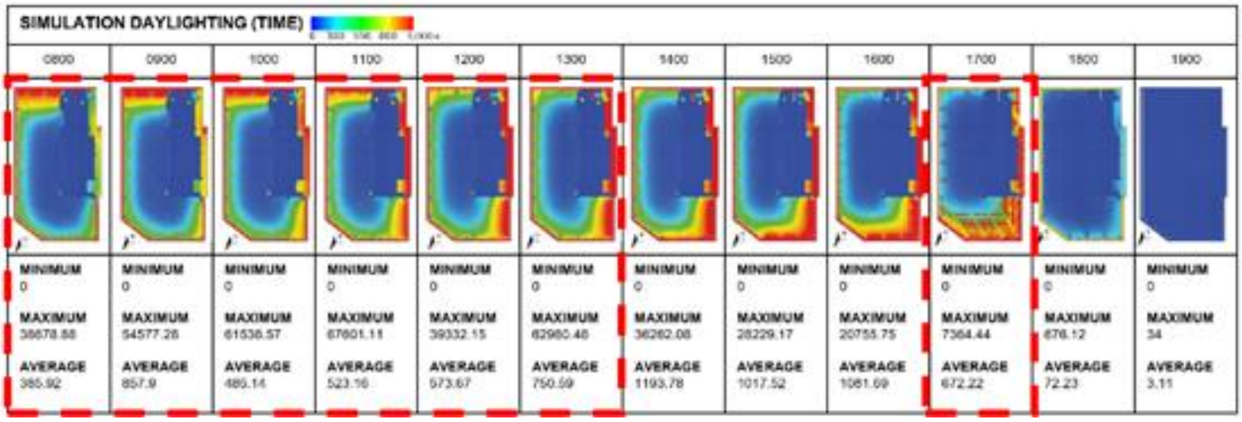
b) the maximum and minimum illuminance reading;

c) average illuminance reading in the area.



| SIMULATION DAYLIGHTING (TIME) | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MINIMUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAXIMUM | 38667.11 | 54732.44 | 61440.03 | 67669.57 | 65801.64 | 62678.4 | 36859.69 | 37341.65 | 29401.79 | 12589.32 | 1302.23 | 49.66 |
| AVERAGE | 1406.99 | 1363.74 | 1338.44 | 1675.34 | 1947.92 | 2203.95 | 2140.00 | 2359.03 | 2196.46 | 1081.51 | 134.18 | 5.85 |

**Table 3.0 Simulation daylighting report for existing design.**



| SIMULATION DAYLIGHTING (TIME) | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MINIMUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAXIMUM | 38678.88 | 54577.28 | 61536.57 | 67601.11 | 39332.15 | 62980.48 | 36262.08 | 28229.17 | 20755.75 | 7364.44 | 676.12 | 34 |
| AVERAGE | 385.92 | 857.9 | 486.14 | 523.16 | 573.67 | 750.59 | 1193.78 | 1017.52 | 1081.69 | 672.22 | 72.23 | 3.11 |

**Table 4.0 Simulation daylighting report for proposal design.**

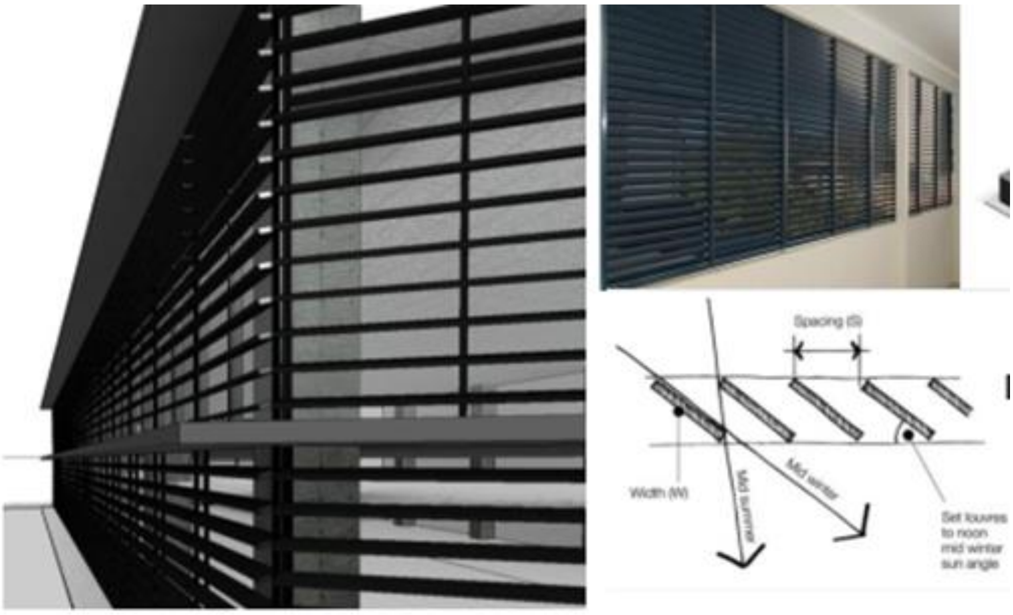



**Figure 3.0: The images for the proposed external louvre façade as a shading device.**

## 5. Conclusion

As a conclusion, this study reveals that the existing design does not effectively utilise natural daylight to provide optimal comfort for the office workstation area, as recommended by the Japanese Industrial Standard (JIS Z 9110, 2010) for lighting levels. This is reflected in the LEED scorecard, where the building did not score effectively at the "Indoor Environmental Quality" category, specifically EQc6: Controllability of systems – thermal comfort and EQc8.1: Daylight and Views - Daylight. The use of full double-glazed walls may contribute to a modern and aesthetic appearance, but it compromises the primary function of the building, which is to provide a comfortable working environment that supports the well-being of its occupants.

Simulation data demonstrates that the addition of external louvres, acting as shading devices, helps to reduce direct sunlight penetration into the building, which can cause discomfort and heat gain. The average daylight illumination level from the existing facade is 1057.04 lux, which decreased to 791.67 lux with the proposed facade incorporating shading devices. These daylight levels meet the recommended requirements, with the optimal range being between 300 lux and 1000 lux.

In conclusion, architects and daylighting specialists need to conduct research, perform site analyses, and be mindful of the site context to achieve sustainable design aligned with the vision of Sustainable Development Goals (SDGs). In order to meet this goal, designers must strive to achieve appropriate average illumination levels that align with the recommended standards outlined in JIS Z 9110, 2010, without compromising the primary purpose of creating a space that serves its occupants. This approach will ultimately lead to improved productivity and lower energy consumption.

## 6. References

1. Mayhoub, M.S. & Rabboh, E.H. Daylighting In Shopping Malls: Customer's Perception, Preference, and Satisfaction. Energy and Buildings. 2022 January 15. Vol. 255.
2. Htet, A., Liana, S.R., Rani, S.Y., & Bhaumik, A. The Effectiveness of Daylight Management in Building: A Review. AIP Conference Proceedings. 2023 August 24:1-7.

3. Abdullah, W.N.H.W., Tharim, A.H.A., Ismail, A. & Ahmad, A.C. Determination of Design Solutions to Overcome the Daylighting Design Failure Observed in Existing Educational Building. International Journal of Sustainable Construction Engineering and Technology. 2022 13(2) :153-167.
4. Khairi, N.H. The Importance of Natural Lighting in Buildings and Its Guide. European Journal of Agricultural and Rural Education. 2021 2(6): 1-4.
5. Yunitsyna, A. Evaluation of the Visual Comfort and Daylight Performance of the Visual Art Classrooms. Journal of Daylighting. 2023 10(2023): 117-135.
6. Fatma S. Hafez, Bahaaeddin Sa'di, M. Safa-Gamal & Y.H. Taufiq-Yap ,d , Moath Alrifaey. Energy Efficiency in Sustainable Buildings: A Systematic Review with Taxonomy, Challenges, Motivations, Methodological Aspects, Recommendations, and Pathways for Future Research. 2022 December 6. Vol. 45.
7. Rabee M. Reffat & Rehab M. Ahmad. Determination of optimal energy-efficient integrated daylighting systems into building windows. 2020 September 12. Vol. 209.
8. Yoshizawa, N., Mochizuki, E. & Iwata. Light Environment In Japanese Office Buildings After The 3.11 Earthquake-Field Measurements On Illuminance Levels and Occupants, Satisfaction. 10th International Conference on Healthy Buildings 2012. 2012 July 12. :114-119
9. Christine Blume, Corrado Garbazza & Manuel Spitschan. Effects of light on human circadian rhythms, sleep and mood. 2019 August 20. 147-156.
10. Light Stanza Website. Simulation software. https://lightstanza.com/
11. Tomohiro, H. Introduction to The Building Standard Law, Building Regulation in Japan, (Ver.July 2013). 2013 July. The Building Centre of Japan.
12. Bureau of Environment Tokyo Metropolitan Government. 2011. Low Emission Building TOP30 in Tokyo
13. Pzarch14. 2012. Daylighting + Architecture | The Daylight House, Yokohama, 2012. January 2012. https://pzarch14.wordpress.com/2012/11/13/daylighting-architecture-the-daylight-house-yokohama/
14. Autodesk. 2020. Autodesk Revit 2020.
15. Japanese Standard Association (JSA), Japanese Industrial Standards Committee. 2021 October 20, 2010 Edition.
16. United Nations Department Of Global Communication, Sustainable Development Goal, 2023 September.
17. U.S. Green Building Council, LEED rating system. 2020 August 23.
18. Nomura Real Estate Co. Tokyo Toranomon Global Square. 2023.