Daylighting simulation analysis for sun shading on hotel design in West Jakarta

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Abstract. The main objective for this paper is focused on an evaluation of sun-shading daylighting in a four-star hotel design mass. The daylighting has potential and considers as the best strategy for energy saving. Lowering energy costs can directly increase revenue, coupled with the potential for gradual increase in PLN electricity. Apart from financial and service benefits, saving energy is also a form of concern for the sustainability of the environment which has an impact on social life. The method that used in this paper is quantitative simulation, which is presented in the paper by specification of daylighting in a four-star hotel design on solstice day, 21st December. The simulation is done by Velux Daylighting Visualizer, with a couple of lost variables. The simulation for this condition represents two extreme cases for maximum and minimum daylight levels in annual evaluation.

Keywords: daylighting simulation, energy saving potential, Velux Daylighting Visualizer

1. Introduction
Daylighting became a minor architectural issue due to the availability of efficient electric light sources, cheap, abundant electricity, and the perceived superiority of electric lighting. Supplying adequate daylight to work areas can be quite challenging while electric lighting is so much simpler. It offers consistent lighting that can be easily quantified, but it has some serious drawbacks. The energy crisis of the mid-1970s led to a re-examination of the potential for daylighting. At first, only the energy implications were emphasized, but now daylighting is also valued for its aesthetic possibilities and its ability to satisfy biological and human needs.

According to ICED in 2014, the hotel sector at this time, the success of reducing energy costs can directly increase revenue, coupled with the potential to increase the price of PLN electricity gradually. Based on the data, PLN electricity energy used by hotels has an average of 76% in Jakarta. Of the 76%, 5% to 30% of electricity is used for artificial lighting. For this reason, natural lighting can contribute by reducing the use of electrical energy for lamps by providing adequate lighting at these light points. In addition, solar energy can also be utilized for generating electricity for factories (Mangindaan D, 2020) by employing solar panels.

In the Journal of Optimasi Sistem Pencahayaan dengan Memanfaatkan Cahaya (Nurhani A., 2011) that lighting is needed by humans to visually recognize an object, where implementing an efficient lighting system can save electricity and is profitable. This is because lighting or lighting consumes approximately 30% of the total energy in a building. Therefore, in the journal requires a lighting design strategy by optimally utilizing natural light.
2. Literature review

This study will be using Daylighting Simulation Analysis for Historical Hotel Rooms by Prof. Ing Jiri Hirs, CSc. and peers, 2019 IAPE, Oxford, as the main reference simulation journal. In this journal, the daylighting simulation evaluation is in a historical hotel rooms named Hotel Thermic, that located in the Spa Island in Piestany in Slovakia. The conclusion for this journal is the daylight simulations show importance of interior design for indoor visual comfort. There is also potential electric energy savings because of less consumption of artificial lighting in light-colored rooms. This journal used DIALux Evo 7.1 as the software for simulations.

In Journal the Performance of Daylight through Various Types of Fenestration in Residential Buildings (Sharifah Nor F. S. H. and Zarina Yasmin H. H., 2011) a good lighting strategy is needed to reduce the energy consumption of artificial lighting. To provide effective internal illumination, placing the right opening in the right position with the right type of window and glass is important. Research in this journal discusses various types and materials of glass and windows, to improve the quality of sunlight that penetrates residential buildings. Based on the assessment, it was identified that glass and windows had a significant influence on daytime performance and thermal performance in the residential building.

This paper outline is using Daylighting Metrics for Residential Buildings journal by Mardaljevic, J, as a guideline for the simulation process. The journal methodology is done by virtual laboratory with dwelling based on a real house which the design commonly found throughout Europe. The 3D model has separated area, which is coloured and named differently with horizontal calculation planes at table and work-top height.

3. Factors Affecting Daylight Performance

Based on the book Heating, Cooling, and Lighting Sustainable Design (Norbert Lechner, 2015), natural lighting is obtained with 3 designs, namely by orientation, forms, and color. In this study focus on the building type of opening, due to the most influential optimization of natural lighting. While other factor such as orientation, cannot be chosen due to the limited research by site limitation and building regulation; lighting through the roof, Jakarta unsupportive location will cause increasing temperature of the room; space planning, color and view and daylighting are not the main issues in this study.

a) Orientation
Because of the direct sunlight effect. Southern orientation is usually the best for natural lighting. The south side of a building usually gets the lowest sunlight and all day throughout the year.

b) Forms
The shape of the building can determine how many windows can be placed in each direction, the number of skylights or clerestories that can be placed on the roof, and how much lighting access in the area per floor. The forms contain five different forms from the Heating, cooling and Lighting Sustainable book by Lechner, 2015, but in this study, it will be focused on the second form from the theory, due to the lack of the outside views.

c) Color
The use of bright colors for indoor or outdoor to reflect more light into a building and further into the interior. Bright colored ceiling can add light entering from clerestory. White or bright colors on the exterior wall also enhance natural lighting. Brightly colored facades are very important in urban areas to increase the availability of solar lighting on the lower floors and sidewalks. Brightly colored interiors not only reflect light further into the building, but also spread to reduce dark shadows, glare, and excessive brightness ratios. The ceiling must have the highest reflectance factor possible. Floors and small pieces of furniture are the most critical reflectors and, therefore, may be a low reflecting factor (dark finishes)
4. Velux Daylight Visualizer Parameters

In this simulation software, there are several attributes that tie into building design and natural lighting, these attributes can be described as follows.

a) **Material**
   Velux materials consist of Plastic, Wood, Stone, Fabric, Organic, Metal, Window Glass, Solid Glass, Light Diffuser, and BSDF. List of materials that can only be selected and simulated on the Velux Daylight Visualizer.

b) **Color / Surface**
   This surface is based on the above material, where on Plastic there are several colors, namely White paint, Beige paint, Light Gray paint, Yellowish Paint, Greenish Paint, Light Blue paint and White Polyurethane and the finishing on each color is divided into two, namely matt finish and semi-gloss finish. The choice of plastic also includes different reflectance, roughness and specularity.

c) **Location**
   The locations in this simulation consist of several big cities such as Amsterdam, Buenos Aires, and so on. However, there are no cities in Jakarta or Indonesia, for this reason, Singapore is used in this simulation, where the city has the same climate as Jakarta.

d) **Orientation**
   The simulation in the Velux Daylight Visualizer software can be reset to match the site location used, from 0° to 359°.

e) **Sky Conditions**
   Sky conditions on Velux are divided into three, namely Sunny, Intermediate and Overcast, where on Sunny, the sky is cloudy, Intermediate is a little cloudy or within normal limits, and Overcast the sky is cloudy.

f) **Month (time)**
   This Month, software users can choose January to December on the 21st. This month is based on the Annual Pseudo Motion of the Sun, in the book Science of Astronomy Sailing for ANT III and IV by Cahya Fajar Budi Hartanto, M.Mar. namely June, September and December.

g) **Hour (time)**
   At this time, users can fill in the hours according to their wishes, from 00.00 to 23.00, from minutes 00 to minutes 59.
   This research uses 08.00, 10.00, 12.00, 14.00 and 16.00 hours to simulate a four-star hotel, at which time the hotel has active users.

5. Lux Standard based on ICED 2014

Based on the provisions in the Practical Guide to Energy Saving in Hotels by ICED (2014), it has a minimum standard of lighting for different hotels (Table 1).

| Room function      | Lighting level (Lux) |
|--------------------|----------------------|
| Reception room     | 300                  |
| Lobby              | 350                  |
| Multi-purpose room | 200                  |
| Meeting Room       | 300                  |
| Dining Room        | 250                  |
| Cafetarias         | 200                  |
| Bedroom            | 150                  |
| Corridor           | 100                  |
| Kitchen            | 300                  |

*Source: A Practical Guide to Energy Efficiency in Hotels, ICED 2014*
6. Methodology
6.1. The method of study
The methodology of this study is quantitative analysis methods using simulation methods. This simulation method is done in the presence of the dependent variable and the independent variable. The independent variables in this project are site size, maximum length and width of the site, and site index. The dependent variable in this study is the orientation, the size of the building opening, the mass of the building, the color of the building and the shading around the site.

This simulation method is carried out with the Velux Daylighting Visualizer software with the variables in the software, among others, material, color, orientation, location, sky conditions, time of month and time of day.

6.2. Outline
The 3D model for the four-star hotel is shown in Figure 1. The 3D model shows the building design has window size 1.2 x 3.2 m with clear distance of 1.2 m as wall of the building. The coloured areas in the plan view show the horizontal calculation planes where illuminance was predicted. The spaces evaluated were, the lobby (wg01), the dining room (wg02), Cafetarias or lounge (wg03), and room corridors (wg04). The calculation planes are at 1 meter above the floor level for every room, with the highest point of the floor level.

![Figure 1. Images of plans and 3D of the subject of daylighting simulation analysis.](image)

6.3. Simulation window opening with sunshading
The study involved in making a simulation with the four-star hotel design that was designed by the peers with four-story height and with single slab system, to find out the optimal composition for the natural lighting design. The opening of window 1.2 x 3.2 m will be simulated with Velux daylighting visualizer due to the relevant research for the indoor daylighting for the luminance, illuminance, and daylighting factors information.

7. Result and Discussion
7.1. General Discussion of West Jakarta, Indonesia
The site of this study located at Roa Malaka, West Jakarta, Jakarta Capital City, Indonesia. Figure 2, where it is shown that Jakarta located at Java Island just below the equator line.
Historically, West Jakarta is one of DKI Jakarta's tourism destinations, wherein the region there are several heritage buildings or historical relics of Jakarta during the Batavia era. One of the tourism areas that are famous for old buildings is Jakarta's Old City, wherein the region there is the Fatahillah Museum, the Ceramics Museum, and the Wayang Museum.

At present, the tourism sector is one of the important economic sectors in Indonesia and has been determined to be one of the priority sectors (leading sector) in Indonesia's development for the 2015-2019 period. That resulted, the government will develop the Kota Tua tourism area as a national tourism destination. (regional.kontan.co.id, July 2019).

7.2. Site Condition
This site is located on Jalan Kali Besar Timur, Roa Malaka, Tambora, West Jakarta. It has an area of 5,200 sqm, with KDB: 75, KLB: 3.00, KB: 4, KDH: 30, and KTB: 55. In this area, there are no buildings that have basements, and also very minimal use of parks. On the site, there is an athlete's homestead, an old warehouse and a restaurant that has been closed for a long time. The condition of this site will be described as follows. In the south there is an old building which has a height of 2 floors. On the north side of the site there is a Mercure hotel which has a height of 2 floors at the front and 9 floors at the rear. On this site it is close to the Intan Bridge, which is one of the tourist attractions of the old city.

7.3. Simulation daylighting window opening without sun shading
The simulation is on the 3D model above, with window size 1.2 x 3.2 meters and clear distance 1.2 meter each window. The percentage from this calculation is 50%, due to the clearance and window size are on the same size.

The building 3D made by simulations using SketchUp for the massing and Velux Daylighting Visualizer for the outcome. The orientation of this long size of the site is facing the north and south, which is good for the building opening since majority will be facing south or north. Due to the environment conditions, its unsupportive to the outside view. There is also shadowing of other buildings, which is why the building form following its site.

This study simulation will start from 8:00 AM and 16:00 PM, to accumulate the best daytime opening options and the simulation is carried out on the mass composition of the hotel measuring 81 x 44 meters with a height of 5 meters for the ground floor and first floor, while 4 meters for second until third floor using. In this simulation also using 78% sunlight transmitted for the windows.

This simulation also uses a matte white color for the main material in the overall mass composition. When rendering natural lighting, this simulation is also placed at its location, namely Roa Malaka, assuming the same height of the composition as the surrounding buildings.
6

Table 2. Lux measurement from window 1.2 x 3.2 m²

| Hour Average | Ground Floor | First floor | Second Floor | Third Floor |
|--------------|--------------|-------------|--------------|-------------|
| 08.00 Ave.   | 702.9 lux    | 120.0 lux   | 339.5 lux    | 365.4 lux   |
| 10.00 Ave.   | 416.2 lux    | 513.1 lux   | 578.1 lux    | 649.7 lux   |
| 12.00 Ave.   | 424.7 lux    | 594.6 lux   | 607.7 lux    | 694.8 lux   |
| 14.00 Ave.   | 406.1 lux    | 528.2 lux   | 600.8 lux    | 620.9 lux   |
| 16.00 Ave.   | 252.5 lux    | 296.6 lux   | 342.8 lux    | 362.7 lux   |

The results of the measurement of natural lighting lux from simulations (Table 2) of the two different sizes, namely 1.2 x 2.4 m, and 1.2 x 3.2 m between 8:00 AM to 16:00 PM, are the average lighting in the building over time. From the one-hour average lux, 1.2 x 2.4 m does not meet the required average lux standard, where there’s plenty blue color which means that the lighting is very minimal, is more dominant than all colors, where the minimum lux standard is determined by the government through SNI is 100 lux.

Table 3. Simulation results from window 1.2 x 3.2 m²

| Leveling    | Time              | Average on the mass | Average from times |
|-------------|-------------------|---------------------|--------------------|
| Ground Floor| 08.00 AM – 16.00 PM| 252.5 – 424.7 lux   | 348.58 lux         |
| First Floor | 08.00 AM – 16.00 PM| 296.6 – 594.6 lux   | 447.76 lux         |
| Second Floor| 08.00 AM – 16.00 PM| 339.5 – 607.7 lux   | 493.78 lux         |
| Third Floor | 08.00 AM – 16.00 PM| 362.7 – 694.8 lux   | 538.70 lux         |

7.4. Discussion
The best form of the ICED recommendation is a window wall size of 1.2 x 3.2 meters for natural lighting in hotel compositions (Table 3), because only this size reaches the average standard of lux per room, the minimum recommendation for ICED is 348.58 lux on the ground floor for public spaces such as lobbies, fitness areas, restaurants, lounges and corridors which require the most lighting of 350 lux, 300 lux, 250 lux, 200 lux and 100 lux.

7.5. Simulation daylight window opening with sun shading
Based on previous simulations, it can be seen that the inclusion of natural lighting is still excessive in the lobby on the ground floor which reaches 750 lux, the corridor on the second and third floors reaches 378 lux, and the guest rooms whose average lux reaches 250 lux. However, the inclusion of excessive natural lighting is not evenly distributed, as in the southwest and northeast. This simulation is carried out at 14.00 to get the highest level of lux and 08.00 to get the lowest level of lux in the building. This simulation is based on getting different sizes of sun-shading and glazing on each floor. This research was examined from 4 sides, namely the outside of the building. The side used was the Southeast side, the Northeast side, the Southwest side, and the Northwest side which was applied to the camps.

From Table 2 and Table 3, it can be seen that there are two types of sun-shading, namely the perforated type and the fin wall type. This Perforated type is applied to the highest points of the building mass, namely on the 2nd and 3rd floors of the northeast and southwest, which in the above view are the south and north views.

For the fin wall type, there are also two sizes, namely 500x30 mm and 200x60 mm, where the size of 500x30 mm is used on the 2nd and 3rd floors of medium lighting income points and 200x60 mm is used mostly on the ground floor, at the highest point. The following is the inner face showing the placement of sun-shading. The inner face is divided into 4 sides.

At the front elevation, can be seen in the previous simulation, this glazing changed from 78% to 42% to reduce lux from 1,200 to 700 lux. However, the lux is still excessive, for that we use sun-shading with a size of 200x60 mm with a slope of 30°. This got the right result, namely 316.8 lux where the required lux in the lobby is 350 lux.
On the second side or Southwest side, the ground floor does not use sun-shading because the area has an over stack from the ballroom. The ballroom on the first floor also does not use sun-shading because of the high need for lux. The room program on the third side or Northeast side, is Restaurant and Lounge, which require quite high lux, namely 250 lux and 200 lux. On the Ground Floor, there is no need to add sun shading. The fourth side or Northwest side can be seen, on floor one through three, has a sun-shading fin-wall of a size of 500x30 mm with a clearance of 470 mm. The red part has a high level of lux, so the clear sun-shading distance in that area is reduced to 270 mm.

8. Conclusion

The study of daylighting simulation shows the importance of sun shading, glazing windows for indoor visual comfort. Due to the lux differential in every room, the outcome for the sun shading and glazing following the needed lux in the room. The conclusion from the simulation can be included as follow:

- The daylighting difference outcome from window with heavily and light sunshade
- The daylighting contribution percentage from Velux simulation

This study shows that the use of natural lighting can be used in the design of a four-star hotel in a hotel, because the site chosen supports the application of natural lighting. The wide façade of the building facing north, and south is one of the conditions that the design is adequate for natural lighting. This research also produces the best building mass to obtain optimal natural lighting. This study is following the process of the Daylighting Simulation Analysis for Historical Hotel Rooms, by Prof. Ing Jiri Hirs, CSc, in 2019. Using 3D simulation as a research of the subject with maximum and minimum hour of daylighting and that is 8:00 AM and 16:00 PM.

The objective of this research is to find the percentage of the daylighting contribution for the building. From the simulation, can be concluded that the contribution of the daylighting in four-star hotel at 8:00 AM and 16:00 PM is approximately 80% until 98% on the public areas. In summary, this represents reduction of more than 800 kWh electrical energy annually.

Research suggestions for various parties are to conduct research that has not been carried out by the author, namely simulating solar lighting radiation obtained by the building mass. In this research, the authors did not discuss the radiation or heat obtained in the building mass. For that, it is necessary to reread about research theory and how to do research that comes from books, journals, and other things.

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