Lighting Optimization for Reused Building; Case Study of PLN Convention Hall, Soekarno Hatta, Bandung

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Abstract. Changing the function of a building can have an impact on the lighting required for the installation. This research aims to simulate and compare the need for optimal natural lighting and reduce artificial lighting in a building that functions as a Sports Hall. PLN Sports hall will be redeveloped into the PLN Convention Center Building in Soekarno Hatta Bandung. WWR is a suggestion for optimization without changing the structure and architectural aspects of the building. The analysis is based on lighting and shadow from the Energy Plus Weather File, and then these parameters are processed using honeybee to create more precise WWR variables. Lighting analysis is simulated with two building functions: namely the variable time and different ranges, following the Illumination Standards by IES and SNI. This study's results are divided into four simulations and three various iterations where the existing conditions have an area below 300 lux as much as 93.45%. For natural lighting below 300 lux, it is 60.94%. With the placement of openings based on optimum radiation analysis, artificially below 300 lux is 2.3% (already enter the category of adequate - well lit) and a combination of under 300 lux by 0.30%. The existing conditions are categorized as underlit, iteration 1 is adequate, and iteration 2 and 3 are in the well-lit category.

Keywords: natural lighting, simulation, wwr, grasshopper, honeybee, comparison

1. Introduction
Re-designing an old building generally occurs in Indonesia. Building redesign is changing the appearance or function of a building [1]. PT PLN plans to change the building's role, which was initially a sports building, into a convention center. The convention is defined as a place for meeting people. Its purpose is to exchange ideas, opinions, and information on a common concern or problem from a group. Conventions are generally about providing information packaged in a topic, and usually, there is an exhibition in it [6].

However, one crucial factor in changing the building's function will become natural lighting and artificial lighting. For this reason, applying lighting to buildings must be considered carefully to produce a good performance. The benefits of lighting are needed, especially in buildings that have a function as an exhibition venue. Some standards that need to be considered in designing the light in this convention center are the room's function that uses the projector, which requires dim light intensity. So it is less
It is advisable to use natural lighting. However, it is highly recommended for natural lighting in the exhibition area because the room is spacious and for efficient energy use. [6]

Natural lighting is lighting that the light source comes from the sun. Because the sun is the only source that produces natural light (daylight) accompanied by heat energy [2], it introduces natural lighting through openings in buildings [3]. Sunlight has the advantage that they are natural, available free of charge, renewable, and used for therapy. But besides the benefits, it can have disadvantages, namely their unregulated intensity and heat into the room.

Artificial light comes from human-created tools, such as incandescent lamps, candles, kerosene lamps, and torches. Artificial light is undoubtedly necessary because we cannot depend entirely on the availability of natural light. Therefore, artificial light is needed to complement natural light, not a substitute for natural light. It requires even light over a vast space. If the spacious room uses a transparent top to get sunlight, this is not recommended in tropical areas because it will make the room very hot.[lechner]

The illuminance of some of the lumens from a light source will illuminate a particular surface. A meaningful comparison of various illumination schemes is possible only when comparing the light falling on equal areas. Therefore, illumination is similar to the number of lumens falling on each square foot (meter) of a surface. The illumination unit is the footcandle (lux)[3].

WWR is a suggestion to optimize the previous building for a redesign without changing the structure and architectural aspects. Processed using Ladybug, Honeybee, and Butterfly can also perform thermal simulation (CFD) through the available openings. The resulting data will become a recommendation for lighting design in new buildings without changing the structure and architectural aspects of energy use.[8]

2. Literature review (Illuminance standards)

In designing a building's lighting, several standards regulate the amount of light that needs to enter the building. The following are some of the measures that can be used to design a convention hall building's lighting to function as an exhibition and auditorium.

| Building Type       | Space Type       | Maintained Average Illuminance at working level (lux) | Measurement (working) Height (1 m - 3.3 feet) |
|---------------------|------------------|------------------------------------------------------|---------------------------------------------|
| Office Buildings    | Single Offices   | 400                                                  | at 0.8 m                                   |
|                     | Open Plan Offices| 400                                                  | at 0.8 m                                   |
| Conference Rooms    |                  | 300                                                  | at 0.8 m                                   |

*Source: IESNA 9th edition, 2000 [4]*

| Building Type     | Maintained Average Illuminance |
|-------------------|--------------------------------|
| Exhibition rooms  | 300                            |

*Source: SNI 03-2396-2001(2001) [5]*
Table 3. Illumination Standards by Book “Conference, Convention, and Exhibition Facilities”

| Building Type   | Maintained Average Illuminance |
|-----------------|-------------------------------|
| Exhibition halls| 500                           |

*Source: Lawson, F., 1981. [6]*

3. Method

This research is a quantitative descriptive study comparing the simulations carried out and regulations regarding natural and artificial lighting in a building that has changed its function. In changing the role of a building into other functions, natural lighting and artificial lighting are some of the things that influence it.

![Diagram of simulation process](image)

*Figure 1. Convention Hall Floor Plan*

Using The Richoneros application with a grasshopper plug-in as a medium for simulation is supported by honeybee and ladybug (Figure 1). For simulating natural lighting using illuminance, WWR (ratio between opening and wall size). Then for artificial light using the IES (Illuminating Engineering Society) file as the lighting source. In the end, a comparison using the table below for each simulation and regulation shows that optimal lighting recommendations are obtained for buildings that have changed function as a convention center (Table 4).

Table 4. Lighting Levels

| Status       | Maintained Average Illuminance |
|--------------|-------------------------------|
| Under-Lit    | 100 – 300 (200) lux           |
| Adequate     | 300> lux                      |
| Well-Lit     | 500> lux                      |

*Source: IESNA 9th edition, 2000 [4]*
3.1. Object Data
The research method used is a simulation of the study object that will undergo a redesign, namely the PT PLN sports building, into a convention center. This building is located in Bandung, located at Jalan Soekarno Hatta No.436. The convention center building is a building that will be built by PT PLN to provide a new function so that its use is more optimal. This building has an area of 1375 m2, which will later function as a show and exhibition.

![Figure 2. (a) Bandung City Maps; (b) Building Location](image)

The context in the surrounding buildings is only shrubs and even there are no low-context buildings around it. With a height of up to 12m and a spacious interior it creates an inner dark surrounding. Also the use of a double facade at the top of the building covering the four directions of the building. This is used as an input to the grasshopper context. The interior of this building is generally divided into 3, namely the main stage area - visitors, backstage, and maintenance area (toilet).

![Figure 3. Convention Hall Floor Plan](image)

![Figure 4. Convention Hall Elevation](image)
Bandung Climate Profile.
The thermal profile of Bandung has a Dry Bulb Temperature, which is the air temperature measured by a thermometer that is freely exposed to the air at 19.29°C with the highest temperature reaching 27.4°C and the lowest at 12.7°C. Then there are also aspects such as Dew Point Temperature, which is the temperature that must be cooled by air (at constant pressure and constant water vapor content) to achieve excellent saturation. Bandung has an average dew point temperature of 15.98 °C with a range between 10.3 °C as the lowest limit and 20.8 as the highest limit. Then with an average humidity of 82.29% with a minimum threshold of 41% and a maximum of 100%.

For direct solar radiation in the city of Bandung has an average of 121.37 Wh / m2, with the hottest radiation reaching 1054 Wh / m2 and natural luminance with an average of 11,300 Lux.
3.2. Study Parameters

This simulation's initial stage is to determine the weather file; the standard file used is the EnergyPlus Weather File. EPW itself is a standard format used and validated by the US Department for Energy (DOE). The file contains weather data that is used as simulation parameters. It can also reduce EPW data to graphs and tables (3.3. Bandung Climate Profile). [10]

Furthermore, the model is converted from a version of the mesh and geometry brep into an HBZone (HoneyBee Zone), where at this stage, the determination of the roof, walls, context, and openings occurs. In this stage, the determination of RAD Material was also carried out and divided into two categories, namely opaque with the type of tangible objects and opaque and translucent with open and permeable properties (RGB transmittance 0.6 - Stopsol glass). At this stage, the WWR (Window to Wall Ratio) determination is also carried out. [11]

Furthermore, the sky-based model's determination is based on the EPW file and analysis period, namely months, days, and hours. It produces direct and diffuse sunlight radiation (natural 0.0 diffuse 76.0) and sky file path that time phase.
The model is simulated using the Honeybee daylight simulation component, and there are three types of simulations in this component, namely to look for illuminance (lux), radiation (kWh), and luminance (candela). [12] This simulation uses the illuminance type search.

The results obtained are illuminance values, test points, radiation geolocation files, and a RunRadSim script. Can be obtained The average, minimum, and maximum bounds based on the simulation results. If the simulation uses artificial lighting, it uses a component annual result with inputs in occupancy files (generators), IES Luminaire, and the Lighting Control Group.
The simulation results are then converted into a grid-based mesh, and the data is compared with the illuminance results. Then the area that meets the lux (parametric) standard is compared with those that do not.

4. Findings and Discussion
4.1. Study Parameters
The initial stage of working on the existing building model is made in the rhinoceros file format and simulated using grasshopper and ladybug/honeybee for the building’s thermal and lighting conditions, then using a butterfly to simulate building ventilation.

![Figure 12](image)

**Figure 12.** (a) Total Cover Area; (b) Grasshopper Interpretation

Designed in the early stages as a sports hall, the need for natural lighting and lighting was not a priority, but the ventilation was still the main focus in the building's design performance. The floor or building area is 1375 m², and the illuminance or lux area that must be met is 200 lux / m², and if used as an exhibition area, the minimum must have 300 lux / m².

The simulation results show that from the total area of 1375 m². The area under 200 lux amounts to 1285 m², then those below 300 lux are 1287 m², and those below 500 lux are 1303 m². The percentage is relatively high, 91.78% below 200 lux, 93.45% under 300 lux, and 98.61 below 500 lux. A built-in opening is 332 m² compared to an entire wall of 4044 m² (WWR coefficient 0.082 against coefficient 1). The results obtained have an average luminance of 94.91 Lux, then a maximum limit of 5830 Lux and a minimum limit of 0.2 Lux. Natural lighting sources only appear from 2 points, namely North and South, with an average coefficient of incoming light of 5 Lux. [12]

![Figure 13](image)

**Figure 13.** (a) Illumination analysis in existing

The simulation results of a total space area below 300 lux more than 65% can be seen in the image above, creating a dark space, especially in the middle of the room and the supporting room with average lighting only reaching 15 lux. Therefore, this sports building does not have optimal lighting if its function is to become a convention center building. It takes the installation of 300 lux for both exhibition and performance functions without changing the structural and architectural aspects.
4.2. **Iteration 1: Optimization of Natural Lighting**

After knowing the existing database (existing building), the next step is to create iterations based on standard requirements and optimizing iterations. One of the iterations is to optimize natural lighting and ventilation and reduce artificial lighting. By looking at the previously existing conditions where an area of 1011 m², which does not meet the standards of a total area of 1375 m², is a relatively high number of the dark regions. Reducing/replacing dead walls (brick/opaque) and replacing them with more adaptive openings, such as wood lattices or filigree/openwork.

![Figure 1](image1.png)

**Figure 14.** (a) Replacement/ alternative material, (b) New material emplacement

For prototype sampling, the replacement material has specifications for fiber-reinforced wood (Conwood) with a size of 50 x 20 mm with a partition height of 3.7 m. Based on the radiation simulation, for the most optimal lighting. It must place at points A, B, C, and D. the specification replacement of dead wall material (brick/opaque) into wooden lattices occurs at points A (15 m), B (14 m), C (15 m), and D (15 m).

The simulation results show that from the entire area of 1375 m², the area under 200 lux is 563 m², then those under 300 lux are 838 m², and those under 500 lux are 1004 m². The percentage is relatively low, 40.94% below 200 lux, then 60.94% below 300 lux, and 73.01% below 500 lux. Then, the results are with a default opening of 332 m² compared to the number of walls of 4044 m² (WWR 0.082). It has an average illumination of 136.30 lux, a maximum limit of 50.60 lux, and a minimum limit of 313.99 lux.

![Figure 2](image2.png)

**Figure 15.** (a) Illuminance Analysis Results

The results obtained are optimal because the total space area is below 300 lux below 65% (the simulation releases an opening of 60%). Can see it in Figure 15, the incoming light creates space but with the COV (Cone of Vision), which is quite sharp, carries heat energy in it. As previously mentioned by Lecher, natural light takes heat energy, which is one of the disadvantages of natural light because it has a heating effect on buildings.
4.3. Iteration 2: Optimization of Artificial Lighting

The second iteration maintains the existing natural lighting and ventilation conditions, increasing lighting efficiency and artificial lighting. For this alternative, the existing wall (brick/opaque) is still used. Optimization is done using lamps and lighting using honeybee and ladybug simulations but adding the IES lighting format's artificial lighting aspect. [13]

![Image of the lamp specifications]

Figure 6. (a) Replacement/alternative material

With the specifications, the lamps used are in TL and Spotlight lamps with the format of photometry type c and IES files for IESNA simulation: LM-63-1995 with a voltage of 14.5 watts and lux of 75 per lamp. With 100 dots, the total wattage used is 1450 watts, and the resulting lux or illuminance is 80 lux/m². A comparison between many lamps and low voltage value results in diffuse lighting instead of direct lighting.

Then, the results obtained using the TL lamps' artificial lighting showed that the average area under 200 lux illumination was 2.7 m² compared to the site area of up to 1377 m² to be categorized as a well-lit area. It can classify as a well-lit area for areas below 300 lux as much as 31.85 m² and below 284.64 for under 500 lux. The percentage is relatively medium to high, 0.2% below 200 lux, then 2.3% below 300 lux, and 20.70% below 500 lux. [12]

![Image of electrical lighting simulation]

Figure 17. (a) Electrical Lighting Illuminance Simulation (Top View) (b) (Isometric View)

4.4. Iteration 3: Optimization of Natural Lighting and Artificial Lighting

By looking at the two iterations above, one of the next alternatives is to combine the two simulations, namely between natural and artificial lighting. The process itself means combining natural illuminance values with IES simulation using Ladybug and Honeybee.
Still using the same IES and photometry as the previous simulation, it can be found that the use of these types of lamps in the form of TL and Spotlight with a smaller voltage of 8 Watts and lux of 75 and the same light point of 100 points means that the total wattage used is 1450 watts and lux. or the resulting illuminance of 80 lux / m². Then, the replacement of the dead wall material (brick/opaque) into a wooden lattice is also carried out at points A (15 m), B (14 m), C (15 m), and D (15 m).

Then, the results were obtained using artificial lighting for TL lamps (IES IESNA Photometric C, 8 Watt LED). Below 500 lux is 62.26 m². The percentage is relatively low, at 0.03%. Below 200 lux, then 0.30% under 300 lux and 4.5% below 500 lux. [13]

4.5. The results of all iterations
The simulation results show that from the total area of 1375 m². The area under 200 lux amounts to 1285 m², then those below 300 lux are 1287 m², and those below 500 lux are 1303 m². The percentage is relatively high.

| Iterate | Under 200 Lux | Under 300 Lux | Under 500 Lux |
|---------|---------------|---------------|---------------|
| Existing | Illuminance | | | |
|         | Under Luminaire | 91.78% | 93.45% | 98.61% |
|         | Illuminance | 8.22% | 6.55% | 1.39% |
| Iterasi 1 | Illuminance | 40.94% | 60.94% | 73.01% |
| Iterasi 2 | Illuminance | 0.2% | 2.3% | 20.70% |
| Iterasi 3 | Illuminance | 0.03% | 0.30% | 4.5% |
| Iterasi 3 | Illuminance | 99.97% | 99.7% | 95.5% |

Reference: Tedjawinata, 2020 – 10 - 15 [1]
5. Conclusion

The results of the iteration simulation results that have been carried out can conclude that artificial lighting is the most optimal but uses more energy than natural lighting. Based on the IESNA standard that the minimum lux convention room is 300 Lux but for international exhibition it requires 500 lux and the standard lux from the SNI is at least 300 Lux. The results of natural lighting Iteration are still categorized as adequate with the value of the amount of light above 200 lux reaching 59.06% but for a light above 500 lux only 26.99%. This is also because of placing the opening at a certain point (with parameters of the week's hottest day and the annual simulation year). Sunlight that flows itself carries solar radiation directly with heat energy that is taken away. As for artificial lighting, the parameters are more controlled (IES), starting from the directional luminaire, then the power from the light source that can be adjusted to scatter light; the fired light is softer because it reflects the material than direct lighting such as natural lighting. After the simulation in iteration 2, the amount of light above 200 lux reaches 99.8%, and lighting above 500 lux reaches 79.3%. Based on the IESNA and SNI standards, it means that artificial lighting is well-lit.

References

[1] A. H. Dictionary, American Heritage Dictionary of the English Language. 2006.
[2] G. Lippsmeier, Building in the Tropics. 1997.
[3] N. Lechner, Heating, Cooling, Lighting (sustainable design methods for Architect), 4th ed. John Wiley and Sons, 1991.
[4] Rea, M. The IESNA lighting handbook: Reference & application (9th Ed.). New York, NY: Illuminating Engineering Society of North America. 2000.
[5] SNI 03-2396-2001. Tata Cara Perancangan Sistem Pencahayaan Alami Pada Bangunan. Jakarta: Badan Standarisasi Nasional. 2001.
[6] Lawson, F. Conference, Convention, and Exhibition Facilities: Planning, Design, and Management. London: The Architectural Press. 1981.
[7] Energy Plus Weather File Directory, https://energyplus.net/weather (last visited: 12 October 2020)
[8] EDGE Green Buildings Dir, http://mundobim.com/construpm/edge-green-buildings-whats-window-to-wall-ratio/ (last visited: 10 October 2020)
[9] Bleil de Souza C., Knight I., 2007, Thermal Performance Simulation From an Architectural Design Viewpoint, Building Energy Performance Simulation Programs, 10th International IBPSA Conference, Beijing, China, pp 87-94. EFRI-SEED: Creating Opportunities for Adaptation Based on PULSE (Population in Urban Landscape for Sustainable Built Environments), National Science Foundation under Grant No. 1038264, www.buildsci.us/efri-pulse.html (last visited: 12 October 2020).
[10] US Department of Energy, EnergyPlus: whole building energy simulation program, http://apps1.eere.energy.gov/buildings/energyplus (last visited: 12 October 2020)
[11] Integrating Simulation in Design, IBPSA NEW S Vol.13 (1), pp 21-26. OpenFOAM® Foundation, OpenFoam: The Open Source CFD Toolbox, http://www.openfoam.com/ (last visited: 12 October 2020)
[12] Ward, G.J. 1994. The RADIANCE Lighting Simulation and Rendering System. Proceedings of the 21st Annual Conference on Computer graphics and interactive techniques, Orlando. Weytjens, L., Macris, V., Verbeeck, G., 2012,
[13] Reinhart, C. F., Walkenhorst, O., 2001, “Dynamic RADIANCE-based daylight simulations for a full-scale test office with outer venetian blinds.” Energy & Buildings, 33:7 pp. 683697. Robinson, D., and Stone, A., 2004,