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A Study on Smart Lighting Design for Sustainable Office Building Performance in South Tangerang

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ABSTRACT

Smart building uses technology to deliver useful and consistent experiences in performances, services and system. Due to climate change and pandemic situation, the implementation of smart building will be important to deliver sustainability in terms of energy efficiency and wellbeing. The purpose of the study is to know how critical of smart design through integrated approach to achieve sustainable performance in building life cycle. Smart lighting design in the office building is the focus of the study. The research method was using qualitative method with a case study approach on the building that has been certified under Greenship New Building 1.2. Smart design through sustainable design approach itself shall consist of these four design tiers: 1) base building design; 2) passive system; 3) active system; and 4) smart building application. According to the study, the result shows how critical the integration among the design tiers by considering energy efficiency and wellbeing to deliver smart lighting system design. Moreover, it can be said that multidiscipline collaboration on design process is a necessary.

Keywords: *Smart building, Smart design, Sustainability, Efficiency, Wellbeing, Lighting.*

1. INTRODUCTION

1.1. Smart Building Definition, Deliverables and Roles in Sustainable Building Performance

The highlighted of sustainable building parameters always changes time to time due to its challenges. In early 2000s, sustainable building corresponded to green building which means resource efficiency specifically in energy. In 2018, World Green Building Council or WGBC has set the target about Net Zero Carbon principle to be applied on all new buildings in 2030. The definition of net-zero carbon building or NZHB is a building with highly energy-efficient with all remaining energy from on-site and or off-site renewable sources [1]. This ambitious vision will be escalated in 2050 by targeting all new and existing buildings will be designed, constructed, and operated with net-zero carbon principle. At this stage, sustainable building parameter put less emission building as priority. However, due to the pandemic Covid 19, health becomes another highlight that need to be promoted in built environment.

Sustainable buildings are about how to use of features and component in buildings, including technology and automation system, as a smart building. Smart buildings can achieve sustainability by their performance with respect to energy, water, waste and pollution for future generation by responsiveness to occupants; well-being of people; low resource consumption with low pollution and waste; flexibility and adaptability to deal with change; and appropriate balance of high and low technology [2].

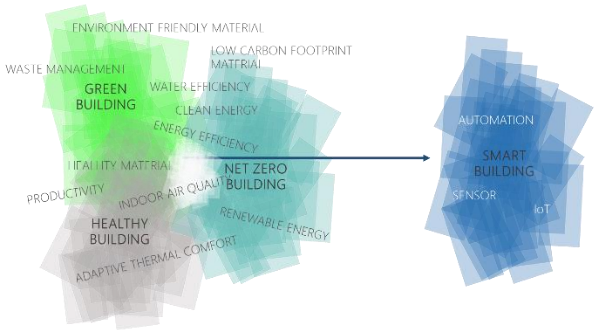

Figure 1 Smart building positioning in sustainability.

As a supporting part of green building, healthy building, and net-zero building, Smart Building integrates several system operations (Figure 1). The system covers on HVAC, lighting, fresh air and security system and creates automation system that respond to outside environment and occupant comfort, that increase building performance, productivity, reduce energy use and operating cost.

According to Wang [3], smart building can be defined based on it deliverables, service, performance and system based (Figure 2). System based by how building use an advanced and integrated building technology systems [4], Service and performance by how smart building also help efficiency of HVAC and other system to various external and internal effects to achieve energy efficiency and occupant comfort [5].

Smart Building increasingly address not only one goal, but serve multiple requirements in parallel. The use of controls and sensor usually to focus on energy savings. User-centeredness can result in a better performance in terms of energy than compared to a control system designed exclusively for saving energy [5].

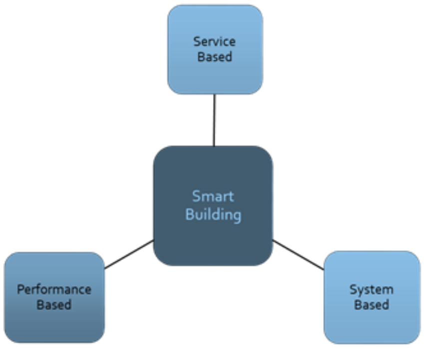

Figure 2 Smart building deliverables.

Smart building increases the efficiency of building and construction, reducing 30% of project management by consolidating system [6].

1.2. Smart Building for Energy Efficiency and Occupants Wellbeing

As a part of the built environment, buildings not only give impacts on their surroundings, they also give impacts on the building's occupants. The energy consumption in the building is directly related to user behavior, influenced by indoor air quality, thermal, visual, and acoustic comfort [7]. Therefore, in order to optimize energy saving, it is necessary to manage the sensing and control system related to occupants' comfort.

Smart Building improves energy efficiency by saves on average 23% energy consumption and help productivity and health by 35% fewer short-term sick leave [8]. The best combination of sensing technology would help achieve an energy efficient and healthy built environment [9]. Smart buildings enable and ensure flexibility, a healthy and comfortable living and working environment for the occupant [8].

Smart buildings save energy by automating controls and optimizing systems [10]. Smart Building improves energy efficiency by saves on average 23% energy consumption and help productivity and health by 35% fewer short-term sick leave [8]. Occupancy Sensors can obtain energy saving 20-28%, and Photo Sensor-Based Lighting Control can obtain 20-60% energy saving [11].

1.3. Smart Design for Smart Building

Smart building incorporates smart design, where the owner needs to communicate the smart element in the building with the stakeholders. Though smart building can be interpreted as automation system, technology application is not the only goal [12]. Moreover, the successful of smart building can be seen by its performance that cannot be detached from the basic design of the building. It can be said that building shall be designed to be responsive to the user, the environment and the technology to deliver sustainable performance. In terms of smart building, this responsive or sustainable design is also known as a smart design.

In terms of the progress of the system, sustainable design has progressively evolved from a static, technical, and product-centric focus towards a focus on dynamic, large-scale system level changes, in which sustainability is understood as a social, technological, and technical challenge [13]. Smart building incorporates sustainable and smart design, where the owner needs to communicate the smart element in the building with stakeholders. Smart building increases the efficiency of building and construction, reducing 30% of project management by consolidating system [6].

According to Lechner, sustainable design process shall go through three tiers: 1) Basic building design stands for the way of design response to the surrounding environment particularly avoiding the unwanted condition that may strike efficiency and occupants comfort; 2) passive system stands for the use of natural energy as much as possible that followed by the consideration of occupants 'wellbeing; 3) Active system stands for the use of mechanical equipment to achieve better performance both in efficiency and occupants 'wellbeing.

2. RESEARCH METHODOLOGY

2.1. Focus of the Study

The focus of the study is on the design process of the lighting system in the office building that already achieved Greenship[1] Design Recognition[2] with gold predicate. The research question of the study is *How critical smart design through integrated approach in pursuing sustainable lighting performance?*

The building is located in South Tangerang City and has three level of basement and 14 level of floors. The main function of the building is leased office with other supporting facilities.

2.2. Research Methodology

The research is using a qualitative method with a case study approach. The data was collected from the design documentation such as drawings, simulation, calculation and material specification that has been provided in the tender design stage. The writer will describe the process and the parties 'involvement by referring the modified of Lechner Three Tier Approach[3] that divided into four tiers (Figure 3): 1) basic building design; 2) passive design approach; 3) active design approach; and 4) smart building application.

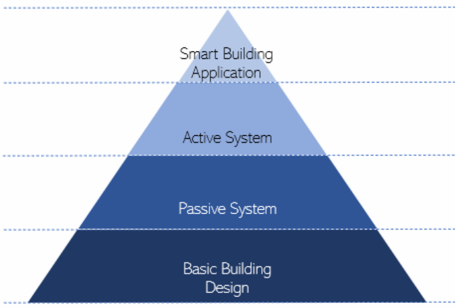

Figure 3 Modified of Lechner tier approach.

In this case study, the four tiers in the lighting system will be explained by this following sequence: The tier 1 deals with building form and orientation; The tier 2 deals with the façade design optimization in order to accommodate both energy efficiency and wellbeing; The tier 3 deals with design installation and product selection; The last tier deals with smart system applied in the lighting system to boost the sustainable performance.

3. RESULTS AND ANALYSIS

3.1. Basic Building Design

For the upper structure, the building has two different floor types: the lower floors stand for car showroom and workshop from first to third levels. The upper floors stand for office and its facilities from forth to fourteenth levels (figure 4).

Despite the lower floors has different footprint area with the upper one, these two floor types have North-South orientation. It means that the basic building design of this case study is responsive enough due to an effort in minimizing solar heat gain from building façade (figure 5).

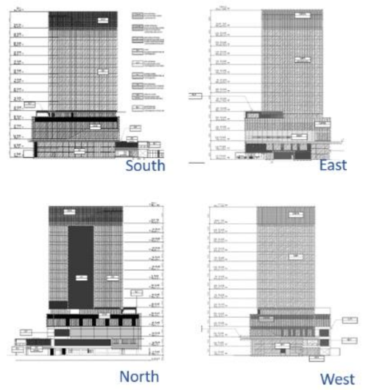

Figure 4 Building elevation.

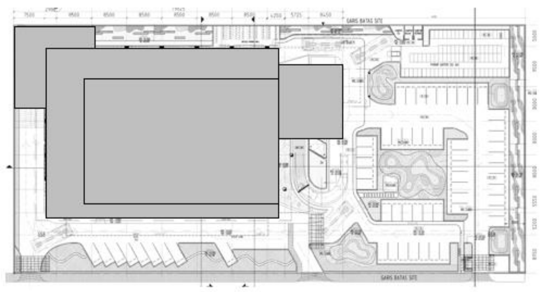

Figure 5 Building footprint in site.

On this tier, the architect and green building consultant have intensive involvement in this process with the following roles:

- Architect optimized the building design to accommodate the functional, sustainability and esthetic aspects by providing several design alternatives for massing.
- Green building Consultant conducted simple building simulation and analysis to give rough depiction for the impact of each design alternative to the energy efficiency and wellbeing.

[1] Greenship is a standard, design guideline and certification system for green building performance that issued by Green Building Council Indonesia. For the certification system, Greenship has four levels predicate for the buildings that attend to the certification process (higher to lower levels): Platinum, Gold, Silver and Bronze.

[2] Greenship New Building has two compliance stages:1) Design Recognition, the stage assesses whether the building has been designed accordance with Greenship criteria; 2) Final Assessment, the stage assesses whether the building has been constructed accordance with Greenship criteria

[3] The modification of Lechner's Three Tier Approach lies on the fourth tier, which is smart building application.

3.2. Passive System

Since the building mass and orientation have been determined, the design team conducted façade design optimization that need to accommodate two considerations: energy efficiency and wellbeing. For energy efficiency the optimization was done by calculating the solar heat gain from façade design through Overall Thermal Transfer Value (OTTV) formula. It was expected the OTTV is lower than 35 watt/sqm so it may reflect the lower external heat gain from the façade. In addition, the design team assured the daylight penetration into the building covers minimum 30% occupiable area. It was expected that the daylight quality shall have 300 lux for minimum illuminance level for the whole working hours. Therefore, energy efficiency can be achieved from the reduction of the cooling load because the building has lower solar heat gain from façade and lighting connected load because of the use of daylighting. Another consideration, wellbeing, design team assured the availability of visual connectivity between indoor and outdoor environment. This criterion is dedicated for building occupants to have visual quality in reducing the stress and increasing productivity at one time. It was expected minimum 75% occupiable area in office spaces shall comply this criterion.

In order to comply all the considerations above, it can be seen that the important keys of façade design optimization are: Window to Wall Ratio (WWR)[4] and façade material properties specifically on Conductivity (U) [5] value, Shading Coefficient (SC) [6] Value that determine the OTTV. Another important key is Light Transmission (LT) [7] Value of the vision glass that determine the daylight penetration in to the building.

After went through design process iteratively, the optimized design criteria were 60% for WWR with chosen glass properties U, SC and LT values were 2,8; 1,6 and 40%. As the result, the OTTV, daylight and outside view area were 32,38 watt/sqm, 51,41% and 91,1% of the total occupied area. These figures 6 show that the optimization has achieved compliances both in energy efficiency and wellbeing.

[4] Ratio between fenestration area and the whole façade area in particular orientation (%)
[5] The rate of heat transfer through the material or a composite (W/m^2K)
[6] The ratio of solar heat gain passing through glass unit to the solar energy which passes through 3mm clear float glass
[7] The amount of visible light waves that transmit through material (%)

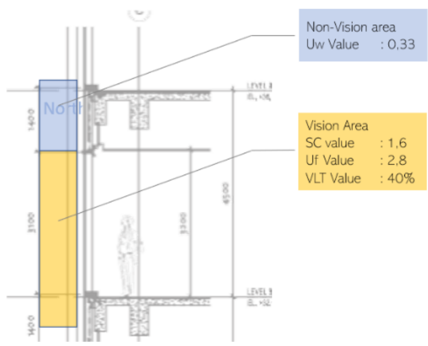

Figure 6 Principal section.

On this process, the architect, façade consultant, mechanical consultant and green building consultant have intensive involvement in this process with the following roles:

- Architect optimized the façade building design that focus on the WWR and material selection to accommodate sustainability and esthetic aspects by providing several design alternatives.
- Façade Consultant provided technical support for the detailed design and the provision of façade material catalogues with various properties that may suitable with grand design for the architect.
- Green Building Consultant conduct simulation and calculation according to the alternatives of façade design and materials whether its compliances to Greenship Criteria: OTTV, Daylight Penetration and Outside View.

3.3. Active System

During this tier, the project team shall determine the lighting installation design. The process cannot be detached from the previous phase, particularly on daylight simulation and calculation. The daylight simulation was conducted by using DiaLux Version 4.12 software. As one of key parameters, this simulation already used the glass material properties that related to the light transmission which was 40% for VLT value. Another key parameter was Light Reflectance (LR) Value of the interior finishing surfaces. The color of the surfaces that the simulation referred to were corresponded with the basic design of the occupiable area in the office spaces. Those were white for ceiling and light grey for wall and flooring. So, the LR value for ceiling, wall and flooring respectively were 100%, 90% and 90%. For sure the WWR of the façade design also was applied on the building model in the simulation. The simulation was conducted in two different times: 09.00 a.m. and 03.00 p.m. in a equinox month. The result can be seen on the figure 7 and 8.

The result of daylight simulation indicated the area can be divided into two zone categories: daylight area and non-daylight zones. Daylight Zone is the area that has daylight penetration during the whole working hours with minimum illuminance level is 300 lux. Non-Daylight Zone is the area that has no daylight penetration and/or has daylight penetration for particular working hours only and/or its illuminance level is below 300 lux. These two zones can be seen on the figure 9.

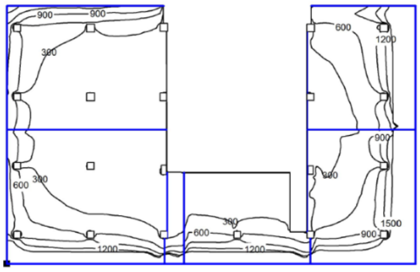

Figure 7 Daylight simulation result on 09.00 a.m.

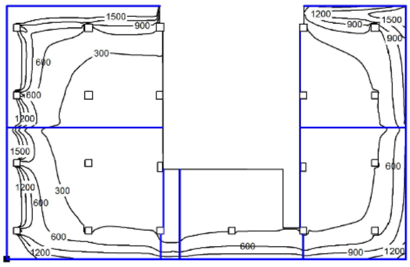

Figure 8 Daylight simulation result on 03.00 p.m.

Furthermore, these two zone categories lead the design team to determine the group of lighting installation. The main idea was to divide the lighting installation into two groups in general: group 1 was installed in the daylight zone that consisted of 70 luminaires and group 2 was installed in non-daylight zone that consisted 84 luminaires. The design result can be seen on the figure 10.

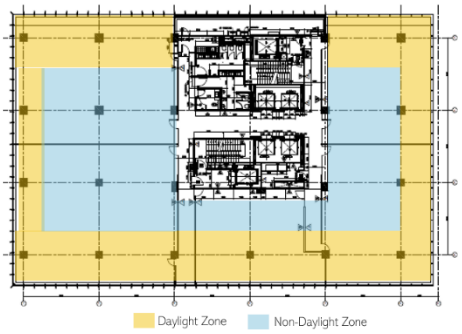

Figure 9 Daylight and non-daylight area.

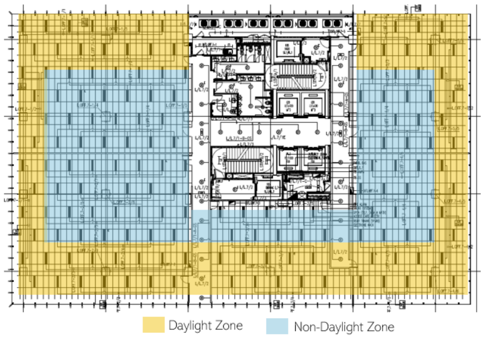

Figure 10 Lighting group installation within two zones.

Since the office are in this building is dedicated for leasing, the determination of number and location of the group of lighting installation not only based on daylight and non-daylight zones but also on the prospective tenant zones. Each typical floor will be divided into 5 prospective tenant zones that can be seen on the figure 11.

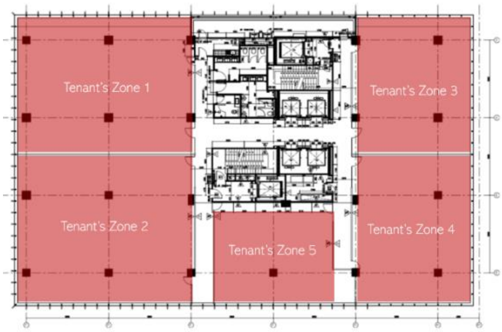

Figure 11 Tenant zones in typical floor.

On this process, electrical consultant has intensive involvement in this process with the following role:

- Electrical Consultant optimized the lighting design installation. The grouping was done by the consideration of daylight and allocated spaces for prospective tenants on each typical floor.

3.4. Smart Building Application

At last, the application of smart building can be determined due to finalized installation of lighting groups. Smart building application that installed on the lighting system is lux sensor that connected among the lighting group within daylight zone and Building Automation System. It was expected once lux sensor learns that the illuminance level on the daylight zone reaches 300 lux, the sensor will give signal to BAS for turning off the lighting group within the daylight zone. Meanwhile, once the lux sensor learns that the illuminance level on the daylight zone reaches below 300 lux, the sensor will give signal to BAS for turning on the lighting group within the daylight zone.

Due to five prospective tenant zones in the office area, similar with the installation of lighting group, the determination of number and location of the installed lux sensors were not only based on daylight and non-daylight zones but also on prospective tenant zones.

For tenant zones with two different orientation, number 1 to 4, were designed to be equipped by two lux sensors. Each sensor will cover the lighting group in daylight zone for each orientation since the illuminance level may differ. Meanwhile, tenant zone 5 was designed to be equipped by one sensor only because of its single orientation. In order to have better depiction the formation of lux sensor installation, the layout can be seen on the following figure 12.

On this process, electrical consultant and green building consultant have intensive involvement in this process.

- Electrical Consultant optimized the allocated number of lux sensors by the consideration of daylight and allocated spaces for prospective tenants on each typical floor.
- Green Building Consultant reviewed the design whether the location and installation system comply the Greenship requirement.

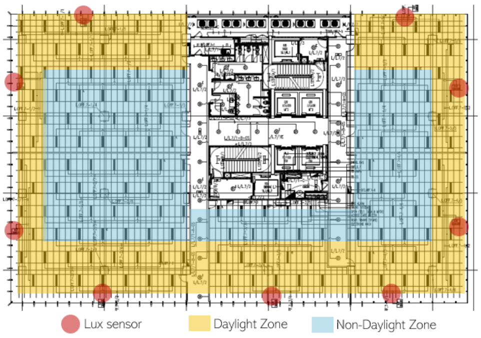

Figure 12 Lux sensor location in lighting system.

4. CONCLUSION AND RECOMENDATION

4.1. Conclusion

According to the analysis, it can be concluded several critical keys to deliver sustainability through smart building application:

- The process happened in the previous tier gives the impact to the next one. As the last tier, smart building application is not merely just installed smart system into the building, but also does need smart design process that conducted previously.
- Smart design process accommodates the integration of passive and active design approaches. It also means that the parties that involved in each approach shall collaborate intensively as early as possible. For the record, the parties involved in this case study was architect, façade consultant, electrical consultant and green building consultant.
- Since the availability of smart building application in this case study is for sustainable performance in terms of energy efficiency and wellbeing, the role of green building consultant is important as a party that ensure the compliance of the targeted goal.

4.2. Recommendation

As known before that this study focuses on the building that functioned as leasing office spaces. So, for the next study, it is recommended to conduct the similar research with different objects such an office building that owned and used by the owner. It is because in this type of the building there will be other aspects that can be look at: the color surface determination for finishing and furnishing; the installation of automatic interior blind on vision glass; and lighting design system among general, decorative and individual lighting that will be incorporated with the use of daylight.

Furthermore, it also will be interesting to conduct the study on the residential buildings since there is occupants 'involvement in the process of applying smart building features.

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