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Evaluation of Natural Light in EcoHouse Bandung

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ABSTRACT

The availability of natural lighting is significant to the quality of life in a residential setting. A residence that is conducive to health and comfort requires adequate natural sunlight, which can eliminate viruses and mould indoors and improve the health of its occupants. Furthermore, the strategic incorporation of natural lighting can also lead to a reduction in energy expenditure. This research aims to evaluate the natural lighting in the EcoHouse Bandung, designed by SHAU Architecture and Urbanism, to ascertain its effectiveness and identify areas requiring improvement. The methodology employed entails the utilisation of simulations conducted with the Autodesk Ecotect Analysis 2011, encompassing the assessment of Shadow Range, Solar Access Analysis, and Lighting Analysis. The analysis results demonstrate that the EcoHouse Bandung has responded effectively regarding orientation and building envelope utilisation. However, some areas require specific adjustments due to insufficient or excessive light intensity. The analysis indicates the necessity for optimisation in several areas, including workspaces, living rooms, dining rooms, and bathrooms on the first floor. This research identifies three main principles for eco-house design: firstly, primary lighting should not disturb neighbours or cause harm to occupants; secondly, facade materials and technologies should be selected based on each façade's specific requirements; and thirdly, corridors should be considered as primary barriers in reducing excess heat and light. These findings are anticipated to optimise existing conditions and achieve ideal standards that support environmental sustainability and occupant comfort.

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1. INTRODUCTION

The home is a comfortable place for its inhabitants to rest and gather. As a place of residence, a home must adhere to the fundamental principles of a healthy and comfy dwelling, namely, lighting, ventilation, as well as air temperature and humidity [1]. Indonesia's location in a tropical region ensures year-round exposure to high-intensity sunlight. Sunlight plays a crucial role in both the occupants' well-being and the physical integrity of the building and its contents. Several benefits of sunlight penetrating a building include eliminating viruses and fungi that may thrive indoors. Direct sunlight can also enhance the health of its inhabitants.

The amount of sunlight entering a room should be adequately regulated and considered because sunlight not only provides illumination but can also introduce heat energy into the space [2]. Thoughtful planning is required to achieve optimal comfort levels for occupants while avoiding excessive energy usage. If sunlight penetration into space is too high, it can potentially raise room temperatures, leading to increased reliance on artificial ventilation. Conversely, if a room receives too little natural light, it may increase energy usage for artificial lighting. [3].

The case study utilised in this research is the House Bandung, designed by SHAU Architecture and Urbanism. An eco-house embodies the principles of energy efficiency and environmental friendliness by optimising resource usage [4], [5], [6]. Benefits derived from eco-friendly housing systems include reduced operational energy and water usage costs, improved inhabitant health, particularly indoor air quality, and minimised environmental impact [7]. One key focus in eco-house design principles is building orientation and energy usage efficiency [8], [9].

This research aims to comprehensively evaluate the design and planning of the EcoHouse Bandung, explicitly focusing on the influence of natural lighting as one of the critical factors in shaping eco-house principles. The research results are expected to provide the necessary guidance to optimise existing conditions, thereby achieving ideal standards that support environmental sustainability and inhabitant comfort while positively contributing to their well-being and the surrounding ecosystem.

2. RESEARCH METHOD

This study employs quantitative data processing methods that can be measured in numbers and calculations to maintain objectivity. The Ecotect Analysis simulation process commences with generating a three-dimensional model based on the Ecohouse Bandung design created by SHAU. The creation of the 3D model entails the specification of materials, floor and ceiling heights, and the dimensions of doors and windows. This analysis employs the Autodesk Ecotect Analysis 2011 software. The study's supporting data is adjusted to Bandung's climatic data, site coordinates and orientation, and neighbouring buildings' height and mass conditions.

This study employs three distinct analytical techniques. The initial analysis is Shadow Range, which simulates the effects of solar shading on the site. The second analysis is Solar Access Analysis: Incident Solar Radiation, which is employed to quantify the solar radiation present on the site and façade. The third and final analysis is Lighting Analysis: Natural Light Levels Analysis, which assesses the amount of natural light penetrating indoor spaces.

In this study, the analysis results obtained from Autodesk Ecotect Analysis 2011 will be subjected to further examination through the application of a descriptive method. This approach has been selected to provide a detailed explanation and comprehensive elucidation of the data obtained from the simulations, offering an in-depth understanding of the various observed data and conditions. The descriptive method allows the researchers to identify, analyse, and present findings systematically and in a structured manner, ensuring that every relevant aspect is clearly and accurately disclosed.

This research aims to gain profound insights into the significance of simulation analysis as a tool in building design. The data processing methodology and stages of analysis can serve as crucial references for designers seeking to enhance building designs for greater energy efficiency and environmental sustainability. Moreover, this study provides valuable contributions to advancing science and technology, particularly within architectural and construction sciences, specifically regarding sustainable building design in tropical climates such as Bandung.

2.1. Natural Light

Light is an electromagnetic wave that can be natural, from the sun, or artificial, from lamps. There are several types of natural light, which can be classified as direct sunlight, scattered sunlight and sunlight reflected in the atmosphere, resulting in low-level skylight, and sunlight reflected outdoors or indoors. Natural light is characterised by its variability, which is influenced by climate, season and weather [10]. In addition to the amount of light entering a space, light distribution is essential to avoid losses.

The ability of natural light to kill viruses, diseases and moulds that can grow in buildings, thus indirectly contributing to the health of building occupants, is one of the benefits of natural light for buildings and their occupants. The design of buildings should consider the effectiveness of natural lighting [11]. Lighting effectiveness can be understood as meeting the lighting requirements for the intended purpose. Lighting effectiveness can be measured by the intensity of light falling on a work surface. Several factors influence the intensity of light entering a room, including site conditions such as orientation and dimensions, building envelopes including materials and light openings, and spatial compositions that position light on the work surface [12]. In this context, SNI-03-6197-2000, which regulates energy savings in lighting systems, can be used as a reference when planning development projects and as a standard for evaluating this research [13].

Table 1. Natural lighting level standard

Room Function	Illumination level (Lux)
Terrace	60
Living Room	120 – 150
Dining Room	120 – 150
Workspace	120 – 150
Bed Room	120 – 150
Lavatory	250
Kitchen	250
Garage	60

Source: [13]

2.2. Eco-House

EcoHouse is a housing concept that incorporates green and environmentally friendly living spaces [14]. The term 'eco' in EcoHouse is derived from ecology and refers to an architectural approach that emphasises harmony with nature and the sustainability of ecosystems. This concept began to influence the housing industry in Indonesia in the 1980s, led by pioneers such as Y.B. Mangun Wijaya, Eko Prawoto and Heinz Frick [15], [16]. This approach does not serve as a binding standard, i.e. there are no fixed measurements; rather, it embodies the harmony between humans and their natural environment [17]. From an environmental perspective, architecture design using an ecological approach aims to maximise the potential of natural resources [18]. Here are four primary considerations when designing a home with the EcoHouse concept: green open spaces, sanitation systems that support conservation, household waste management and energy use efficiency [14]. Implementing the EcoHouse concept provides several benefits, including reduced operating costs for energy and water, improved occupant health through better indoor air quality, and reduced environmental impacts such as minimising waste and heat effects within the building [19].

2.3. Precedent Study: EcoHouse Bandung

The EcoHouse Bandung, designed by the architectural firm SHAU Architecture and Urbanism, is one of their projects that implements eco-principles. This private residence covers an area of 495 square metres, with the broadest site orientation to the north and south. The EcoHouse Bandung was designed considering the direction of sunlight, shading from neighbouring buildings on the site, airflow and interior shading, all analysed through digital simulations (Figure 1).

The building has two levels, divided into public and private functions. The first floor consists mainly of gathering spaces such as the living, family, and dining rooms. The ground floor contains several spatial tasks that appear to merge into a single space. This design aims to optimise the flow of air and light by eliminating partitions, thus creating larger spaces [21]. Meanwhile, the second floor is dominated by private and quiet spaces such as bedrooms and prayer rooms. On the second floor, a void connects the second-floor corridor to the dining room on the first floor. The presence of voids in the building provides excellent opportunities to improve views, lighting, and ventilation, as it can reduce air temperature [9]. The roof level is enclosed by a green roof, which helps to reduce indoor temperatures by minimising the heat reflected from the surface [8]. In addition, climbing plants are used as a visual barrier between the public space in the garage and the inner garden (Figure 2).

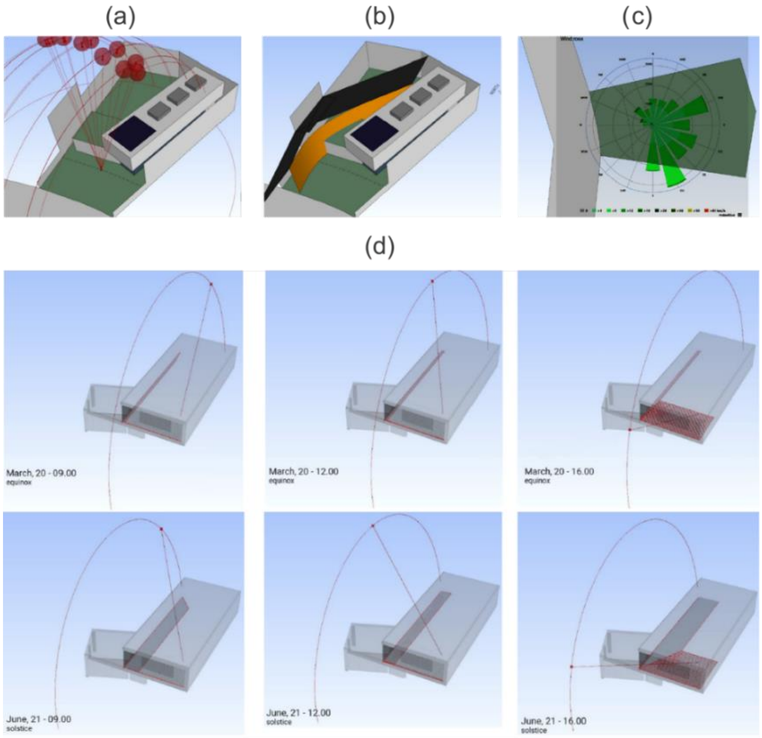

Figure 1. Digital simulation, (a) solar analysis, (b) site shading analysis, (c) airflow analysis, and (d) interior shading analysis [20].

Figure 2. EcoHouse Bandung by SHAU Architecture and Urbanism, (a) front view, (b) north hallway of the second floor, (c) ground floor garden, (d) rooftop garage plants [20].

3. RESULTS AND DISCUSSION

In the early stages of building design, one of the most crucial steps is to consider the conditions of the surrounding neighbourhood. Solar shading simulations and solar radiation analyses were conducted based on data from the existing buildings and the conditions surrounding the site (Figure 3). Figure 3a indicates that the northern side of the site is exposed to solar shading from adjacent structures in the afternoon, while the eastern side is exposed to shading in the morning. The white areas with dashed lines indicate areas without solar shading from surrounding buildings. Sunlight plays a pivotal role in a home and its occupants, including its capacity to eliminate disease-causing viruses and provide essential vitamins to the residents [22]. The results of the solar shading analysis conducted on neighbouring buildings demonstrate that EcoHouse Bandung is precisely positioned within the delineated dashed line area in Figure 3.

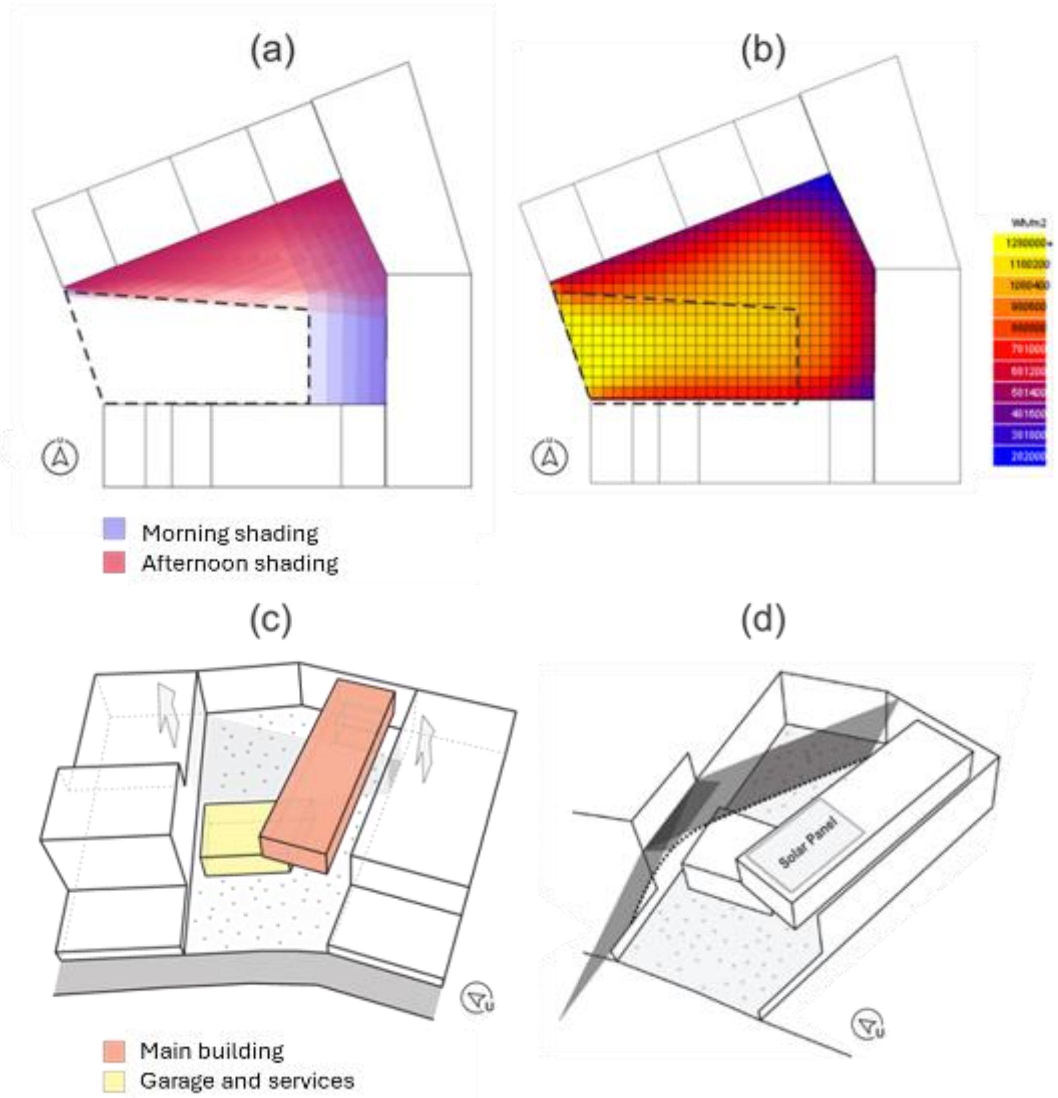

Figure 3. Neighbourhood site simulation, (a) solar shading analysis, (b) solar radiation analysis, (c) building mass placement, (d) solar panel placement.

Conversely, areas exposed to sunlight throughout the day experience high levels of solar radiation reception, reaching up to 1,280,000 W/m^2 (Figure 3b). Several steps can be taken to address excessive solar radiation reception, including determining building orientation, selecting building envelope materials and landscaping, placing openings, and designing room functions. Implementing these strategies improves energy efficiency and enhances the comfort and well-being of the building occupants.

After analysing the shading effects of the neighbouring buildings, a solar radiation analysis was carried out on the building envelope of the constructed design; Figure 4a shows that the west façade, which serves as the main façade, receives the highest level of radiation, approximately 541,200 Wh/m². The north side, which faces the courtyard, has the second highest level of radiation at approximately 405,900 Wh/m². Meanwhile, the south and east sides, directly adjacent to the neighbouring walls, have the lowest radiation levels at 270,600 Wh/m². The designers decided to orient the building mass from east to west, allowing the shortest sides of the building envelope to receive sunlight. A practical design strategy implemented was to position the west side of the building to benefit from the shading provided by neighbouring structures. It aligns with Ashadi's research by Ashadi et al. (2016), which states that afternoon sunlight has the highest intensity.

Windows and ventilation openings, which allow light and heat to enter, are located on the north and south sides of the building. The next challenge is managing the second-highest radiation levels on the north side to take advantage of the sunlight while controlling the heat entering the building. On the other hand, placing openings on the west side should be avoided because prolonged exposure to sunlight will increase the indoor temperature [23]. Changing the placement of the west side is a challenge for designers because the west elevation is the main facade and needs to create a strong impression on the residence.

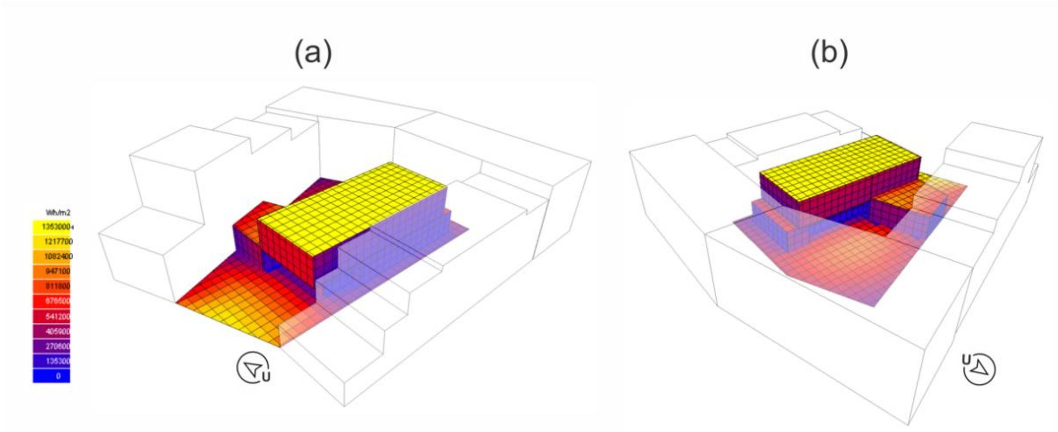

Figure 4. Solar radiation analysis on the building envelope, (a) east and south sides and (b) north and west sides.

According to recommendations from previous research, the EcoHouse Bandung has long sides oriented towards the north and south. The west facade, which serves as the main facade, is designed to be closed off from openings (Figure 5a). On the ground floor, the west-facing facade employs solid materials such as walls, as this side directly opens into the living room. On the second floor, vertical elements on the west side incorporate perforated material with sliding panels, as this area serves as the terrace for the main bedroom.

The north-facing facade, overlooking the inner court, features two contrasting materials. On the ground floor, the design maximises openings with sliding glass doors from the family room, dining room, and dry kitchen. A terrace along the north side was created to reduce the heat from sunlight entering the building. On the second floor, both the east and north sides utilise sliding panels, allowing the occupants to adjust the exposure according to the bedroom and study room needs. The sliding panels are made of Soltis fabric with Précontraint technology, a material resistant to deformation and tearing caused by rain, UV rays, and wind, and most importantly, capable of blocking up to 97% of heat [24].

Figure 5. Building envelope, (a) east side, (b) north side [20].

Once the building envelope and the terrace response on the northern side had been identified, a daylight analysis was conducted within the building (Figure 6). This analysis tests the amount of sunlight a horizontal section receives, such as the floor. The simulation results indicate that the east facade, with its solid walls, effectively blocks unwanted sunlight and heat in the study and living rooms. However, the two rooms in question receive only approximately 100 lux, below the standard minimum of 120 lux [13]. Illumination of less than 120 lux necessitates artificial lighting, which increases electricity consumption. One potential solution is to maximise openings on the living room's south side and the study room's east side, which faces the outdoor corridor. Similarly, the maid's bedroom receives approximately 100 lux. It is below the minimum standard of 120 lux—positioning the opening on one side results in an uneven distribution of sunlight within the room.

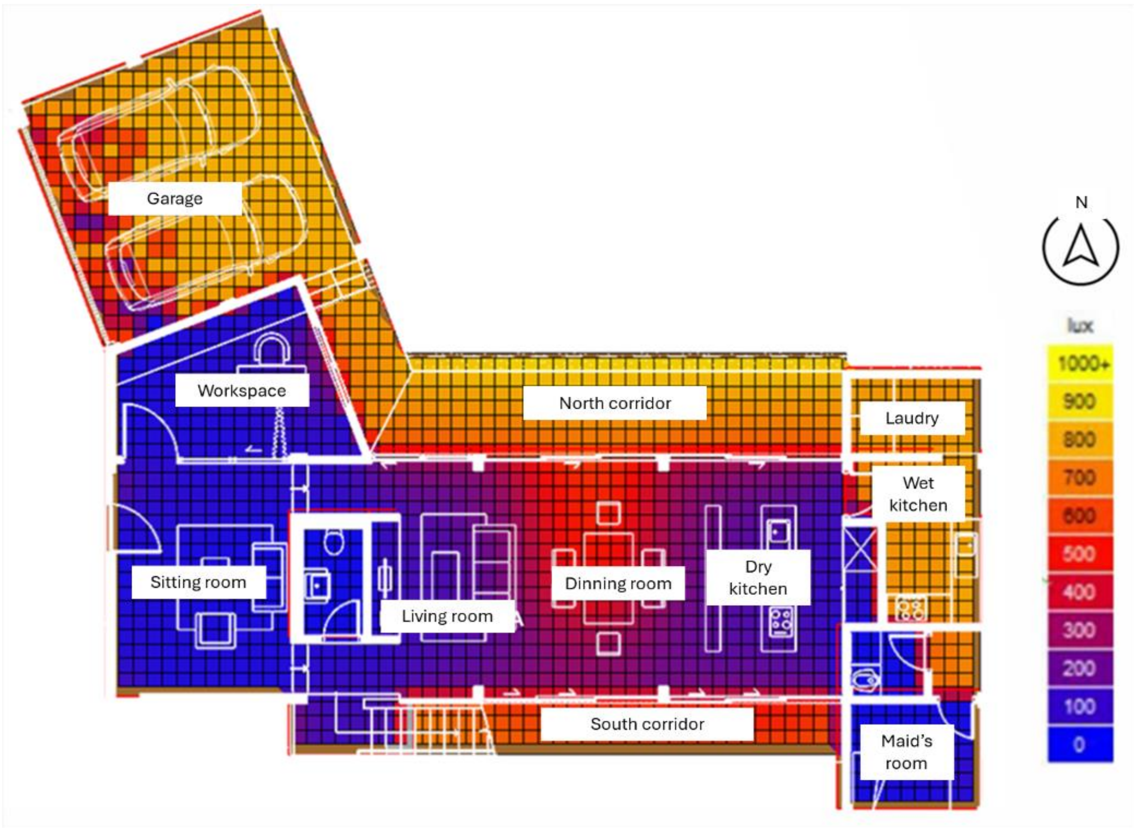

Figure 6. Daylight analysis of 1st floor

The northern and southern corridors act as a barrier to sunlight entering the rooms. Although the barriers between indoor and outdoor areas on the first and second-floor corridors are sliding glass doors, the family room and dry kitchen receive moderate lighting levels of approximately 150 lux for the family room and 250 lux for the kitchen, which is within the upper limit according to SNI standards [13]. This light division is due to the design strategy of having corridors on both the north and south sides, which ensures that the family room and dry kitchen do not exceed maximum lighting limits. In contrast, the dining room receives high light intensity, around 400 lux, due to the void above the dining area exposed to the sliding doors on the second floor. Potential solutions include replacing the glass type or adding dark-tinted layers [12]. Another approach is to relocate the sliding panel facade on the second floor's north side closer to the void.

The laundry room and wet kitchen have openings without door or glass window barriers, resulting in illumination levels reaching 700 lux. Although these are secondary spaces with minimal activity, adding a canopy or louvre would help control the sunlight entering these areas [25], [26]. Between the living and family rooms, the bathroom forms an internal space. A well-designed bathroom requires direct sunlight to minimise the growth of bacteria and mould [27]. Therefore, the bathroom should be situated on the west side, where it can receive adequate lighting [23].

Figure 7 presents three daylight analysis results with different sliding panel configurations. Figure 7a shows the condition with the sliding panel fully open, Figure 7b shows the sliding panel 50% open, and Figure 7c shows the sliding panel fully closed but with light still entering through gaps between the panels. The corridor serves as a perimeter on the second floor, playing a crucial role as a barrier for sunlight entering the rooms. Sliding panels significantly affect the light falling on the northern and western corridors. Still, it less impacts the amount of light entering the interior spaces. The second-floor bedrooms, study, and bathroom receive adequate lighting, ranging from 100-200 lux. The rooftop, which serves as the garage roof on the first floor, has a high light reception level of over 900 lux. Therefore, choosing grass material for the rooftop is a wise decision to minimise light and heat reflection from entering the interior spaces. [28], [29].

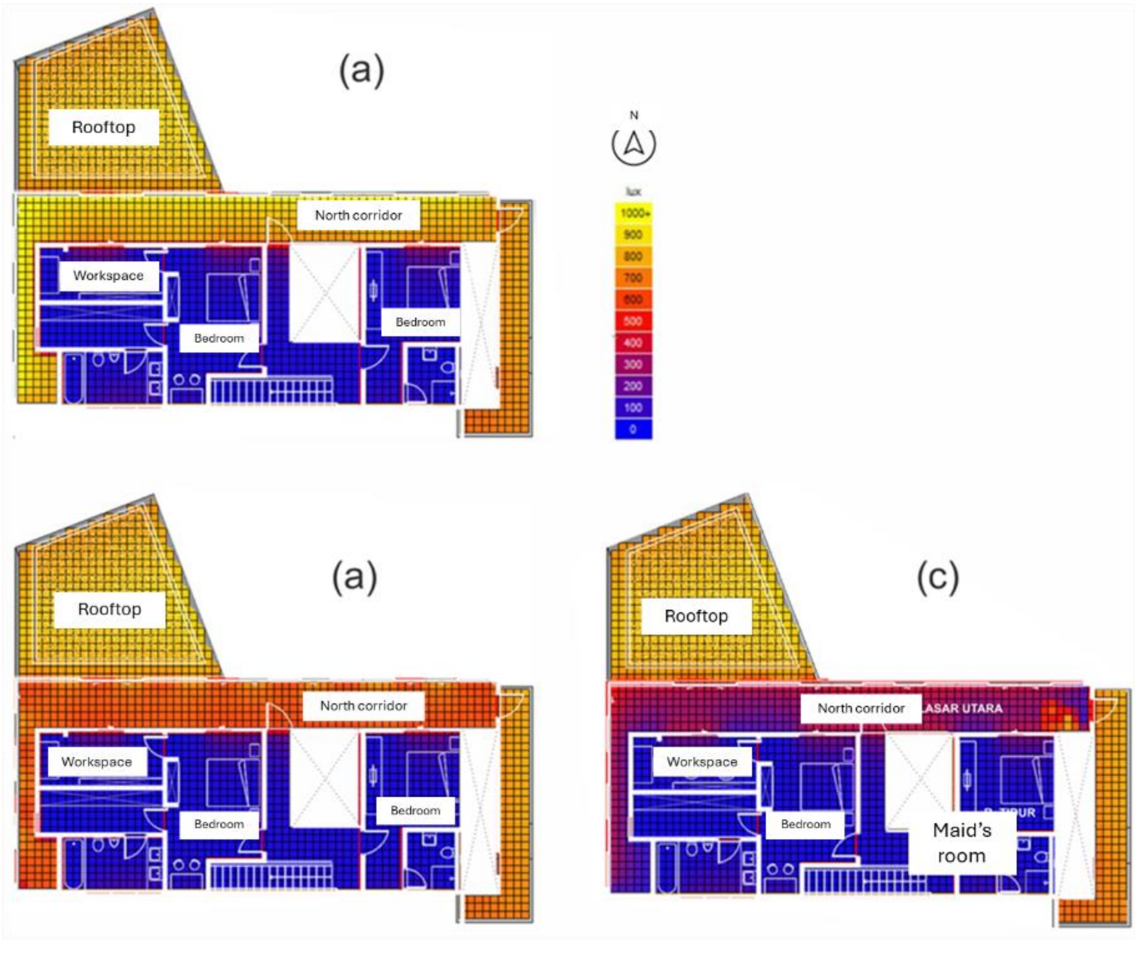

Figure 7. Daylight analysis of 2nd floor, (a) sliding panel fully open condition, (b) sliding panel 50% open condition, (c) sliding panel fully closed condition.

4. CONCLUSION

The EcoHouse Bandung residence is designed based on eco-house principles, utilising digital simulations such as neighbouring building shading and internal space shading. The evaluation results from Autodesk Ecotect Analysis 2011 indicate that the building orientation aligns with the site's analysis of neighbouring building shading. The central building mass receives optimal sunlight without being shadowed. However, there is significant daylight admittance, as demonstrated in the solar radiation analysis calculated for the building envelope. The selection of solid materials on the west side of the building and maximising openings on the north side with sliding panels are appropriate measures. Nonetheless, daylight analysis suggests the need for optimisation in some workspaces, living rooms, dining areas, and first-floor bathrooms.

From the EcoHouse Bandung structure, we can appreciate and adopt several design principles and implementations that could impact residents' comfort. The first principle ensures the direction and amount of light entering the site, avoiding detrimental effects on the building and neighbouring structures. The second principle ensures that facade materials or technologies are compatible with the magnitude of radiation the building envelope receives. The third principle considers the presence of corridors as barriers that can reduce excess heat and light.

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