The Natural Lighting Performance Simulation in The Heritage Building: A Case Study of Gedung Singa Surabaya

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Abstrak. *Gedung Singa Surabaya adalah salah satu gedung pertama di Indonesia yang didesain oleh arsitek kolonial ternama, Hendrik Petrus Berlage pada 1901. Di tengah upaya pemerintah kota Surabaya untuk menghidupkan kembali kawasan kota lama Surabaya, Gedung Singa ini masih terlihat non aktif walaupun memiliki nilai sejarah yang tidak kalah penting daripada bangunan bersejarah di sekitarnya. Penelitian ini bertujuan untuk memodelkan bangunan Gedung Singa secara digital, untuk melakukan simulasi, terutama dalam hal performa pencahayaan alami Gedung Singa. Ditemukan bahwa pada kondisi eksisting, Gedung Singa telah beradaptasi dengan iklim tropis dengan meminimalkan sinar matahari langsung yang masuk ke dalam ruangan, yang berarti melindungi Gedung dari beban panas. Simulasi lanjutan dilakukan untuk mengoptimalkan cahaya pantulan yang telah ada, guna menerangi ruang dalam Gedung Singa dengan lebih merata.*
Keywords: *Bangunan Heritage, Pencahayaan Alami, Simulasi*

Abstract. *The 'Gedung Singa' in Surabaya is one of the first buildings in Indonesia, designed by renowned Dutch Architect, Hendrik Petrus Berlage in 1901. Despite having historical significance equal to that of the surrounding historical building, Gedung Singa appears to be vacant and ill-maintained. In recent years, the Surabaya City Government has already made efforts to revive Surabaya's old city area. Aligning with this attempt, this research aims to model the Gedung Singa via digital architecture software and do simulation to picture the daylight potential use of the building. This research found that the Gedung Singa is well adapted to the tropical climate, which results in reducing the amount of direct natural light penetrating the indoor area of the building, which further, will also reduce the heat load. Then, a more intensive simulation was carried out to optimize the existing bounced natural light to spread the illumination more evenly throughout the indoor areas of the building.*
Kata Kunci: *Heritage Building, Natural light, Simulation*

1. Introduction

Gedung Singa Surabaya is one of the Dutch architecture masterpieces in Indonesia and is prominent during the colonial era. Originally named *Algemeene Maatschappij van Levensverzekering en Lijfrente te Amsterdam,* this building was designed by a well-known Dutch Architect, Hendrik Petrus Berlage to accommodate an insurance company office, located in the southern Krembangan area, a region with significant historical value (Puspita & Dharmatanna, 2024b). This building was and still is commonly called as Gedung Singa, for the two lion statues in the left and right side of the main door. The two lion statues were sculpted by Joseph Mendes da Costa, a sculptor, who was inspired by the Egyptian archeology discoveries, symbolizing immortality (Angeline Basuki et al., 2024; Utomo Priyambodo, 2021).

This Indische Empire style mixed with Art Nouveau building consists of two storeys with quite spacious attic room, and also a courtyard that separated the building into the front and back area, connected by narrow service areas, like the lavatories. The courtyard serves as a source of natural lighting and ventilation. The front area of the building functioned as a commercial and storage area. This section has a clerestory facing to the exterior, with the 2.5 height above the floor. The back area functioned as a safe to protect the investment and precious documents. The second floor was used as an office and meeting area, as seen in the figure 1 below.

(a) 1st Floor Plan (b) 2nd Floor plan

Figure 1. Original plan of Gedung Singa
Redrawn and translated from (Angeline Basuki et al., 2024)

To present, Gedung Singa belongs to an insurance company, after dynamics in the ownership (Nanang Purwono, 2022). The shift in transportation routes from river to land has caused physical and spatial degradation of colonial buildings (Agustianti & Dharmatanna, 2025), including Gedung Singa. Population density and changes in land use (Puspita & Dharmatanna, 2024a) have threatened to erase the identity of historic buildings located alongside the Kalimas River. The Surabaya City Government itself has initiated a revitalization in Surabaya's old city area, yet the maintenance and repair that has been done in Gedung Singa has only reached its facade, and has not been able to reactivate the building. The concern of this matter displayed by the Ambassador of The Netherlands for Indonesia, Lambert Grijns, shows the building's essential value in the context of revitalization, also as a symbol of cultural diplomacy. The adaptive reuse plan to change the function of Gedung Singa as a museum or the centre of Indo - Dutch cultural relationship has been proposed (Swara, 2024).

The study of natural lighting in heritage buildings has been one of the vital research focuses in the building preservation field. Previous studies have shown a number of strategies that can be implemented to increase the daylight performance, including adding skylights (Marzouk et al., 2020, 2021; Sönmez et al., 2024), adding light shelf to existing opening and modifying ceiling design as a reflector (Soleimani et al., 2021). All of the mentioned previous studies have used simulation methods, with various parametric design softwares. Besides, to assure the even distribution of the natural light within the building, another research has recommended to modify the size of the openings in the heritage buildings, based on the numerical calculations (Prihatmanti & Susan, 2017). Yet, another research, which used specific heritage building case study and occupant interview has concluded that the change in openings type and size were seen as a negative refurbishment attempt by the building user, as it will disturb the originality of the building (Wise et al., 2021), and rather suggested a 'soft retrofit' adaptations, including efforts to change the building user behaviour, without changing the facade.

Nevertheless, beside the the rules, regulations and class category of the heritage buildings, the variety in building use from the heritage building also affects the kinds of adaptation strategies chosen, or suggested, in order to achieve optimized use of the daylight, where in Surabaya, previous studies regarding the natural lighting study in heritage buildings have been done in a domestic residential context. (Antaryama, Ekasiwi, Irvansyah, et al., 2018; Antaryama, Ekasiwi, Mappajaya, et al., 2018). Therefore, this research aims to give recommendations on design modifications that can be done in Gedung Singa, to maximize the usage of natural lighting in the building, as based on our interviews with the stakeholders, such as the community around the building, as well as the craftsman that worked on the building's facade and interior installment, the building has a dark and mystical impression.

This research intends to explore the potential utilization of the natural lighting in Gedung Singa, which can support the plan of adaptive reuse and revitalization, through the lighting efficiency, in the middle of the development of Gedung Singa's neighbourhood, which resulted in shading of original clerestory windows at certain times of the day throughout the year. To support this objective, visual simulation modelling was developed as a strategic approach to analysing natural lighting conditions inside the Singa Building, as well as a digital representation in efforts to preserve and reactivate cultural heritage buildings. This three-dimensional model not only serves as a documentation tool but also as a medium for design exploration and performative analysis, enabling the visualisation of the interaction between natural light and interior architectural elements throughout the day and year, particularly in the context of surrounding environmental developments that have obstructed the clerestory windows. Through this modelling process, the building's spatial character, window proportions, and distinctive architectural elements can be accurately remapped, enabling the evaluation of potential for integrating passive design principles without altering the building's original elements. This approach serves as a crucial foundation for designing non-invasive adaptive reuse strategies, thereby preserving the historical value and authenticity of the building while simultaneously enhancing energy efficiency and spatial functionality to address the needs of contemporary urban communities.

2. Methodology

This research used a qualitative method, with a design based analytical descriptive, in order to explore the potential of passive design, especially in terms of natural lighting, in Gedung Singa, as part of the building's reactivation strategy. Sources of the primary data are collected through building observation, visual documentation as seen in figure 2, as well as the secondary data from picture archives and literature studies regarding passive design and adaptive reuse theory. From the building observation, data from interviews with the stakeholders regarding their perception on Gedung Singa were also collected and summarized. Here, the stakeholders included two heritage experts, Gedung Singa's guard, a few neighbours across Gedung Singa that live and open food stalls by the building and the workers, as well as the contractors that helped to renovate the facade of the building. The interviews took place in two months, in a semi structured interview flow.

Then, the building was modelled using three dimensional modelling through Autodesk Revit. This method was done to gain a more holistic view of the spatial configuration, including the order of the space, the opening proportions, facade element and internal circulation (Dharmatanna, 2025).

After the digital model was created, the next step is the building performance analysis using Autodesk Forma, to evaluate the potential of natural lighting use to reduce the energy consumption to light the interior of the building, and thus, to nullify the gloomy perception that the stakeholders had for the Gedung Singa. Autodesk Forma was chosen to be used as it has real time climate data, so that the simulation result is more accurate and up to date (Dharmatanna & Wijaya, 2025).

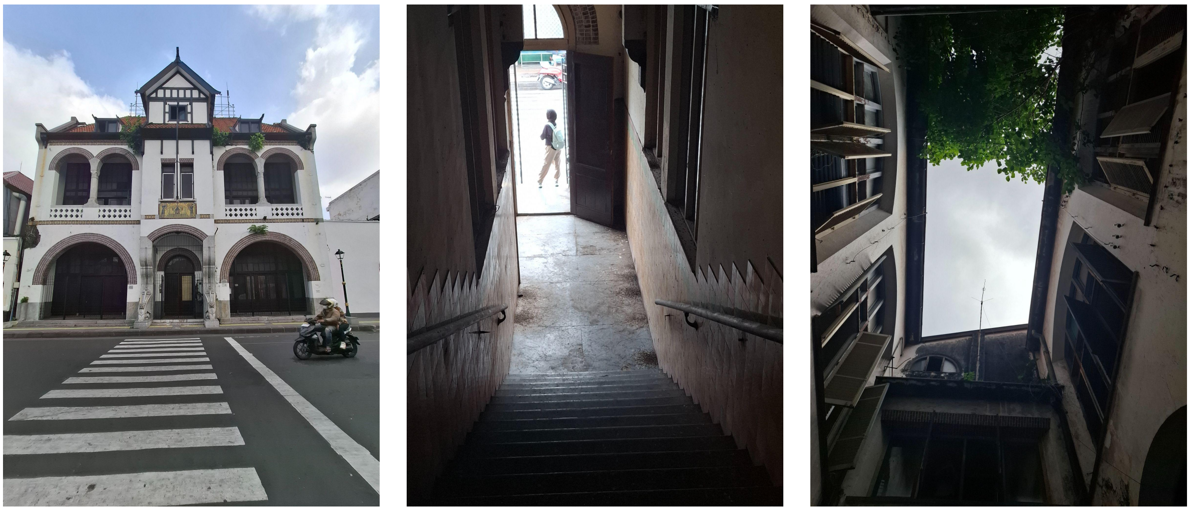


Figure 2. Field Observation

This simulation step helps to identify the effectiveness of the opening and courtyard proportion implemented in the building implicitly, especially in projecting: (1) the daylight potential, and (2) the sun hours condition in Gedung Singa. The daylight potential simulation will show the potential of each building facade being imposed by daylight. The sun hours simulation by Forma will show how many hours one side of the building gets the direct sunlight in one day that can be specified. The Gedung Singa's front facade is facing to East - Southeast orientation, which results in maximum sunlight exposure in the morning throughout the year. As Surabaya is located in 7^0 South Latitude, therefore the simulation was conducted on December 21st, when the sun is at the Earth's winter solstice, close to Surabaya position. Yet, throughout December, Surabaya will have a rainy season with overcast sky conditions in 88% of the month (*Cuaca Kota Surabaya Desember, Suhu Rata-rata (Indonesia) - Weather Spark*, n.d.). The condition in December will be least favourable for the daylighting performance, therefore if the condition in the simulation proved to be meeting the standard or even, improved, the optimization will be beneficial to be implemented in the real world, even in other months, where the sky is clearer..

The simulation itself will be done in two phases. The first phase will picture the existing condition whilst the second phase will inform the performance of natural lighting after the suggested change was done in the building, to optimize the condition found in the first phase simulation. The overall research scheme could be found in Figure 3. The findings of this process could serve as a recommendation to modify the interior design of the Gedung Singa, to achieve even lighting using daylight, that has been tested and pictured by simulation.

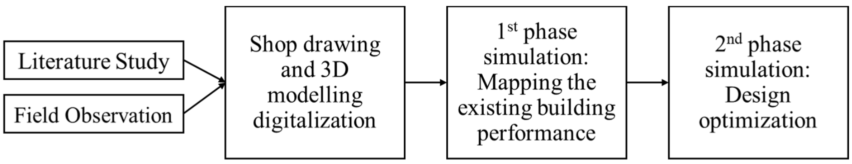
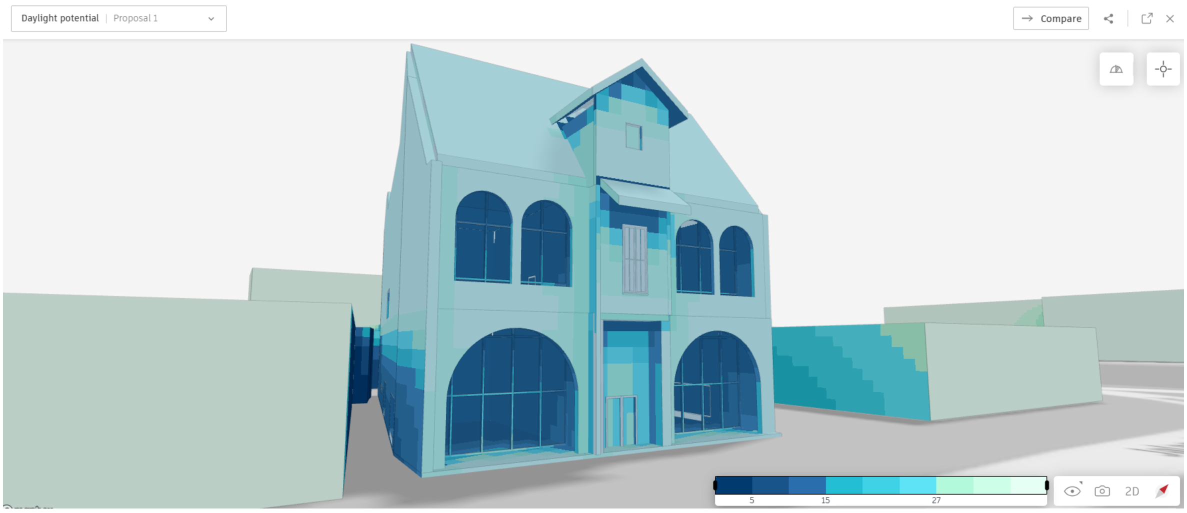


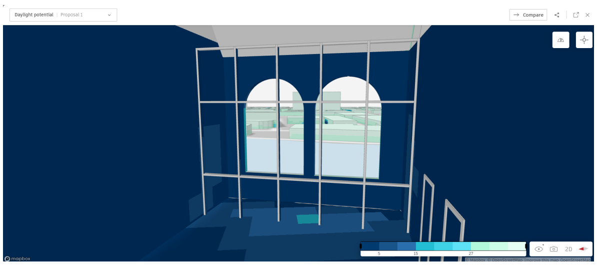
Figure 3. Research Scheme

3. Result and Discussion

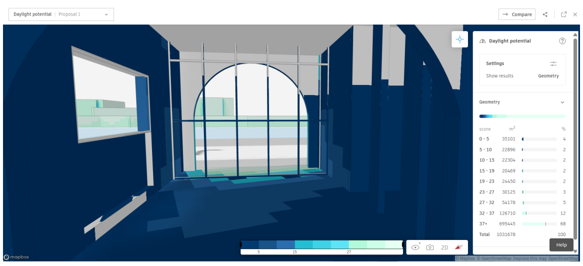
The first phase of this research resulted in a three dimensional model of the Gedung Singa. The model was redrawn using the data from the literature study (Angeline Basuki et al., 2024), with adjustments to the existing conditions captured during the field visit, where there were several areas of the Gedung Singa that had been added walls that did not found in the original plan of the building, such as the wall under the stairs, the addition of partitions and also the clerestories. After the 3D model is ready, the model is then simulated using Autodesk Forma, to minimize the damaged components and errors due to the file format conversion, and thus, ensure the simulation precision.



(a) Exterior daylight potential



(b) Second floor



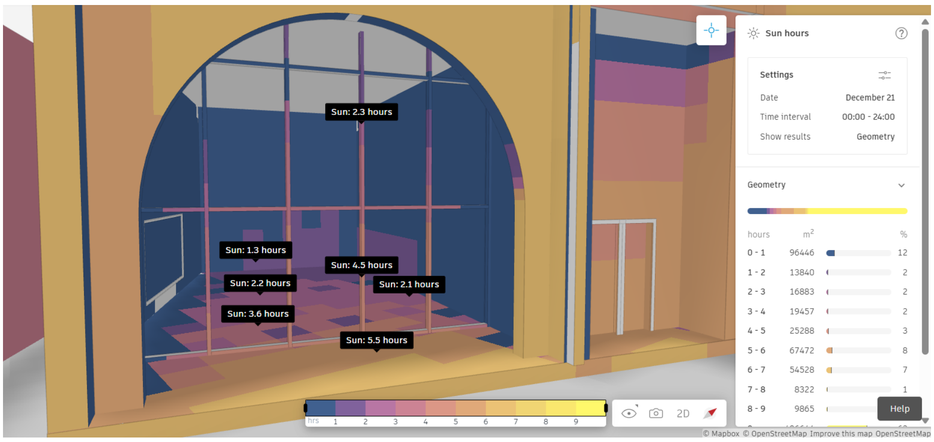
(c) First floor

Figure 4. Existing daylight potential simulation

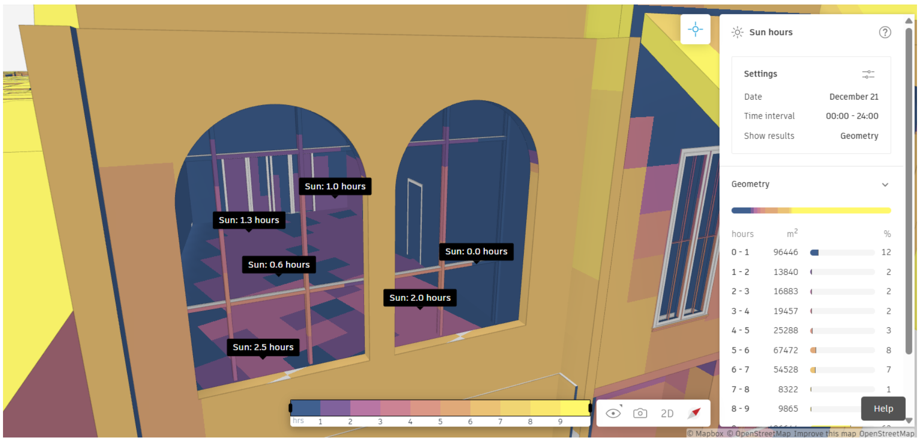
The existing condition of the Gedung Singa has an overall low level daylight potential throughout the indoor area. This can be seen in Figure 4, which shows that the Gedung Singa has a high sun exposure, represented by the cyan colour in the front building envelope area, which becomes darker at the first floor level, especially in the area next to the neighbour's building mass. The colour result from the indoor area simulation is dark blue, that signifies the low level of direct natural light in the indoor area, that makes the building rather dark and may cause glare when the building user looks at the outdoor area that has a contrasting high level of light. From the figure 4c, we can see that there is approximately 10% of the total area that scored below 15 and has dark blue colour, which shows that the existing condition needs modification to put more direct natural light to the building. Moreover, the simulations also show the partition panels that block the natural light and add shading to the room, including the use of solid wood doors that decrease the natural light intensity, as captured during the site visit in figure 5, as it only comes from the clerestory windows above them.

Figure 5. Daylight barrier panels to the interior

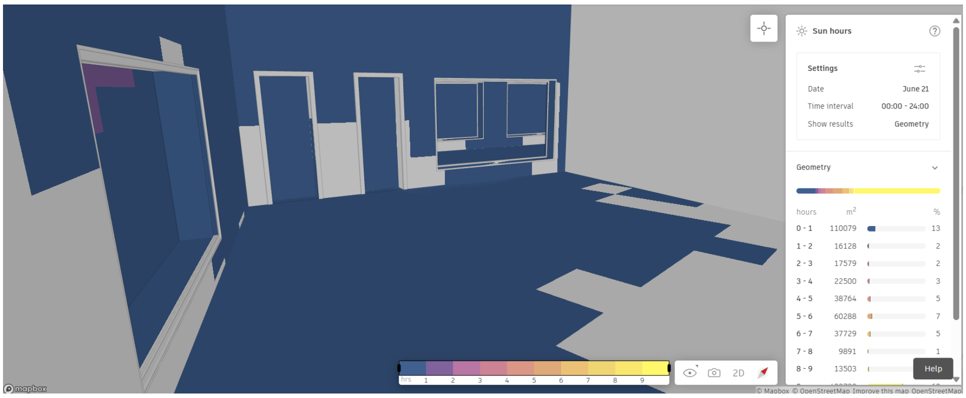
In addition to the daylight potential, this research also studies the sun hours of the building. The initial simulation shows that the Gedung Singa has been designed to adapt to the tropical climate, which limits the entry of direct sunlight. This can be seen from the simulation result in Figure 6, where the direct sunlight will fall on the area of the first floor's terrace area for approximately 5.5 hours long. This value continues to decrease, even in the first segment of the Gedung Singa's interior, which is only 1.3 hours in a day. The presence of the neighboring building, Prima Master Bank, on the southern side of Gedung singa, creates the shadowing effect to the clerestories and makes daylighting from that particular side of the building less effective. On the second floor, the lighting of the front terrace area is further reduced to 2.5 hours a day, as the Gedung Singa used a wall as the railing that also blocks the direct sunlight. The closest area from the opening at the second floor has only got 1.3 hours of direct sunlight. The deeper interiors are even completely shadowed by the mass of the building walls and only lighted by bounced lighting. The existing courtyard in the centre of the building is also not very effective in increasing the sun hours to the room that is located adjacent to the outdoor space area.



(a) First floor sun hours simulation



(b) Second floor sun hours simulation

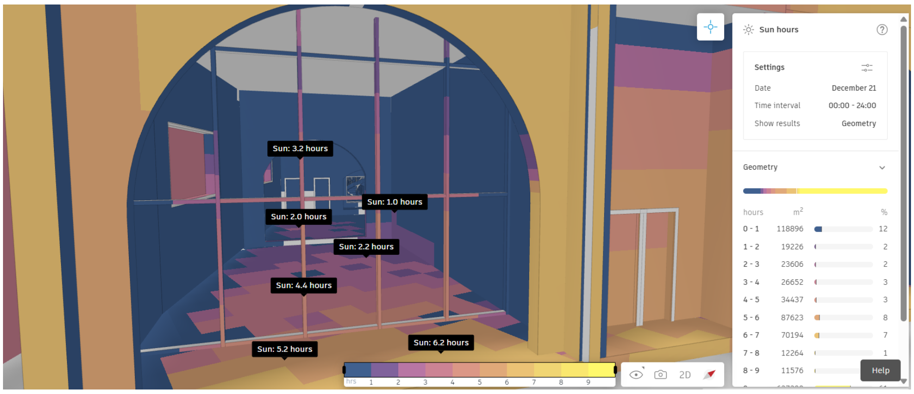


(c) Sun hours in the room adjacent to courtyard

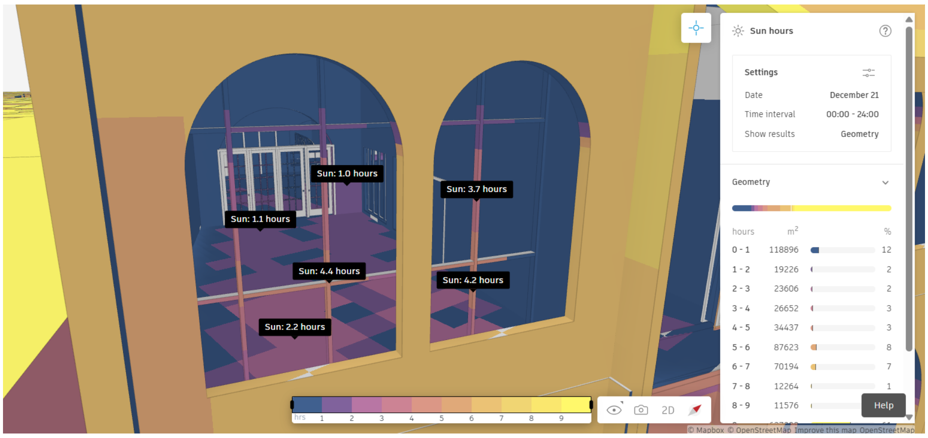
Figure 6. Existing sun hours simulation

The findings from the first simulation phase aligned and explained the result of the interviewed stakeholders in relation to their perception of the Gedung Singa, which, according to them, was gloomy and even scary. Therefore a follow up simulation was conducted, responding to the perception, to make the natural daylight spread more evenly. Optimization was suggested by removing the panels that block the natural light, and adding more glass to the wooden doors and windows at the front of the building. Moreover, the internal walls in the second floor were also replaced with a glass moveable partition with glass, ensuring the flexibility of space that comes with more modern adaptive reuse strategy, as well as allowing more natural light to penetrate the rooms that used to be blocked by walls and partitions. These changes are still aligned with the Surabaya city government regulations as written in the Regulation Number 1 established on 2024 regarding the preservation and management of heritage buildings, that allows the practice of design adaptation, as long as preserving the heritage values by adding facilities as needed (Pemerintah Kota Surabaya, 2024). It is still possible to do minor and limited changes in the interior, as long as preserving the originality of the structure and construction, architectural style and aesthetics, and are in harmonious balance with the surroundings.

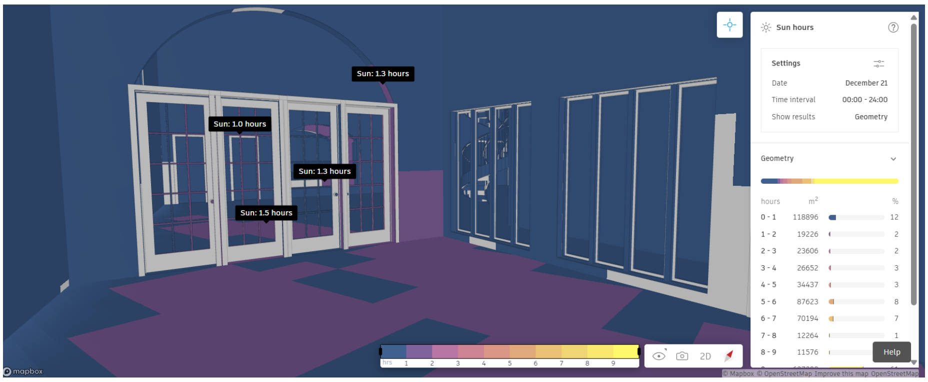
The result of this second phase simulation can be seen in Figure 7. The sun hours of the overall building have been increased. As the blocking partitions, as seen in the figure 5 and modelled in figure 6, have been removed, the daylight can penetrate further into the room, with a minimum of one hour of direct sunlight in a day for the first area behind the terrace on the first floor. The elimination of the partition also caused the second segment of the room to obtain direct sunlight both from the first indoor area and from the courtyard, even though the direct sunlight exposure is limited to an hour a day in the simulated day.



(a) Blocking panels on the 1st floor were removed



(b) Moveable glass windows partition



(c) More direct sunlight enters the room on the second floor

Figure 7. Modified sun hours simulation

If permitted by Surabaya City Government's regulation, adding glass and wood operable partitions could also be a consideration to maximize the spread of natural light into the building on the second floor. We can see from the simulation, the usage of such a partition enables the sun hours to be increased from no sun hours to 1.5 hours per day. Beside these strategies, as the intensity of the bounced daylight will be determined by the character and material that the building elements had, such as the material, reflectivity and colour of the floor, wall and ceiling, it is imperative to do a regular maintenance, such as repainting the stained moldy paint and cleaning to the building, so that the light coloured walls and ceilings can reflect the daylight more effectively. This can also be seen in Figure 8, where the indoor daylight potential has also been increased.

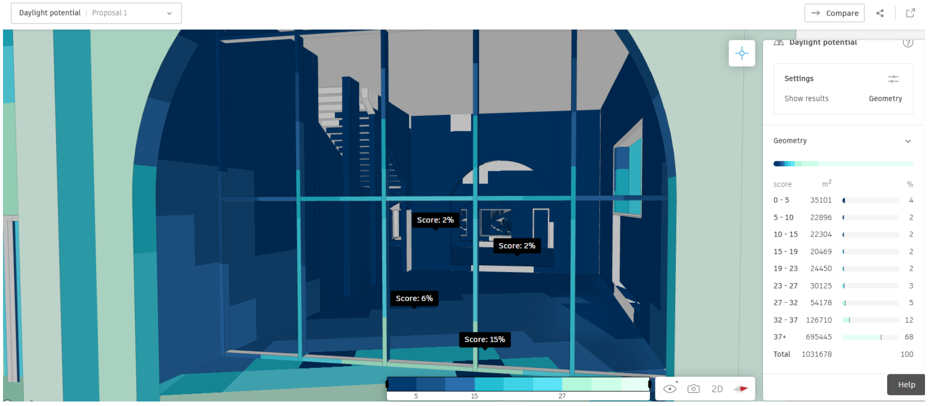
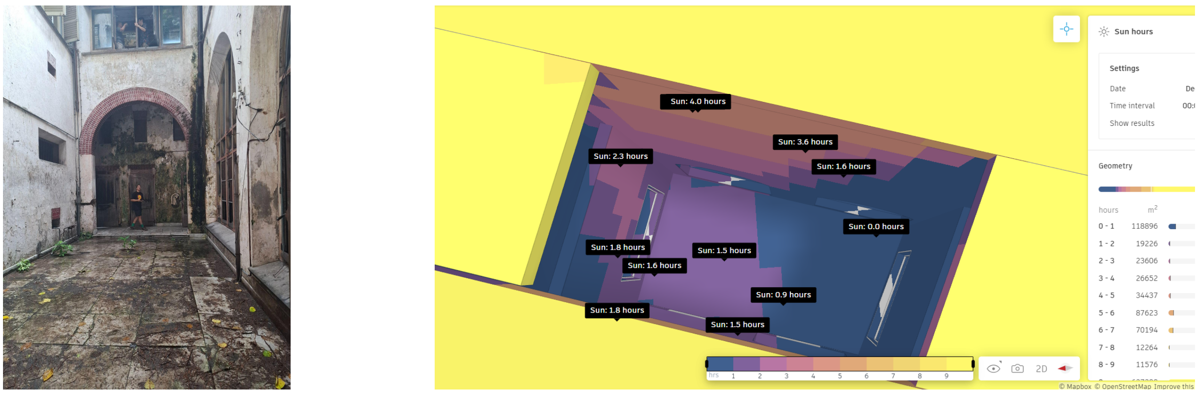


Figure 8. Increased daylight potential

In terms of the courtyard, as the building has the first category of preservation, (Vokasi UNAIR, 2023) the change in the courtyard size and proportion, as well as the adjustment in the openings facing the courtyard are strictly prohibited. As we can see in Figure 9, the base of the courtyard is exposed to direct sunlight for only about 1 hour a day, therefore the actual condition of the courtyard from the field observation, needs more careful maintenance, repair and attention, as the humidity had caused the floor and walls to be moldy. The proportion of the courtyard's width is narrower than the height of the building enclosing it that makes it stagnant in wind movement, yet still provide a slight chance of daylighting exposure, especially for the openings on the second floor. Yet, this condition can not be optimized by improving the proportions to give the building better performance. Therefore, maintenance and condition repairment is needed in this area. A change in courtyard base material could be considered, for example, to make the courtyard more porous to the soil below, so that the moss and mould could be well controlled, as there will be less puddle in the courtyard.



(a) Existing Courtyard (b) Courtyard sun hours simulation

Figure 9. Existing condition and simulation of the courtyard

4. Conclusion

From this study, it was found that the Gedung Singa has implemented lighting principles that support the building's thermal performance, namely minimising direct natural lighting that has the potential to also introduce excessive heat loads into the building. However, due to the depth of the Gedung Singa, sunlight reflections cannot reach the centre of the building, which in its existing condition is also covered by interior panels. Therefore, this study suggests conducting a "soft retrofit" by removing the interior panels that were not present in the original floor plan of the Gedung Singa, replacing partition walls with glass partitions with wooden frames that align with the design of other doors and windows, and ensuring proper maintenance of the building's finish to guarantee the effectiveness of natural light reflection into the building. Since the Gedung Singa is a Class A cultural heritage building, changes to the front façade design and courtyard area are not permitted under regulations.

This research could serve as the prototype for further research within the topic of assessment of daylight performance in heritage building. Future research can focus on integrating natural and artificial lighting to support the reactivation of the assessed heritage building, in order to obtain more comprehension and closeness to real operational conditions, where it will not only use daylighting but also artificial lighting.

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