Contents available at: www.repository.unwira.ac.id

ARTEKS
JURNAL TEKNIK ARSITEKTUR

https://journal.unwira.ac.id/index.php/ARTEKS

Research paper

doi: 10.30822/arteks.v9i2.3187

Bus stop design strategy based on visual comfort level in Bandung City

Nada Elfira Dwi Kania*, Agustinus Nur Arief Hapsoro, Irwan Sudarisman, Riksa Belasunda

Master of Design Study Program, Faculty of Creative Industries, Universitas Telkom, Bandung, Indonesia

ARTICLE INFO

Article history:
Received February 07, 2024
Received in revised form May 08, 2024
Accepted May 21, 2024
Available online August 01, 2024

Keywords:
Bandung
Bus stops
Daylight lighting factors
Visual comfort

***Corresponding author**: Nada Elfira Dwi Kania
Master of Design Study Program, Faculty of Creative Industries, Universitas Telkom, Indonesia
Email: nadaelfiradk@student.telkomuniversity.ac.id

ABSTRACT

High sunlight and poor air quality in the city of Bandung affect the level of visual comfort. In designing bus stops, space is needed that has visual comfort so that the facilities are maintained and can function well. This research was conducted to determine visual comfort as measured using the Daylight Factor (DF) at bus stops in Bandung. The method used is a quantitative experiment using Drajmarsh and Ladybug software. To identify a bus stop design with stable visual comfort, analysis was conducted at various times and places. The results of the study are guidelines for creating publicly accessible spaces, such as bus stops, in Bandung that make utilization of natural light from the sun from morning to night. This light is crucial for visual information, thermal comfort, and building energy efficiency.

Introduction

The capital of Indonesia's West Java Province is the city of Bandung, which experiences a temperate, humid mountain environment ("Kota Bandung - Official Website of Pemerintah Daerah Provinsi Jawa Barat" n.d.).

The city of Bandung has an average monthly temperature of 23.5^{0}C, 200.4 mm of rainfall, and 21.3 days of rainy weather (Bandung, Indonesia - Monthly Weather Forecast and Climate Data n.d.). With an average high temperature of 29^{0}C (84.2^{0}F), and an average low temperature of 20.4^{0}C (68^{0}F), October is the warmest month while August and September are the months with the most sunshine in Bandung, with an average of 8,5 hours of sunlight ("Bandung, Indonesia - Detailed Climate Information and Monthly Weather Forecast | Weather Atlas" n.d.)

The US AQI value for Bandung's air quality in the middle of 2021 was 83, indicating "Moderate" conditions. The World Health Organization (WHO) supports and employs the United States Air Quality Index (US AQI) figure as a classification system. At 46 g/m3, the concentration of PM 2.5 pollution places the city of Bandung's air quality in the "Unhealthy for sensitive groups" category, according to the US AQI number of 127. It is advised that residents of Bandung stay inside due to the poor quality of the air to keep more contaminated air from entering the space. Especially for people who have a higher level of sensitivity ("Bandung Air Quality Index (AQI) and West Java Air Pollution | AirVisual" n.d.).

The city of Bandung's high sunshine levels and poor air quality can cause discomfort with warmth and sight. The Daylight Factor (DF) can be utilized to quantify thermal and visual comfort.

Bus stops are included in lighting quality classes C and D, which are 15%–30%, according to the National Standardization Agency (BSN) about processes for creating daytime natural lighting for buildings based on lighting quality classification ("Standar Nasional Indonesia Badan Standardisasi Nasional Tata Cara Perancangan Sistem Pencahayaan Alami Pada Bangunan Gedung," n.d.).

According to Ade Kurniawan and Darajat (2011), although Indonesian bus stop designs currently adhere to international standards, Jakarta and the surrounding areas' bus stops lack proper bus stop maintenance. In addition to decreasing the need for artificial light, daylight additionally helps reduce cooling loads and energy usage (Sari 2017). Sari (2017) asserted that based on SNI 03-2396-2001, the minimum DF standard is 0.91% and the maximum is 19 for the reading room. Mangkuto et al. (2015) added that the Indonesian National Standard (SNI) recommends a daylight area of 33.3% relative to the total floor area. From the simulation performed by Mangkuto et al. (2015) in a classroom at ITB University, Bandung City, it was discovered that the minimum daylight area had a dynamic metric with daylight autonomy of 50%. Meanwhile, according to Freewan and Al Dalala (2020), it is advised to use anabolic systems, light shelves, upper windows in corridors, and translucent materials when creating educational buildings that demand careful consideration when designing the indoor visual environment. These elements can increase the amount of daylight, especially at the back of the corridor, by an average of more than 100%. The analysis's findings indicate that there is less of a variation in daylight quality at the rear as compared to the front, which enhances sunlight quality and reduces glare. This analysis simulates the examined devices using the IESVE (radiance) calculation engine of the daylight simulation program with the use of specialized tools to facilitate effective parametric modeling (Freewan and Al Dalala 2020). Based on an examination of case studies conducted in different academic classrooms, it can be concluded that while the energy savings (WFR) for both LED and fluorescent lighting are the same, rectangular room shape provides better energy outcomes. The highest energy yield is likewise obtained for geometric square spaces. A square classroom with south-facing rectangular windows, 12% WFR, and fluorescent lights is the best scenario out of all of them, utilizing 467.5 kWh of energy annually (Rubeis et al. 2018). According to other studies, the area has a humid subtropical climate with significant yearly energy demand for hot water, space heating, and space cooling. Considering these circumstances, rectangular buildings are considered to be more efficient than other types of buildings. Energy-efficient building materials with a thickness of 290 mm are used in place of traditional wall materials to enhance thermal comfort in buildings. This results in a decrease in thermal lag from 16.48 to 11.12 and an increase in thermal lag from 0.02 to 0.18 (Prakash et al. 2021). Because the building is oriented towards the reverse, which reduces the use of artificial light in the BIT Mesra dormitory building in Ranchi, India, the maximum daylight factor, thermal comfort, and energy performance under clear sky conditions for buildings with conventional and nano building materials on walls and roofs have a maximum daylight factor in the range of 1-11% and 1-21% for floors and walls. With a root mean percentage error of 1.24%, the correlation between the simulated and experimental daylight factor values was determined, and the overall measurement uncertainty in the experiments was computed as 0.1421%. This strategy has been demonstrated to be successful and is adaptable to any building design, with adjustments made based on the building's location and climate (Ahmad et al. 2022). In preventing glare levels in buildings, maintaining visual comfort, and reducing greenhouse gas pollution, colored glass with corrosion elements in traditional Iranian buildings can reduce glare levels. In particular, Blue and Red colors can increase sunlight, prevent glare, and prevent excess illumination of more than 2000 Lux, while Yellow, Green, and Transparent colors allow as much sunlight to enter the interior space as possible. Furthermore, according to the findings of a high-level performance analysis of interactive kinetic facades produced up of IKF (0-45), IKF (0-90), IIKFCG (0-45), and IIKFCG (0-90), the results for both facades demonstrate that while the number of DA IKF (0-45) cannot meet the minimum requirements, it nevertheless maintains the number of UDI and EUDI within a range that is satisfactory for residents. Particularly, IIKFCG (0-45) exhibits a high degree of efficiency in maintaining a sufficient quantity of DA metrics, with a 34.89% increase over IKF (0-45). In terms of preventing discomfort from the heat and sunlight, both scenarios are effective. When it concerns facades (0-90), they can prevent heat discomfort, allow in enough natural light into the workplace space, and maintain an acceptable range of DA levels. Overall, the interactive kinetic facade integrated with colored glass illustrates good results for increasing the connectivity of the interactive kinetic facade with frosted panels. Especially IIKFCG (0-45) shows a large opportunity compared to other cases based on the evaluation of climate lighting-based metrics (Hosseini et al. 2020). The health industry benefits from the usage of sunshine in buildings as well. Actinic cheilitis is painlessly cured by photodynamic therapy during the day, according to research. As advised, this therapy takes advantage of two hours of sunlight without the use of a lamp (Martín-Carrasco et al. 2020). The patients' afflicted region decreased with a 67% resolution following therapy, according to the findings. Therefore, exposure to sunlight during the day is believed to contribute to photodynamic therapy an effective substitute for treating Actinic cheilitis (Martín-Carrasco et al. 2020). In addition, a study regarding daylight photodynamic therapy (SDL-PDT) has results that can treat actinic keratosis using the indoorLux® system in combination with BF-200 ALA (Ameluz®) with four patients (33.3%) completely cured out of 12 patients and had an average cure rate of 83.75% (range 66.7-100%) (Bai-Habelski et al. 2022).

To enhance visual comfort in buildings, glass shading is required. The development of technology and knowledge causes changes, one of which is in architecture that implements smart buildings. Smart building is the optimization of buildings with high modern technology and uses sensors to control a building (Hapsoro 2020). According to Samadi et al. (2020), a solar shading system via a parametric system is highly recommended. Smart window design has emerged as a means to improve room comfort and achieve building energy conservation. Sun et al. (2021) explains that smart window designs that integrate Temotropic (TT) and Transparent Insulation Material (TIM) materials can simultaneously achieve dynamic heat and sunlight gain, reduce energy consumption, and enhance visual quality. This study demonstrates that the TT PS-TIM window system with carefully selected features can simultaneously increase building energy efficiency (up to 22% when compared to conventional double-glazed windows) and achieve average even daylight illumination, UDI 500-2000 Lux, amounting to 52.2%. With the blades placed horizontally on the TT PS-TIM produces energy balance. Furthermore, the parallel slat TIM (PS-TIM) structure contained in the window unit provides extra thermal resistance and helps direct sunlight (Sun et al. 2021). Utilizing sunlight during the day in library energy at the Faculty of Architecture, Design and Built Environment, Arab University of Beirut (Lebanon) succeeded in using Hollow Cylindrical Prismatic Light Guides (CPLGs) which allow directing light into the library building efficiently providing uniform light distribution in the work area. The proposed design theoretically allows for achieving high efficiency between 64.7% and 78.8% in the work area, avoiding glare and high color production (Omar et al. 2018). According to Balabel et al. (2022), Solatube's new lighting system technology could become a sustainable building development worldwide. This is due to the analysis's recommendation to employ Solatube technology, which is based on Saudi Arabia's abundant solar energy potential. The entire amount of electrical energy utilized can be reduced by 20–30% with Solatube technology. Furthermore, Solatube technology can receive up to 18 points in the "Mosradam" ranking system for its contributions to energy efficiency, renewable energy, indoor thermal comfort, daylight and visual comfort, innovation, and the reduction of light pollution (Balabel et al. 2022).

From the preceding description, it is possible to identify a problem: no research has examined the average daylight factor utilizing case studies of public spaces in the form of bus stops in the city of Bandung. Research on daylight factor measurements in bus stop design is therefore essential, particularly in Bandung, which has a humid tropical environment.

This research employs data from the results of questionnaires distributed online, which are then analyzed utilizing the content analysis method. Open-ended questions are employed to generate more comprehensive and diverse responses. A total of 142 respondents, aged between 19 and 28, were collected, comprising 79 women and 63 males. This age group of respondents typically has good explanation skills for their responses. Due to their invalidity, 32 pieces of data were deleted. Since the respondents were selected from 29 different Indonesian cities, they can offer a general overview of bus stops throughout the country. Respondents to the study discovered that disorganized, humid, and unsanitary bus stops are among their disadvantages, as is the prevalence of criminal activity like pickpocketing brought on by vandalism and darkness Apart from that, we conducted a direct survey at two bus stops on Jalan Soekarno Hatta, Sekejati, Bandung, West Java. From the results of the survey analysis, it was directly found that problems at the SMK Negeri 7 bus stop were poorly maintained, and dirty, and there were acts of vandalism, as well as inadequate facilities in the form of lighting. This problem is presented in figure 1.

Figure 1. Documentation of a bus stop survey at SMK Negeri 7, Bandung

The second direct survey's findings revealed issues, including untidy, moist dirty, vandalized areas, and insufficient lighting facilities. In figure 2, these issues are depicted.

Figure 2. Documentation of survey of Soekarno Hatta bus stop, Bandung

According to Departemen Perhubungan RI (2002), regarding standardization of bus stops, from a physical aspect, a bus stop is a semi-open waiting room equipped with space dividers or partitions, seats without backrests, roof coverings to protect from exposure to sunlight and rainwater. Bus stops are usually located behind the sidewalk with a size range of ≤2m x ≤4m. Bus stops typically measure less than two meters by four meters and are situated behind sidewalks. To make the waiters at the bus stop comfortable, the bus stops are designed to accommodate up to 20 passengers at a time.

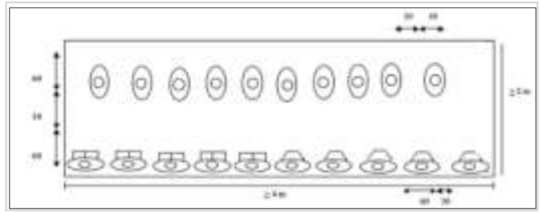

Figure 3. Bus stop shelter capacity (10 standing, 10 sitting)
Source: (Departemen Perhubungan RI 2002)

Caption:

a) Space per passenger at the stopping place 90 cm x 60 cm;
b) Clearance between passengers:
   - In the city 30 cm
   - Between cities 60 cm
c) Size of stopping place per vehicle, 12 m long and 2.5 m wide;
d) Minimum protection size 4.00 m x 2.00 m.

Figure 3 is a technical guideline (Departemen Perhubungan RI 2002), this is the perfect scenario for a bus stop's capacity: no one utilizes the area improperly, there is no passenger accumulation, and there is only waiting for the bus. Three different bus stop designs that are generally applicable throughout Indonesia are likewise governed by the technical criteria. Technical recommendations advocate the following design types:

1) Type 1 bus stops use aluminum material

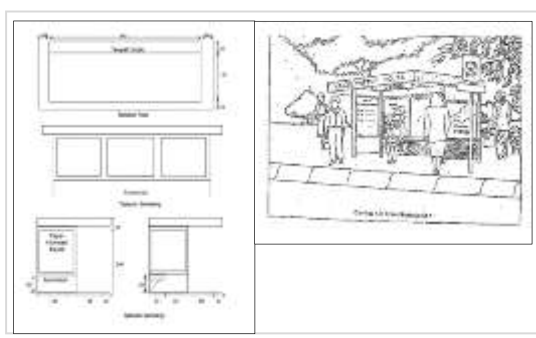

Figure 4. Type 1 bus stop
Source: (Departemen Perhubungan RI 2002)

2) Type 2 bus stops use fiberglass and aluminum materials

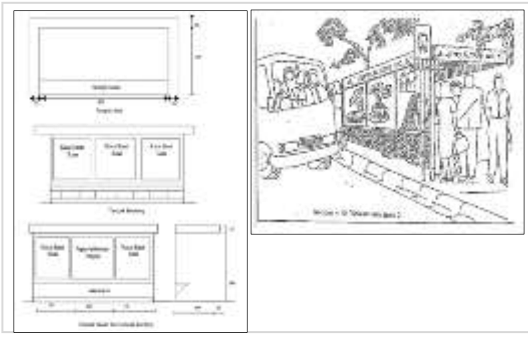

Figure 5. Type 2 bus stop
Source: (Departemen Perhubungan RI 2002)

3) Type 3 bus stops use wire mesh, fiberglass, aluminum

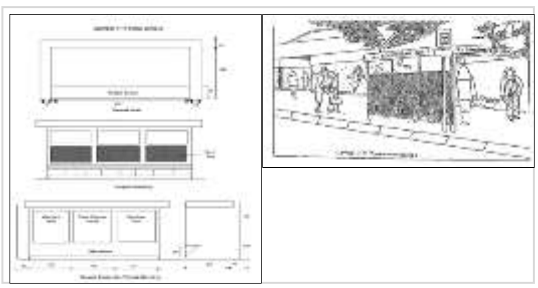

Figure 6. Type 3 bus stop
Source: (Departemen Perhubungan RI 2002)

Additional details of the technical guidelines for all types of bus stops:

- Building materials are adapted to local conditions;
- The minimum size with an effective area for a bus stop is Length = $\geq$ 4, width $\geq$ 2 m.

In theory, visual comfort has a very strong relationship with building lighting so that it not only functions to demonstrate objects but also functions to build psychological visual comfort which influences user productivity (Jamala and Rahim 2017). Even further, Aan Kurniawan (2008) explains that when people experience visual comfort, it indicates that their sense of sight is not being disrupted by their surroundings. In addition to measuring the light intensity in the room following SNI regulations, the user's impression of the lighting is required to determine whether or not it is comfortable. Predicated on SNI 03-6575-2001 For work-related activities, 3000 lux with a 4% daylight factor is the minimum skylight criterion. Because the temperature and weather are constantly changing, visual comfort cannot be only dependent on sunlight. Instead, sun glare prevention should be taken into consideration (Ismail 2021). To increase visual comfort in buildings, glass shading is needed. According to Samadi et al. (2020), installing a solar shading system using a parametric system that adjusts for changes in time depending on rotation parameters, spacing, and distance from the building face is highly encouraged. Utilizing a parametric shading system has been demonstrated to augment interior illumination, enhance the effectiveness of uniform solar radiation, and, above all, offer incredibly accurate and effective modifications contingent upon the sun's location in the atmosphere above. Intelligent technology allows for the control of shading systems based on environmental circumstances through a variety of three-dimensional rotational shading shapes and four-dimensional performance that offer significant aesthetic and functional benefits (Samadi et al. 2020). Omar et al. (2018) also suggests that designers should consider the potential for increasing the supply of daylight to save electric lighting energy; utilizing daytime physiology which is very useful for housing; in attractive buildings, the use of architectural techniques such as light pipes, atriums, shading, etc. can play a role in improving the quality of sunlight in the space; integrating simulation modeling in conceptual design provides an overview of the advantages and disadvantages so that the design can be changed to be more useful; building systems like LEED, BREAM show different techniques to increase daylight factor in buildings to reduce energy consumption (Omar et al. 2018).

Based on expert theoretical studies, it can be concluded that SNI No. 03-6575-2001 regarding ideal lighting in buildings, room user perceptions, and shading in interior opening elements are factors that affect visual comfort. Therefore, it is necessary to analyze user perceptions and conduct lighting simulation modeling experiments in the room to determine the visual comfort of a building. This provides the foundation for the idea that bus stop designs in the city of Bandung should be examined for visual comfort. This research is intended as a guideline for designing public facilities in the form of bus stops in the city of Bandung that utilize sunlight as natural light from morning to evening which plays an important role in visual information, as well as thermal comfort, and the use of natural lighting for building lighting so that it can be implemented by the community. The city of Bandung is building public facilities in the form of bus stops.

Methods

The process stages carried out in this research are depicted in the research flow diagram in figure 7.

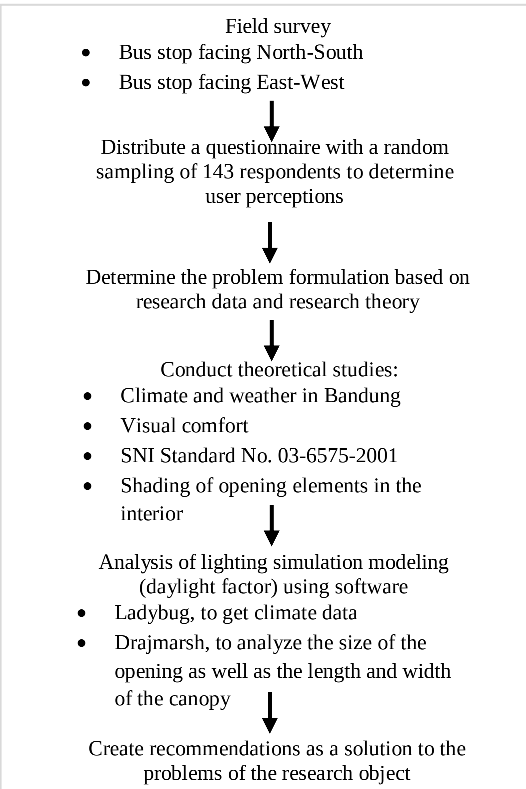

Figure 7. Research flow diagram

The research case study was conducted in the Indonesian city of Bandung, located in West Java. The organization of bus stops facing east-west and north-south directions has been studied. The dimensions of the bus stop under study are 600 x 250 x 300 cm, and they correspond to public facility standards as defined by the Director General of Land Transportation. The space between the sidewalk and the bus stop is 150 cm, which is measured starting at the bus door. August and September, with an average of 8.5 hours of sunlight, are the months with the highest sunshine in Bandung, which is when the research was performed. The analysis was carried out at the hours with the highest sunlight, namely 08.00, 11.00, 14.00, 17.00.

The analysis of bus stops with different placements and at various times aims to determine bus stop designs that have stable visual comfort with the climatic conditions in the city of Bandung in each season.

The Drajmarsh tools (https://drajmarsh.bitbucket.io/daylight-box.html) and Ladybug (https://www.ladybug.tools/epwmap) are utilized in an experimental quantitative methodology. The climate of the city of Bandung is ascertained using ladybug tools, and the results are included in the designs of bus stops. The degree of visual comfort at the bus stop was then ascertained by utilizing daylight factor methods to examine the design findings. Until the software analysis produces reliable indicators, the findings of the Daylight factor study will be re-examined and encompassed in the bus stop design.

Results and discussion

The city of Bandung experiences periods of hot, muggy weather, with inadequate air quality, particularly when it pertains to bus stations situated along major thoroughfares. To make the bus stop aesthetically pleasing, it is designed to be closed and to employ a canopy. The bus stop's design, which is closed but has enough apertures, aims to offer visual comfort in addition to being closed and using a canopy. To lower crime at bus stops and facilitate users' easy and comfortable bus waiting.

Bandung receives the maximum sunlight, with an average of 8.5 hours per day, in August and September. This results in less than optimum daytime hours for facilities like bus stops that are accessible from morning to evening.

The first step of this research was to analyze bus stop designs that do not currently use umbrellas at stations facing East-West or North-South during the months that receive the maximum sunlight in Bandung, which are August and September, with an average of 8.5 hours each day.

Daylight Factor Bus stops with enormous openings that face north-south in Bandung are primarily red, with an average daylight factor of 47.50%. See figure 8 for further information.

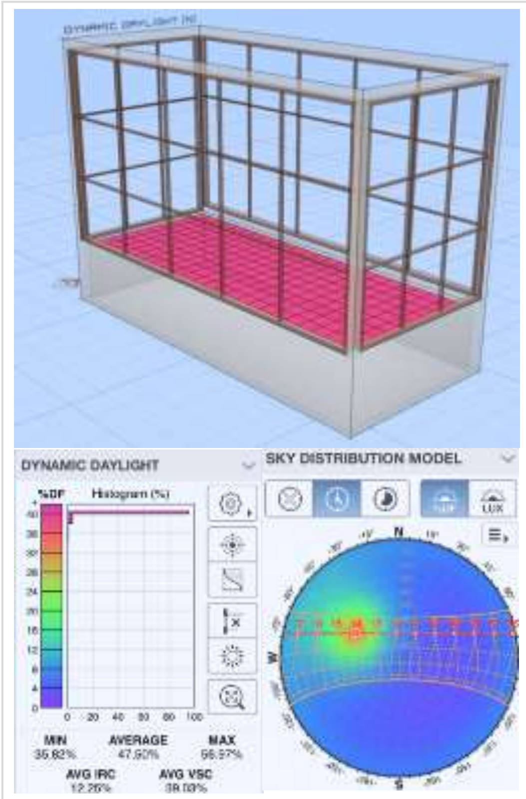

Figure 8. Daylight factor for bus stop design facing North-South at 14.00 WIB, August 2021

The daylight factor at bus stops facing North-South is considered still not thermally comfortable, as outlined in table 1 as follows.

Table 1. Daylight factor table for bus stop designs facing North-South without a canopy

The bus stop design faces North-South				
date	August 21, 2021			
time	08.00	11.00	14.00	17.00
average daylight factor	49.54%	44.56%	47.50%	47.40%
date	September 21, 2021			
time	08.00	11.00	14.00	17.00
average daylight factor	49.19%	41.96%	46.30%	47.41%

Daylight factor is also thermally uncomfortable at bus stops facing East-West, as illustrated in table 2 below:

Table 2. Daylight factor table for bus stop designs facing East-West without a canopy

The bus stop design faces East-West				
date	August 21, 2021			
time	08.00	11.00	14.00	17.00
average daylight factor	55.53 %	47.33 %	51.75%	55.75%
date	September 21, 2021			
time	08.00	11.00	14.00	17.00
average daylight factor	55.48 %	46.20 %	37.92%	55.89%

Bus stations with designs that face east-west and north-south are covered by a horizontal canopy. The bus stop design under analysis included a front horizontal canopy measuring 600 x 80 cm in front, and a side horizontal canopy determining 250 x 95 cm, with a bus stop ceiling height of 300 cm.

The examination of bus stops with horizontal canopies facing north-south reveals that there is still a lack of satisfactory visual comfort. The average DF of 35.56% in August 2021 at 14.00 WIB illustrates this. Refer to figure 9.

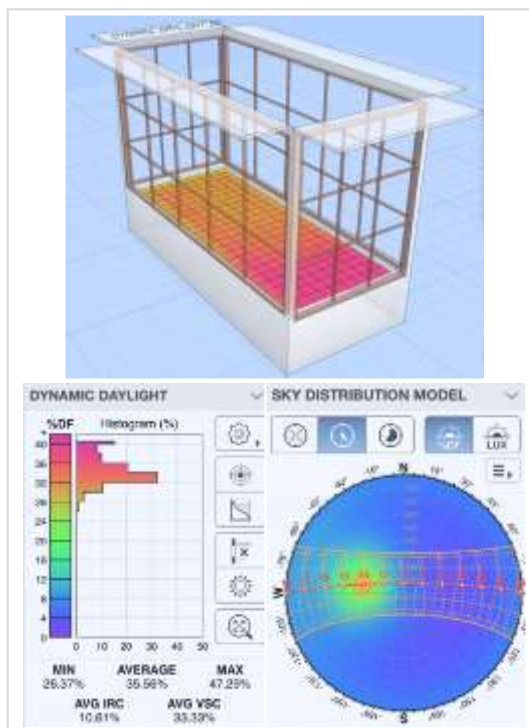

Figure 9. Daylight factor for bus stop designs facing North-South at 14.00 WIB, August 2021 using a horizontal canopy

Analysis in August and September 2021 was also carried out at 08.00, 11.00, 14.00 and 17.00 WIB, described in table 3 below:

Table 3. Daylight factor table for bus stop design facing North-South using a horizontal canopy

The bus stop design faces North-South				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	40.45%	31.62%	35.56%	47.81%
Date	September 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	40.76%	31.70%	36.91%	37.95%

An examination was conducted on designs facing East-West since the average DF findings for designs facing North-South were still unsatisfactory. According to the analysis results, red continues to be the predominant color in bus stop design, with an average DF of 38.77% in August 2021 at 14.00 WIB. Refer to figure 10.

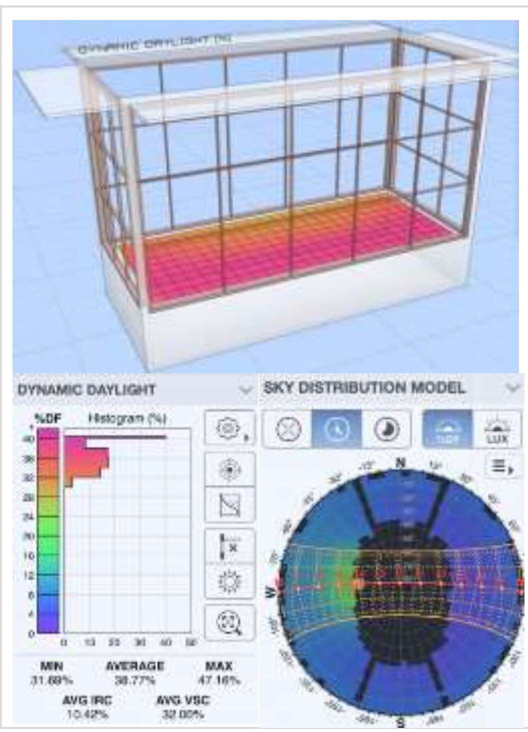

Figure 10. Daylight factor design for bus stops facing East-West at 14.00 WIB, August 2021 using a horizontal canopy

Analysis in August and September 2021 was also conducted at 08.00, 11.00, 14.00 and 17.00 WIB, described in table 4 below:

Table 4. Daylight factor table for bus stop design facing East-West using a horizontal canopy

The bus stop design faces East-West				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	44.61%	31.71%	38.77%	51.07%
Date	September 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	45.72%	31.80%	41.07%	37.83%

Based on the analysis's results, the design approaches both North-South and East-West and employs a 600 x 80 cm horizontal canopy as well as a 250 x 95 cm horizontal canopy on the side with a 300 cm bus stop ceiling height. It's still less comfortable in terms of temperature and vision, and it has a high average daylight factor.

The results of the analysis demonstrate that the bus stop design facing North-South in August 2021 at 14.00 WIB, which employs a horizontal canopy with canopy dimensions at the front of 600 x 300 cm and the sides of 250 x 300 cm, has a fairly low average daylight factor, namely 22.40%. Figure 11 demonstrates this design.

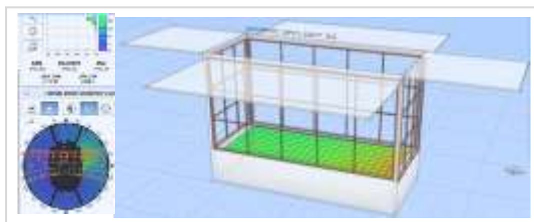

Figure 11. Daylight Factor's bus stop design facing East and West at 14.00 WIB, August 2021 uses a horizontal canopy of 600 x 300 cm and 250 x 300 cm

As a result of this investigation, the daylight factor at the bus stop decreases with increasing horizontal canopy width. On the other hand, an excessively extended horizontal canopy width may hinder the driver's speed. Thus, at bus stops with vertical canopies, an investigation was conducted. The vertical canopy that is in use measures 50 x 5 x 300 cm in front of the bus stop and 95 x 5 x 300 cm on the side. An examination of the bus stop designs facing North-South in August 2021 at 14.00 reveals an average daylight factor of 44.44%, which is still considered high (refer to figure 12).

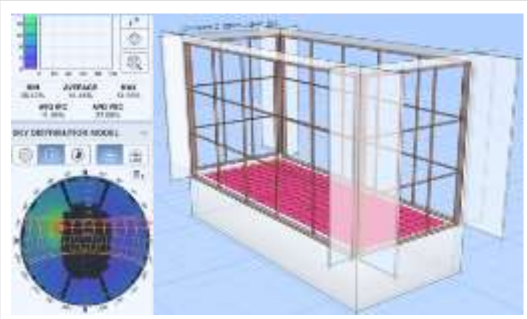

Figure 12. Daylight factor for bus stop designs facing North-South at 14.00 WIB, August 2021 using a vertical canopy

Analysis in August and September at 08.00, 11.00, 14.00, and 17.00 WIB was also performed, described in table 5.

Table 5. Daylight factor table for bus stop design facing North-South using a vertical canopy

The bus stop design faces North-South				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	46.19%	37.01%	44.44%	44.82%
Date	21 September 2021			
Time	08.00	11.00	14.00	17.00
DF average	45.79%	39.97%	43.33%	44.83%

Bus stops facing north-south still have a high and low DF value due to the daylight component in their design. The bus stop design facing east-west with the same vertical canopy was therefore the subject of an examination. Its daylight factor, which is 47.00%, is quite high and visually uncomfortably low, according to the analysis results. (View figure 13 for more information).

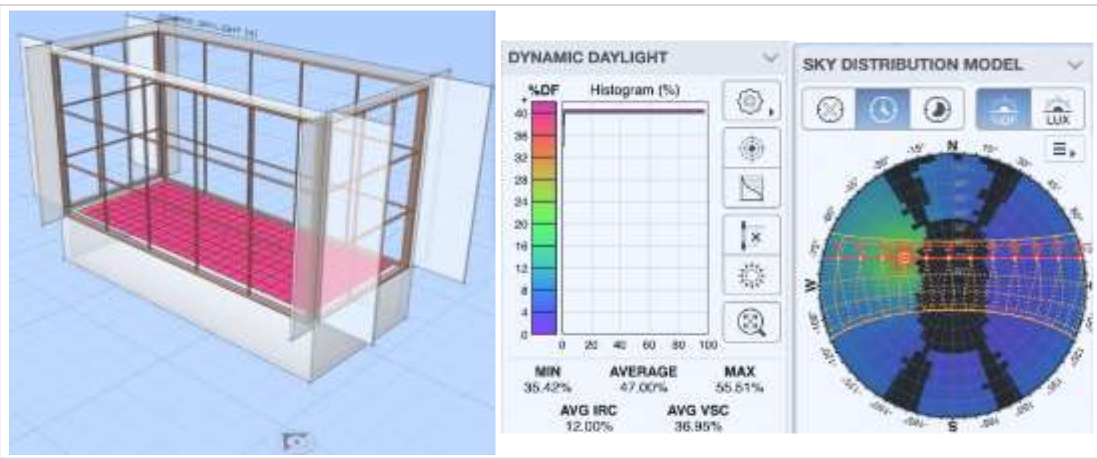

Figure 13. Daylight factor design for bus stops facing East-West at 14.00 WIB, August 2021 using a vertical canopy

The daylight factor in designs facing east and west using a vertical canopy with the same dimensions and the same placement still has a high daylight factor, as described in table 6.

Table 6. Daylight factor table for bus stop design facing East-West using a vertical canopy

The bus stop design faces East-West				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	50.38%	41.69%	47.00%	44.95%
Date	September 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	51.44%	40.74%	48.07%	44.95%

Therefore, an examination of the bus stop design which incorporates the use of additional vertical canopies was conducted. There are six vertical canopies in total, with the dimensions of 150 x 5 x 300 cm at the front and back and 200 x 5 x 300 cm on the sides, spaced 120 cm apart. As it happens, the average daylight factor results obtained were 24.73%, indicating that green dominates the distribution of natural light (refer to figure 14).

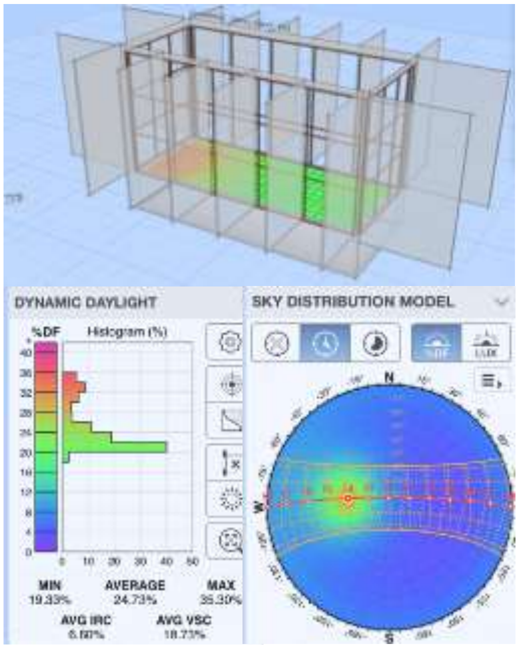

Figure 14. Daylight factor bus stop design that faces North-South

The use of a vertical canopy as described above does have quite good average daylight factor results. However, the dimensions of the canopy can interfere with road speed and are too long for the sidewalk area on the side.

The aforementioned description leads to the conclusion that bus stops with both vertical and horizontal usage have a decent average daylight factor for canopies with larger size. On the side sidewalks, this is excessively wide and disrupts the comfort of the traffic. With a bus stop ceiling height of 300 cm, an examination of the use of horizontal and vertical canopies at bus stops was conducted. The horizontal canopies at the front had dimensions of 600 x 80 cm, while the horizontal canopies on the sides had dimensions of 250 x 95 cm. Then, six vertical canopies with dimensions of 50, 70, and 80 x 5 x 300 cm are positioned at a distance of 120 cm in front and rear.

Analysis of the design facing North-South turns out to have a fairly good daylight factor with an average daylight factor of 22.58% in August 2021, at 14.00 WIB. It is illustrated by the distribution of natural light entering the bus stop which is dominated by green (see figure 15).

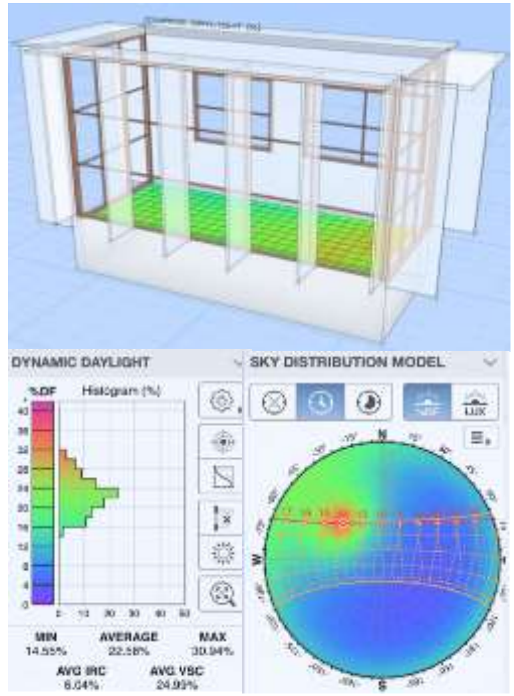

Figure 15. Daylight is a good bus stop design factor when facing North-South

Bus stops facing North-South also have an ideal daylight factor in August and September 2021 at 08.00, 11.00, 14.00, and 17.00 WIB. This is proven in table 7.

Table 7. Daylight factor table for good bus stop design when facing North-South

The bus stop design faces North-South				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	24.98%	22.16%	22.58%	25.09%
Date	September 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	24.60%	18.75%	20.99%	26.18%

The same measurements as above, but facing east-west, were employed in an examination of a well-designed bus stop. In reality, the results of the bus stop design's daylight factor study are increasing. As observed in figure 16, natural lighting has an average daylight factor of 17.67% and is distributed with a green predominance in August 2021 at 14.00 WIB.

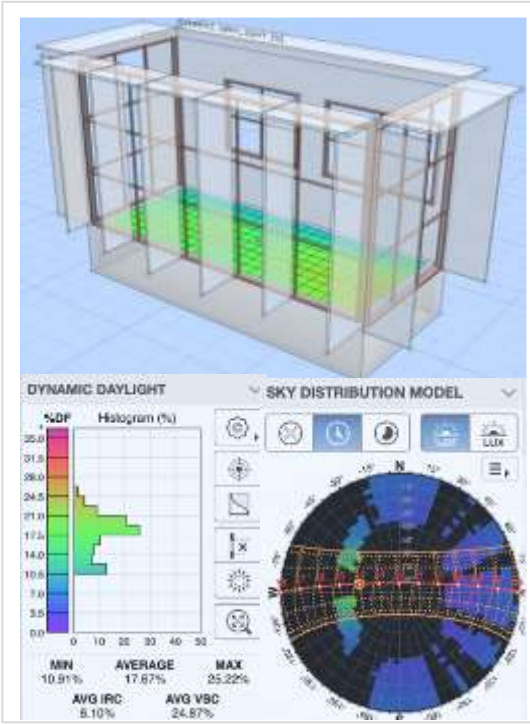

Figure 16. Daylight is a good bus stop design factor when facing East-West

Daylight factor analysis of the ideal bus stop design facing East-West is described in table 8 below:

Table 8. Daylight factor table for good bus stop design when facing North-South

The bus stop design faces East-West				
Date	August 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	27.70%	18.33%	17.67%	19.77%
Date	September 21, 2021			
Time	08.00	11.00	14.00	17.00
DF average	28.63%	17.96%	18.10%	20.18%

Conclusions

It is necessary to note that bus stops in Bandung City require both horizontal and vertical canopies to provide visual comfort. Featuring a bus stop ceiling height of 300 cm, the proportions of the horizontal canopies are 600 x 80 cm at the front and 250 x 95 cm on the side. Then, 6 vertical canopies with dimensions of 50, 70, and 80 x 5 x 300 cm are positioned at a distance of 120 cm in front and rear. The canopy measurements that are selected are those that enable comfortable driving speeds and avoid making the side sidewalks overly wide.

The bus stop design with a canopy has been described as having a good average daylight factor, which is the bus stop design facing North-South in August 2021, at 14.00 WIB has a daylight factor of 22.58% and the bus stop design facing East-West in August 2021, at 14.00 WIB has a daylight factor of 17.67%. Thus, it can be concluded that the bus stop design has dimensions of a horizontal canopy of 600 x 80 cm at the front and a horizontal canopy at the side with dimensions of 250 x 95 cm with a bus stop ceiling height of 300 cm. Then, 6 vertical canopies spaced 120 cm at the front and back with dimensions of 50, 70, and 80 x 5 x 300 cm facing East-West have a better average daylight factor.

It is necessary to build closed bus stops during periods of climate change in Bandung, where it is hot and humid and the air quality is poor.

With an average of 8.5 hours of sunshine per day, Bandung receives the greatest sunlight in August and September. This results in less than optimum daylight factors for amenities like bus stops that are open from morning to night.

Therefore, it is essential to plan closed bus stops and employ canopies, both vertical and horizontal, to enhance visual comfort and building energy efficiency. To provide consumers with visual comfort, an examination of bus stop designs with a good average daylight factor is conducted.

Aspects that influence the average daylight factor in bus stop design are the location of the bus stop facing North-South and East-West, the size of the openings at the bus stop, horizontal canopies, and vertical canopies. After analysis, the dimensions of the horizontal canopy are 600 x 80 cm at the front and the horizontal canopy at the side with dimensions of 250 x 95 cm with a bus stop ceiling height of 300 cm. Then, 6 vertical canopies spaced 120 cm at the front with dimensions of 50, 70, and 80 x 5 x 300 cm have a good average daylight factor. The bus stop design facing North-South in August 2021, at 14.00 WIB has a daylight factor of 22.58% and the bus stop design facing East-West in August 2021, at 14.00 WIB has a daylight factor of 17.67%.

The results of the study have been subjected to the test in both the East-West and North-South directions, as well as in August and September, which receive the most sunlight. According to the analysis's findings, the bus stop's 600 x 250 x 300 cm dimensions, 600 x 80 cm front horizontal canopy, 250 x 95 cm side canopies, and 300 cm ceiling height constitute the ideal for visual comfort in different directions. Then, 6 vertical canopies measuring 50, 70, and 80 x 5 x 300 cm were positioned 120 cm in front of the other canopies.

A reference design for bus stops that can improve visual comfort is the result of this research. Particularly for the city of Bandung, the research results could be useful as suggestions when planning bus stops. More research on thermal comfort at bus stop spaces is required to produce a better design.

References

Ahmad, Asim, Om Prakash, Anil Kumar, S. M. Mozammil Hasnain, Puneet Verma, Ali Zare, Gaurav Dwivedi, and Anukul Pandey. 2022. "Dynamic Analysis of Daylight Factor, Thermal Comfort and Energy Performance under Clear Sky Conditions for Building: An Experimental Validation." *Materials Science for Energy Technologies* 5: 52–65. https://doi.org/10.1016/j.mset.2021.11.003.

Bai-Habelski, Jon Chim, Karla Medrano, Ariana Palacio, and Uwe Reinhold. 2022. "No Room for Pain: A Prospective Study Showing Effective and Nearly Pain-Free Treatment of Actinic Keratosis with Simulated Daylight Photodynamic Therapy (SDL-PDT) Using the IndoorLux® System in Combination with BF-200 ALA (Ameluz®)." *Photodiagnosis and Photodynamic Therapy* 37: 102692. https://doi.org/10.1016/j.pdpdt.2021.102692.

Balabel, A., M. Alwetaishi, A. Abdelhafiz, U. Issa, I. A. Sharaky, A. K. Shamseldin, M. Al-Surf, and M. Al-Harthi. 2022. "Potential of Solatube Technology as Passive Daylight Systems for Sustainable Buildings in Saudi Arabia." *Alexandria Engineering Journal* 61 (1): 339–53. https://doi.org/10.1016/j.aej.2021.06.001.

"Bandung, Indonesia - Detailed Climate Information and Monthly Weather Forecast | Weather Atlas." n.d. Accessed January 1, 2022. https://www.weather-atlas.com/en/indonesia/bandung-climate?c%2Cmm%2Cmb%2Ckm#faq.

Bandung, Indonesia - Monthly Weather Forecast and Climate Data. n.d. Weather Atlas. Accessed January 1, 2022. https://www.weather-atlas.com/en/indonesia/bandung-climate.

"Bandung Air Quality Index (AQI) and West Java Air Pollution | AirVisual." n.d. Accessed January 7, 2022. https://www.iqair.com/indonesia/west-java/bandung.

Departemen Perhubungan RI. 2002. "Pedoman Teknis Penyelenggaraan Angkutan Penumpang Umum Di Wilayah Perkotaan Dalam Trayek Tetap Dan Teratur." *Keputusan Direktur Jenderal Perhubungan Darat*, no. SK.687/AJ.206/DRJD/2002: 2–69. http://hubdat.dephub.go.id/keputusan-dirjen/tahun-2002/423-sk-dirjen-no-687aj.

Freewan, Ahmed A.Y., and Jackline A. Al Dalala. 2020. "Assessment of Daylight Performance of Advanced Daylighting Strategies in Large University Classrooms; Case Study Classrooms at JUST." *Alexandria Engineering Journal* 59 (2): 791–802. https://doi.org/10.1016/j.aej.2019.12.049.

Hapsoro, Nur. 2020. "EVOLUSI ILMU ARSITEKTUR." *Lakar: Jurnal Arsitektur* 03 (01): 18–25. https://journal.lppmunindra.ac.id/index.php/lakar/article/view/5878.

Hosseini, Seyed Morteza, Masi Mohammadi, Torsten Schröder, and Olivia Guerra-Santin. 2020. "Integrating Interactive Kinetic Façade Design with Colored Glass to Improve Daylight Performance Based on Occupants' Position." *Journal of Building Engineering* 31 (March). https://doi.org/10.1016/j.jobe.2020.101404.

Ismail, Isty Cahyani. 2021. "PENGGUNA GEDUNG MENARA BANK MEGA MAKASSAR INTEGRATION OF NATURAL AND ARTIFICIAL LIGHT ON ENERGY EFFICIENCY AND VISUAL COMFORT OF USERS OF THE MEGA BANK MAKASSAR TOWER BUILDING."

Jamala, N., and R. Rahim. 2017. *Teori Dan Aplikasi Kenyamanan Visual*. Makasar: Badan Penerbit UNM.

"Kota Bandung - Website Resmi Pemerintah Daerah Provinsi Jawa Barat." n.d. Accessed January 1, 2022. https://jabarprov.go.id/index.php/pages/id/1060.

Kurniawan, Aan. 2008. "Analisis Tingkat Pencahayaan Alami (Studi Kasus Ruang

Kelas SMA Negeri 9 Makassar." *Jurnal Teknik Sipil & Perencanaan*.

Kurniawan, Ade, and Teddy M Darajat. 2011. "Desain Halte Untuk Masyarakat Urban (Studi Kasus : Daerah Jakarta Dan Sekitarnya)." *Daerah Jakarta Dan Sekitarnya) Inosains* 6 (1).

Mangkuto, Rizki A., Anindya Dian Asri, Mardliyahtur Rohmah, F. X.Nugroho Soelami, and R. M. Soegijanto. 2015. "Prediction of Daylight Areas with the Use of Students Assessment and Computer Simulation in the Tropics: Case Study in Bandung, Indonesia." *14th International Conference of IBPSA - Building Simulation 2015, BS 2015, Conference Proceedings*, no. December: 26–33.

Martín-Carrasco, P., M. Sendín-Martín, J.J. Domínguez-Cruz, and J. Bernabeu-Wittel. 2020. "Actinic Cheilitis Treated With Daylight Photodynamic Therapy." *Actas Dermo-Sifiliográficas (English Edition)* 111 (10): 883–85. https://doi.org/10.1016/j.adengl.2020.10.015.

Omar, Osama, Berta García-Fernández, Antonio Álvarez Fernández-Balbuena, and Daniel Vázquez-Moliní. 2018. "Optimization of Daylight Utilization in Energy Saving Application on the Library in Faculty of Architecture, Design and Built Environment, Beirut Arab University." *Alexandria Engineering Journal* 57 (4): 3921–30. https://doi.org/10.1016/j.aej.2018.10.006.

Prakash, Om, Asim Ahmad, Anil Kumar, S. M. Mozammil Hasnain, Ali Zare, and Puneet Verma. 2021. "Thermal Performance and Energy Consumption Analysis of Retail Buildings through Daylighting: A Numerical Model with Experimental Validation." *Materials Science for Energy Technologies* 4: 367–82. https://doi.org/10.1016/j.mset.2021.08.008.

Rubeis, Tullio De, Iole Nardi, Mirco Muttillo, Stefano Ranieri, and Dario Ambrosini. 2018. "Room and Window Geometry Influence for Daylight Harvesting Maximization - Effects on Energy Savings in an Academic Classroom." *Energy Procedia* 148: 1090–97. https://doi.org/10.1016/j.egypro.2018.08.050.

Samadi, Sahba, Esmatullah Noorzai, Liliana O. Beltrán, and Saman Abbasi. 2020. "A Computational Approach for Achieving Optimum Daylight inside Buildings through Automated Kinetic Shading Systems." *Frontiers of Architectural Research* 9 (2): 335–49. https://doi.org/10.1016/j.foar.2019.10.004.

Sari, Nike. 2017. "Kuantifikasi Kenyamanan Visual Dengan Daylight Factor Method Pada Ruang Baca Teknik Fisika ITS Surabaya." 2017. https://repository.its.ac.id/44606/3/2413100008 - Undergraduate_Theses.pdf.

"Standar Nasional Indonesia Badan Standardisasi Nasional Tata Cara Perancangan Sistem Pencahayaan Alami Pada Bangunan Gedung." n.d.

Sun, Yanyi, Robin Wilson, Hao Liu, and Yupeng Wu. 2021. "Numerical Investigation of a Smart Window System with Thermotropic Parallel Slat Transparent Insulation Material for Building Energy Conservation and Daylight Autonomy." *Building and Environment* 203 (January): 108048. https://doi.org/10.1016/j.buildenv.2021.108048.

Author(s) contribution

Nada Elfira Dwi Kania contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Nur Arief Hapsoro contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Irwan Sudarisman contribute to methodology, supervision, and validation.

Riksa Belasunda contribute to methodology, supervision, and validation.

This page is intentionally left blank