8th International Conference on

Architecture Research and Design (AR+DC)

November 1-2, 2016

# Adaptive reuse of heritage building and the impact to the visual comfort: Assessed by the lighting quality

Rani Prihatmanti[a*], Maria Yohana Susan[a]

[a]*Interior Architecture Department, Ciputra University, Surabaya-Indonesia*

*Corresponding author. Tel.: +6231-745-1699; fax: +6231-745-1698

*E-mail address:* rani.peanut@gmail.com

---

**Abstract**

Heritage buildings are designed mostly to be adaptive with the local climate. The main purpose of these adaptive strategies is to create users' thermal comfort as well as solving the problem of high rain precipitation in the tropical climate area. These thermal adaptation strategies will definitely influence room daylight condition. External shading device used in heritage building is one of thermal adaptation strategies, but it will also obstruct the daylight penetration. Design solution should be thought to maximise daylight condition. However, the design solution for heritage building has its own limitations where certain guidelines must be adhered, especially when resizing the existing windows to obtain better daylight condition is needed. This research studies the daylight condition on the designated schools and finding the most feasible solutions to overcome the lighting problems. The existing condition of the daylight was measured using lux meter and the data obtained were analysed descriptively by comparing to the related references in order to gain a maximum result. A simulation by using computer software was also conducted for simulating daylight level in both buildings. Based on the measurements that have been conducted, it shows that the daylight level on the designated buildings was below the standard and the current artificial lighting system was also failed to create the standard illuminance level The solutions for this problems are resizing the window or creating an artificial lighting system. Although in this research proposes 2 solutions to overcome the problems, the latter solution is considered as the most feasible solution to treat heritage building to be a visually comfortable building without major alteration on the building fabrics since both studied buildings are listed as a National Heritage Monument.

*Keywords:* heritage building; adaptive reuse; daylight; artificial lighting; solutions

---

## 1. Introduction

School building can be defined as the learning environment for every people. It plays an important role in learning performance and productivity on both students as well as the educators. According to (Bernardi & Kowaltowski, 2006), schools should be safety, accessible, and comfort for all the users. Comfort can be defined as the favorable conditions related to functionality, thermal, illumination, and its acoustic conditions. Unfavorable conditions of comfort in schools, such as high temperatures, excessive noise, inadequate illumination, excessive occupation density in the classroom and finally inadequate equipment in relation to age groups can have negative influences on the students' school performance and can cause health problems, physiologically and psychologically.

Nowadays, green building rating tools have included the assessment of the Indoor Environmental Quality (IEQ) in order to obtain a healthy occupants and one of the assessment is regarding the visual comfort. The issue regarding the effect of the indoor light level to the visual comfort has been highlighted since the last few years. This is also related to the green building trend where building occupants are required to be comforted when they are indoor, including in the schools. In order to enhance the quality of school buildings, we must first be able to effectively *measure* and *assess* school building performance. The lighting provided in a building must accommodate the occupants' activity uniformly and it needs an appropriate planning on the lighting systems. If the daylight is insufficient, artificial lighting is compulsory to obtain the required illuminance level. (Benya, 2001) stated that the challenge of the indoor lighting is to provide a lighting system that is energy efficient, has a long life, and requires minimal maintenance. Nevertheless, not all buildings could accommodate the appropriate lighting for the occupants. One of the factors is the building itself. Buildings that are not meant to be built as its main purpose or have undergone a major renovation to a different function are prone to cause discomfort to the occupants (Prihatmanti & Bahauddin, 2011). This case commonly happens in heritage buildings that have been adaptively reused. Therefore this research aims to study the indoor lighting performance in schools that are located in heritage-listed buildings and finding the most feasible solutions to overcome the problems occurred.

## 2. Literature Review

### *2.1. Lighting in Schools*

Light is a crucial element in a learning environment. Without light, students and teachers could not perform their daily teaching-learning activities. There are two main lighting systems, daylighting and artificial lighting. Daylight is a source of light that comes from the sky vault. About half of all the lighting energy used by buildings could be saved by daylighting (Lechner, 2009). For some building types such as office and school, daylight can save energy for about 70%. Previous studies have been conducted regarding the benefits of daylight in a classroom. It has been scientifically studied that students studied in a sufficient daylight classrooms had a significantly greater improvement over the course of one school year in math and reading skills than students in classrooms with no daylight (Heschong, 2002 in (Mott, Robinson, Walden, Burnette, & Rutherford, 2012)). There are numerous aspects of daylight that make it desirable as a light source. Well-designed fenestration systems can provide light for the performance of visual tasks; a distant focus for the eye, allowing the eye muscles to relax; and psychological benefit from viewing the exterior world. Despite its benefits, there are some disadvantages of daylight when the amount is excessive such as glare. To minimize glare, fenestration controls should prevent direct sunlight from entering classrooms. Shades, blinds, louvres, baffle systems, and roof overhangs can be used to control the daylight. (IESANA (Illuminating Engineering Society of North America), 2000).

The performance of daylight in building interior can be assessed through the illuminance level as well as the Daylight Factor (DF). Illumination shows the level of illuminance, which variety depends on the brightness of the sky, therefore it is impossible to specify a daylight level by a fixed illuminance level in lux. According (SNI (Standar Nasional Indonesia), 2001) no. 03-6575-2001 for artificial lighting in the building, the minimum indoor illuminance level for a classroom is 250 lux. As mentioned previously, DF also needs to be considered in measuring the daylight level. DF could be defined as the ratio of the illumination indoors to outdoors on an overcast day. It is a good indication of the effectiveness of a design in bringing daylight to the indoor. Moreover, DF also used as a good indicator of the relative brightness between the interior and the window. The higher DF value means the more effective of the design in bringing daylight into the indoor. In this case, it could also indicate as reduced brightness contrast.

This research was conducted in 2 classrooms as the study object, and based on McMullan (2007), the typical average daylight factor for a classroom is 5%, while the minimum daylight factor is 2%. (Heerwagen, 2004) mentioned that using daylight to illuminate the building interior requires some treatments, i.e. from the site development, building forms, building envelope, until the interior of the building. Regarding the illumination from the building envelope, it needs an opening on the building envelope itself. In this case, the designer should think about the selection of the window's locations, shapes, and sizes. There are two methods for sizing the window based on its purpose. First, the basis of which were the sizing of windows to enable occupants to view the external world; and the second one is the basis of which were the sizing of the windows to admit daylight to the interior. However, based on the objective, this study is strongly related to the second one. For sizing windows in the vertical envelope, according to (Heerwagen, 2004), there are two rules-of-thumbs that are suggested for vertical windows:

$$DF_{average} = 0.2 \times (\text{glazing area/floor area}) \quad (1)$$

$$DF_{minimum} = 0.1 \times (\text{glazing area/floor area}) \quad (2)$$

The difference between the above-mentioned two formulas is on how much of the daylight should enter the space. ‘DF average' formula will be used if the design wants to ensure that minimum DF can be found uniformly in the work plane. While the ‘DF minimum' formula will be applied if the design requires different DF values in the certain spaces, e.g. some work planes would have more DF value and the others would have less. This research will use the DF average formula to ensure that minimum DF can be found uniformly in the work plane.

When daylight is insufficient, artificial lighting is required in order to meet the lighting standard and the recommended illuminance level depends on the tasks to be performed. The common tasks performed in most regular classrooms all the time include writing, reading printed material, and reading from various media i.e. whiteboards, projector screen, computer/laptop, and other video monitors. High contrasting surfaces or sources like whiteboards, laptop, and video monitors could cause glare that causing visual discomfort. Visual impairments alone can induce behavioural problems in students, and the level of concentration and motivation in the classroom (Mott et al., 2012).

Good lighting design takes into account the location of these components within the room, and their positions are to avoid reflected glare from highly contrasting sources (McCreery & Hill, n.d.). Once the desired illuminance has been determined, other factors, such as direct and reflected glare, shadows, and color, should be considered in the luminaire and lamp selection. The type of luminaire selected also depends on the ceiling height and type. In high-ceilinged spaces, suspended direct-indirect luminaires provide down lighting and reflected light from the ceiling. For the low-ceilinged spaces, ceiling-mounted or recessed luminaires are the best choice. Well-designed indirect lighting systems provide low-brightness, shadow-free illumination (IESANA (Illuminating Engineering Society of North America), 2000).

Sufficient indoor light level has a detrimental effect on the building occupants, including students. Indoor lighting is widely known to give a significant role in satisfying visual comfort as it is highly affecting students' satisfaction and their academic performance; and several studies have been conducted to highlight the lighting performance in learning environment ((Axarli & Tsikaloudaki, 2007; Benya, 2001; Samani & Samani, 2012; Yang, Becerik-Gerber, & Mino, 2013). Winterbottom and Wilkins (2009) in their research reported that the aspects of classroom lighting and decor could promote discomfort and could impair task performance through glare caused by the inappropriate lighting system. It means that when the occupant is forced to experience conditions of visual distress for some time; the individual's vision will progressively degrade as fatigue and discomfort increase (in Amasuomo and Alio, 2013). Moreover, as stated by (Mott et al., 2012), visual perception strength could have a considerable impact on cognitive abilities such as concentration and memory. The mood may also determine the sharpness of these cognitive abilities and can be influenced by the quality and amount of lighting in a certain space (Veitch & McColl, 2001; Beauchemin & Hays, 1996; Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Another study by Ott (1976, as stated in (Mott et al., 2012)), cool white fluorescent lighting in classrooms can drastically improve the behavior of students who are hyperactive or have learning disadvantages

Artificial lighting is the second largest building energy consumers (Lechner, 2009). According to (Heerwagen, 2004), artificial lighting has three main functions: first as a general lighting or as the main replacement of daylight; and second is for supporting certain task in a certain area, which is called task lighting; and the last is for exposing decorative features or commonly known as accent lighting. The work of artificial lighting depends on two main factors, the light source and the lighting fixture. The lamp as a general light source of artificial lighting has some types. The commonly found in the market is the incandescent lamp, fluorescent lamp, and LED. Due to efficiency energy issues, LED has the biggest efficacy among the others. LED light uses far less energy (watt) to produce the same light output (lumen) compare to the other types. In artificial lighting system, illuminance value from the light source defines as luminous flux that reaches one-unit surface area. The value is described by this mathematical equation (De Chiara, Panero, & Zelnik, 2001):

$$F = \frac{(E \times A)}{(UF \times LLF)} \qquad (3)$$

Where as:

E = Illuminance that reach the surface area (lux)

F = Luminuous flux that falls into any surface area (lumen)

A = Surface area

UF = Product Usage Factor (0.7)

LLF = Light Loss Factor (0.8)

Apart from the type of lamps used, the quality of the light also depends on the maintenance of each building, where maintenance is a critical factor in effective lighting. Maintenance staff should plan to perform group lamp replacements on a regular schedule. Even if lamps have not burned out, they often become very dim after lengthy periods. Lamps need regular cleaning, as dirt and dust can minimize the output of illumination (McCreery & Hill, n.d.). Building with high ceiling is at risk of this issue, such as the Dutch Colonial style buildings where the ceiling could reach up to 5 or 6 meters. Generally, the lamps are suspended until the normal ceiling height of a room, which is approximately 3 meters.

*2.2. Heritage Building and Adaptive Reuse*

As stated previously on the Introduction, change of building function could also influence the lighting quality. Heritage buildings that have been adaptively reused are prone to the poor quality of the indoor illuminance level. In the past, buildings are meant to be responsive to the local climate including the thermal, acoustic and the lighting. Fenestrations were optimized to control the thermal condition inside the building causing occupants comfort. But as the earth's temperature rises for the past few years, air conditioning systems were installed and the fenestrations were blocked. These thermal adaptation strategies will definitely influence room daylight condition. External shading device used in heritage building is one of thermal adaptation strategies, but it will also obstruct the daylight penetration. Thus, artificial lighting was required to illuminate the space as a supplement for the inadequacy of daylight.

Surabaya, the second oldest and biggest city in Indonesia, has an amount of heritage buildings that have been left by the Dutch during their colonization from the year 1870 until 1940. The architecture in Surabaya was developed rapidly after the year 1900 when professional architects from the Netherland came to work in Indonesia including Surabaya. The common architectural style commonly found in Surabaya is the Empire Style or known as The Dutch Colonial style. The Governor of the East Indies, H.W. Daendels brought this style in 1080. Ever since that, the Empire Style was widely used throughout the Java Island, including in the Surabaya city. (Handinoto., 1996) stated that the Dutch Colonial style is influenced by the neo-classical style that occurred in the Europe, however, due to the high temperature and heavy rainfall, the buildings that were built in the East Indies, were made to be adaptable to the local climate and using the local materials.

According to the previous study by (Prianto, Bonneaud, Depecker, & Peneau, 2000), Dutch Colonial buildings ventilation system are generally high in ceiling (more than 3.5 meters) and equipped with ventilation mesh, wall full of openings, tall doors and windows, hollowed attic, high roof, path around the buildings as a form of circulation, and a tower that functions as a wind catcher (refer to Fig. 1). The main building characteristics are usually symmetrical in layout and its building mass, 1-2 story building with hip roof, terrace in the front part of the house, Greek-style columns that support the canopy/cantilever as a horizontal shading device.

Fig. 1 Interior of a School During the Dutch Colonialisation

Heritage building is an evidence of history. By conserving those buildings, it helps to understand the past as well as to contribute for the future generations. It can give the sense of continuity and belong to the place where people live. One method for conserving heritage building is by adaptive reusing it. Adaptive reuse could be defined as rehabilitating or renovating heritage buildings or structures for any uses other than the present uses that involve no change to the culturally significant fabric, changes that are significantly reversible, or changes with minimal impact (ICOMOS (International Council on Monuments and Sites), 2000). Another definition of adaptive reuse stated by (Bullen, 2007), adaptive reuse is known as one of the effective strategies to improve the sustainability of the existing building by lowering material, transport and energy consumption, as well as helps to reduce pollution.

The studied buildings in this research are gazetted as the national heritage building due to the historical significances under the Surabaya City Regulation on Heritage Building Conservation no. 5 year 2005. By that reason, these buildings must be maintained and conserved according to the guidelines for heritage building conservation. The alterations that have been done to accommodate the new purpose have created new problems on the quality of the indoor environment. This issue needs to be highlighted since people nowadays spend most of the time indoor.

## 3. Methodology

To determine the quality of the light in the studied classrooms, this cross-sectional research is quantitative in nature. Qualitative data was also conducted to support the quantitative data analysis.

### *3.1. Qualitative data*:

There are two types of qualitative data collected in this research: site observation and documentation. The site observation was conducted to observe the condition inside and surrounding the classrooms, the position and size of the openings (windows, doors, and air vents) as well as the position of the artificial lights. Documentation in the form of photographs was also taken as a proof of evidence and to support the data analysis.

### *3.2. Quantitative data*:

As mentioned previously, daylight was measured through illuminance level as well as the DF value. The designated classrooms were observed and divided into equally 1.2 x 1.2 m grid for conducting the measurement. Illuminance levels in every grid's points were measured at the work plane height or on top of the students' desk (0.75 m), by using a handheld light meter, at daylight condition (when artificial lighting is off). Illuminance levels were also measured at the Side Measurement Point (SMP) and the Main Measurement Point (MMP). The daylight factor assessment was done exactly on the SMP and MMP by measuring indoor illuminance level and outdoor illuminance level at the same time. If the illuminance level and DF value are low, it needs an accurate treatment of window sizing based on the mathematical calculation by using formula number (1). Simulation with computer software was also used to analyse the impact of window resizing. In this research, VELUX Daylight Visualizer software was used. It is a professional and accessible tool for simulating daylight levels in buildings. The calculations output has been validated against CIE 171:2006 to assess the accuracy of lighting in a computer program.

Artificial lighting was measured subsequently after the daylight measurement. This illumination level was also measured using a direct reading hand held the light meter in an equally divided grid 1.2m x 1.2m, on the studied classrooms while the lights were on. Similar to the daylight measurement technique, the artificial light level measurement was also taken at the work plane height. Reading on the result is taken directly once the number on the meter does not fluctuate. Before conducting the real measurement, a preliminary survey was conducted to choose the appropriate classroom from each school. Due to the limited permission given by the respected schools, measurements were taken during the last few subjects taught in each school that are approximately 1 to 2 p.m. The dismissal is at 3 pm daily.

### *3.3. Selection of the Research Objects:*

There are two school buildings selected in this research, Santa Maria High School and St. Louis High Schools. Both schools were selected based on the criteria for this research. Since the aim of this research is to assess the lighting condition in the adaptively reused heritage building, therefore the main criteria are the age of the building has to be more than 50 years old. According to (UNESCO, 1972) and Surabaya City Regulation for Heritage Building Conservation (Surabaya, 2005), a building will be considered heritage if it is already 50 years old. The schools selected are both prominent private schools until today and those buildings were listed as the National

Heritage Monument by the Surabaya city Government in 2005. Both schools are located nearby and in the midst of the elite settlements during the Dutch colonization. The designated schools are:

*a. Santa Maria High School*

This building is located in Jalan Raya Darmo (previously known as Darmo Boulevard) 49 Surabaya and was built from 1920 to 1924. It was built as a female Catholic school (*Hogere Burgerschool*/HBS)-cum-monastery belongs to the Ursuline. During the Indonesian independence war period, the National Army occupied this Art-Deco Style building as their military basecamp. Besides, this building was also the military basecamp for the Japanese Military, Gakkutotai Dai-Ichi Chuutai, during the Japanese occupation in Surabaya during the World War II. After the Indonesian Independence Day, this building was converted again into a local high school in 1949 (www.smasanmarosu.sch.id, 2015; www.ursulinindonesia.org, 2015).

*b. St. Louis High School*

This Catholic-based high school was built on Jalan Polisi Istimewa (previously known as Coen Boulevard / Jalan Dr. Soetomo) in 1923 by a team of an architect from Weeteenreden Batavia: Hulswit, Fermont and Ed. Cuypers. It was built to accommodate only the male students from the previous school Bijzondere Europeesche Lagere Jongens Schools (ELS) that was built in July 1862. Similar to Santa Maria High School, this building was also occupied by the Syuu Tokubetsu Keisatsutai (the Japanese police contingency) during the Japanese occupancy in Surabaya. Due to the importance of this building, this place was also recognised as the first place for raising the Indonesian flag replacing Hinomaru flag several days after the Indonesian Independence Day. This building was converted again into a local high school in August 1st, 1951 until today (smakstlouis1sby.sch.id., 2015).

Fig. 2 Santa Maria High School Surabaya

Fig. 3 St. Louis High School Surabaya

According to the preliminary observation that has been done, there were additional building that was built recently to accommodate the increasing number of students every year. To obtain the objective of this research, the classroom selected must be located in the heritage wing. The measurement was conducted in one class on each building since the classrooms are typical in terms of their form and size. The detailed information regarding the studied classrooms is tabulated in Table 1 as follows:

Table 1. The Comparison of Both Studied Objects

| | Santa Maria High School | St. Louis High School |
|---|---|---|
| Location & Orientation | Second floor, North facing, | Second floor, West facing |
| Room Dimension | 7.20 m x 7.90 m | 6.80 m x 12.2 m |
| Floor Materials | Dark grey terazzo tiles | Multicoloured terazzo tiles |
| Wall Materials | Construction: brick wall | Construction: brick wall |
| | Finishes: white matte paint & ceramic (1.3 m from the floor level) | Finishes: light yellow matte paint & ceramic (1.2 m from the floor level) |
| Ceiling Materials | White painted, 3 m height | White painted, 5 m height |
| Number of Openings | 1 single wooden swing door, | 1 double swing door (active) |
| | 2 jalousie windows, 1.80 m x 1.00 m (2 m from the floor level) | 1 double swing door, 2.60m x 1.60m (permanently closed) |
| | 2 jalousie windows, 1.80 m x 1.00 m (1.2 m from the floor level) | 2 tall windows with wooden jalousie, 1.60 m x 1.50 m (1.5 m from the floor level) |
| | Airvents are above the windows adjacent to the entrance door | 2 tall windows with clear glass panes, 1.60 m x 1.50 m |
| | | Upperwindows are 1.60 m x 1.00 m are above all doors & windows |
| Total Openings Area (based on the number of openings) | 7.2 $m^2$ | 16.96 $m^2$ |
| Window Treatment | Clear transparent glass, covered with light pink coloured curtain | Tall windows: clear transparent glass, covered with light peach coloured curtain |
| | | Upperwindows: clear translucent textured glass, without internal shading |
| Artificial Lighting Sources | 4 armatures of cool white TL on ceiling | 2x4 armatures of pendant cool white TL suspended to 3 m |
| Furniture | Gloss-stained wooden desks & chairs with glossy green iron frame | Gloss-stained wooden desks & chairs |
| | Whiteboard, 2 memoboards | 2 whiteboards, memoboard |
| Number of Occupants | 34 students & 1 teacher | 45 students & 1 teacher |

In order to capture the worst daylight condition, the classroom selected on both schools was on the second floor and located at the end of the corridor. The lamp armatures on both schools were attached to the ceiling with a similar lamp used and same height in average. In the St. Louis School, the lamp armatures were suspended until 3 meters from the floor level because of the existing ceiling height is 5 meters (refer to Fig. 4 (b)). The outcome of this research is to create an artificial lighting plan for the studied classrooms by assuming the light source is 18W-2000 lumen of LED bulb.

(a) Santa Maria High (b) St. Louis High School

Fig. 4 Research Objects

## 4. Results and Discussions

*Santa Maria High School*

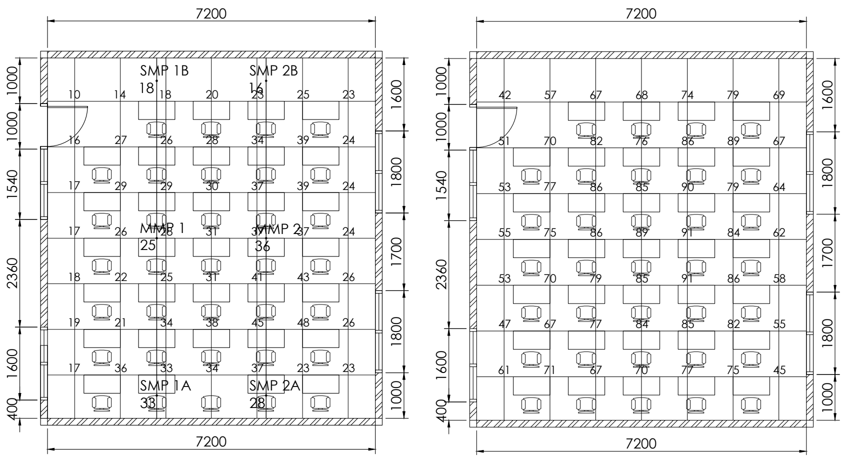
Based on the observation, this classroom is located at the end of the corridor on the second floor (refer to Fig. 5 (a)). Since this building is categorized as a colonial building, this classroom is accessed from a corridor with wide overhangs. As seen in Fig. 5 (a), the daylight directly enters only from the two windows (180 x 100 cm) on the left with internal shading. Indirect daylight also enters from the window that is adjacent to the entrance door. This class is currently occupied by 34 students and 1 class teacher.

(a) Position of the classroom (b) Position of the windows

Fig. 5 The Condition of the Classroom X-7

Fig. 6 External Shadings

After the measurement was taken, the indoor illuminance level in daylight condition is in the range between 10-48 lux (see Fig. 7 (a)). These numbers are below the illuminance level standard for a classroom, which is 250 lux (SNI no. 03-6575-2001). This case shows that the abundance of outdoor illuminance is failed to bring good indoor illuminance level. The obstruction of the visual line comes mostly from the new surrounding buildings and the additional external shading as in Fig 6. These obstructions, i.e. the corridor and external shading devices, are purposely built to minimize the penetration of daylight into the classroom. The field measurement shows that the system could bring higher illuminance level. However, the current artificial lighting system was failed to create the standard illuminance level. As seen in Fig. 7 (b) the current indoor illuminance level in artificial lighting condition is between 42-91 lux.




(a) The Daylight Condition (b) The Artificial Lighting Condition

Fig. 7 Indoor Illuminance Level in Classroom X-7

Daylight Factor is calculated by comparing the illumination indoors to outdoors at SMP and MMP. From the calculation, it is known that the daylight factor in classroom X-7 is between 0.1% to 0.3%. Window resizing is proposed to create daylight factor obtain the standard level (5%). Based on the mathematical equation number (1), the total window area should be resized from 7.2m$^2$ into 14.22m$^2$. The proposed new window size is 1.8 m x1.6 m, and the DF result after window resizing can be seen in Figure 8. Moreover, it can be seen that the range of DF is around 2% - 5% that meets the standard level for DF in a classroom.

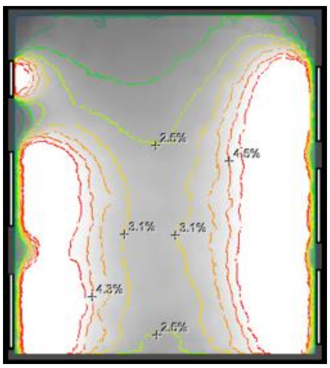



Figure 8. Velux Result of Daylight Factor After Window Resizing at Classroom X-7, Santa Maria School

Another solution proposed to overcome the lighting problems in this classroom is to put a certain amount of artificial lights that is carefully measured based on the building condition. Ceiling fixture lighting is proposed as the lighting fixtures since the ceiling height is sufficient. The illuminance level is calculated by mathematical equation mentioned previously in 2.1. The result shows that the illuminance level reached the standard when there are 12 light sources of 18W and 2000 lumen of LED bulb. The calculation of artificial lighting system is tabulated in Table 2 below and the new ceiling lighting plan with 12 light sources can be seen in Figure 8.

Table 2. Calculation of Artificial Lighting System for Class X-7, Santa Maria High School

| E (lux) | A (m2) | | UF | LLF | F (lumen) | Lumen of LED bulb 18 watt | Number of lamps needed |
|---|---|---|---|---|---|---|---|
| | Length | Width | | | | | |
| (a) | (b) | | (c) | (d) | (e) | (f) | (g) |
| | | | | | (axb)/(cxd) | | (e)/(f) |
| 250 | 7.90 | 7.20 | 0.7 | 0.8 | 25.392,86 | 2000 | 12.20 |
| | | | | | | | **~ 12** |

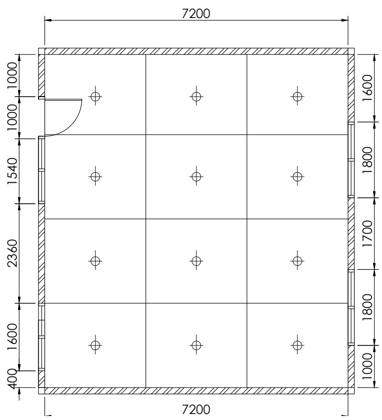


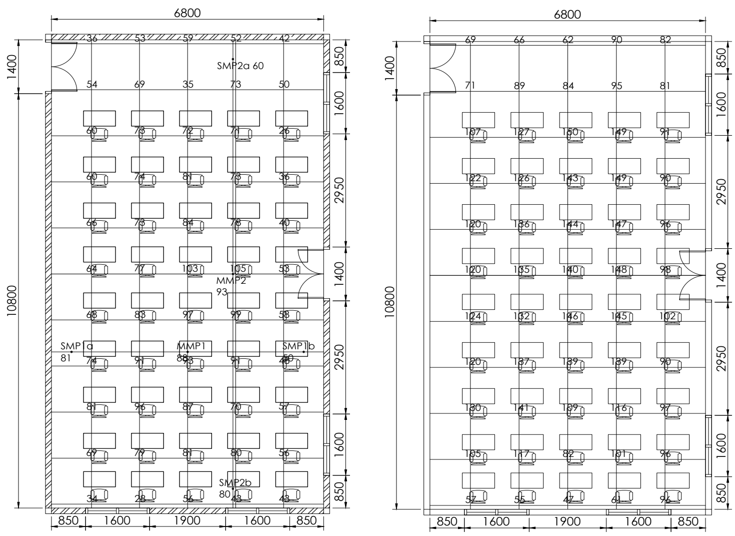

Fig. 9. Proposed Ceiling Lighting Plan for Classroom X-7 Santa Maria

*St. Louis High School*

The classroom used as the research object in St. Louis is classroom XII-IA-9 and occupied by 45 students and 1 class teacher (refer to Fig. 9). Similar to the other research object on the other school, this class is also located at the end of the corridor on the second floor. Compare to the other classroom, there are more openings in this class. Tall windows with upper windows are located in the rear and left wall. The openings are covered with internal shading device in order to minimize the daylight penetration during the daytime. The artificial lightings are suspended until 3 meters from the floor level.

Fig. 10. The Condition of the Classroom XII-IA-9

After the daylight was measured in 120cm grid, it was discovered that the illuminance level is between 26-105 lux. Meaning that the illuminance level is below the standard of illuminance level for a classroom. Nonetheless, based on the measurement conducted, the indoor illuminance level for artificial lighting condition was also below the standard, that is between 47-150 lux. The measurement result can be seen in Fig. 11 (a) and (b).



(a) The Daylight Condition (b) The Artificial Lighting Condition

Fig. 11. Indoor Illuminance Level in Daylight Condition

As mentioned in Table 1, this classroom has some openings. However, the effective apertures for this classroom are 2 tall windows with clear glass panes (1.60 m x 1.50 m) and two upper windows (1.60 m x 1.00 m) above all doors and windows. The others are considered as not effective apertures. Based on the mathematical equation number (1), the window should be resized from 16.96m$^2$ into 20.74m$^2$. To resize the window, this research proposed to remove the wooden jalousie panel in other tall windows. The DF result after removing the jalousie panel can be seen in Figure 12. It shows that the DF value at MMP and SMP points have reached the DF standard level that is around 3%-5%.

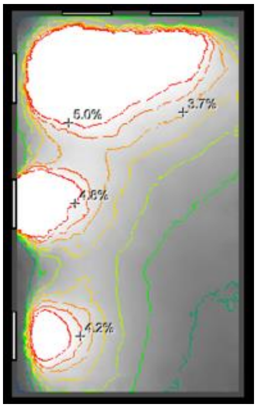



Figure 12. Velux Result of Daylight Factor after Window Resizing at Classroom XII-IA-9, St. Louis

Another solution to obtain better lighting condition, mathematical equation is used to calculate numbers of lighting source needed. As mentioned previously, the lighting source used in this research is 18W-2000 lumen of LED bulb. The recommended lighting fixture is pendant type and should be suspended to 3 meters high to reduce the ceiling height. The calculation for the artificial lighting system is tabulated in Table 2 below. The result shows that this room needs 18 lighting sources to reach the standard illuminance level. The proposed arrangement for the 18 lighting sources is described in Fig. 13.

Table 2. Calculation of Artificial Lighting System for Class XII-IX-9, St. Louis High School

| E (lux) | A (m2) | | UF | LLF | F (lumen) | Lumen of LED bulb 18 watt | Number of lamps needed |
|---|---|---|---|---|---|---|---|
| | Length | Width | | | | | |
| (a) | (b) | | (c) | (d) | (e) | (f) | (g) |
| | | | | | (axb)/(cxd) | | (e)/(f) |
| 250 | 12.20 | 6.8 | 0.7 | 0.8 | 37.035,71 | 2000 | 18.30 |
| | | | | | | | **~ 18** |

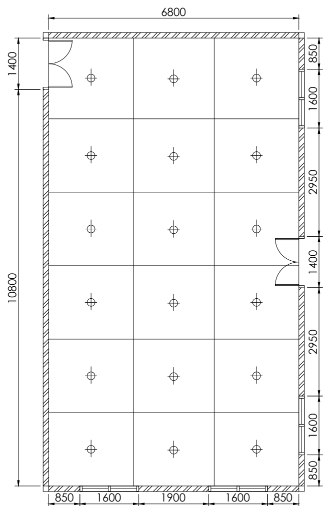


Fig. 11. Proposed Ceiling Lighting Plan for Class X-7 St. Louis High School

## Conclusions

From the field measurements that have been conducted, it shows that the illuminance level in both classrooms in Santa Maria School and St. Louis School are below the standard, for daylight and artificial lighting condition. Obstruction of visual line is the main reason of this matter. The obstructions are known from the new surrounding buildings, external shading devices, and internal shading devices. To overcome these problems, resizing the window is proposed to obtain better daylight condition in both classrooms. By resizing the window, the DF value at the measurement points could reach the standard level, but further research should be conducted to assess the glare and lighting uniformity matters.

One of artificial lighting functions is the general lighting, which means that artificial lighting is the main substitute for daylight. In order to substitute the daylight and to reach the illuminance level standard for classroom, the classroom in Santa Maria High School needs 12 lighting sources with ceiling fixtures, while in St. Louis High School needs 18 lighting sources with pendant lighting fixtures by assuming the light source is 18W-2000 lumen of LED bulb. Although in this research proposes 2 solutions to overcome the problems, the latter solution is considered as one of the best ways to treat heritage building to be a visually comfortable building without major alteration on the building fabrics since both studied buildings are listed as a National Heritage Monument. According to the Burra Charter, the building allows to be renovated as long as the renovation works are reversible, does not change the culturally significant fabric, and with the least impact. The result of this research has been delivered to the respective schools as a basic for upgrading the artificial lighting system to optimize the classroom activities as well as to enhance the visual comfort of the occupants without doing major alterations on the building fabrics.

## Acknowledgment

This research was fully funded by the Indonesian State Ministry of the Research and Technology under the grant scheme No. 050/SP2H/P/K7/KM/2016.

## References

Axarli, K., & Tsikaloudaki, K. (2007). Enhancing visual comfort in classrooms through daylight utilization. In *Proceedings of Clima 2007 WellBeing Indoor*. Helsinki.

Benya, J. R. (2001). Lighting for Schools. *National Clearinghouse for Educational Facilities*.

Bernardi, N., & Kowaltowski, D. C. C. K. (2006). Environmental Comfort in School Buildings: A Case Study of Awareness and Participation of Users. *Environment and Behavior*, *38*(2), 155–172. https://doi.org/10.1177/0013916505275307

Bullen, P. A. (2007). Adaptive reuse and sustainability of commercial buildings. *Facilities*, *25*(1/2), 20–31. https://doi.org/10.1108/02632770710716911

De Chiara, J., Panero, J., & Zelnik, M. (2001). *Time-saver standards for interior design and space planning*. McGraw-Hill.

Handinoto. (1996). *Perkembangan kota dan arsitektur kolonial Belanda di Surabaya, 1870-1940*. Yogyakarta: LPPM Univ. Kristen Petra Surabaya dan Penerbit ANDI.

Heerwagen, D. (2004). *Passive and active environmental controls : informing the schematic designing of buildings*. McGraw-Hill Higher Education.

ICOMOS (International Council on Monuments and Sites). (2000). *The Burra Charter : the Australia ICOMOS charter for places of cultural significance*. Burwood, Victoria: Australia ICOMOS.

IESANA (Illuminating Engineering Society of North America). (2000). *The IESNA lighting handbook : reference & application*. (M. S. Rea, Ed.). New York: Illuminating Engineering Society of North America.

Lechner, N. (2009). *Heating, cooling, lighting : sustainable design methods for architects*. John Wiley & Sons.

Mott, M. S., Robinson, D. H., Walden, A., Burnette, J., & Rutherford, A. S. (2012). Illuminating the Effects of Dynamic Lighting on Student Learning. *SAGE Open*, *2*(2), 1–9. https://doi.org/10.1177/2158244012445585

Prianto, E., Bonneaud, F., Depecker, P., & Peneau, J.-P. (2000). TROPICAL-HUMID ARCHITECTURE IN NATURAL VENTILATION EFFICIENT POINT OF VIEW A Reference of Traditional Architecture in Indonesia. *International Journal on Architectural Science*, *1*(2), 80–95.

Prihatmanti, R., & Bahauddin, A. (2011). THE INDOOR ENVIRONMENTAL QUALITY OF UNESCO LISTED HERITAGE BUILDINGS, GEORGE TOWN, PENANG. In *5th International Conference on Built Environment in Developing Countries*. Penang, Malaysia.

Samani, S. A., & Samani, S. A. (2012). The Impact of Indoor Lighting on Students' Learning Performance in Learning Environments: A knowledge internalization perspective. *International Journal of Business and Social Science*, *3*(24), 127–136.

SNI (Standar Nasional Indonesia). Tata cara perancangan sistem pencahayaan buatan pada bangunan gedung, Pub. L. No. 3-6575–2001, 1 (2001).

Surabaya, W. Perda Surabaya Tentang Pelestarian Bangunan dan/atau Lingkungan Cagar Budaya, Pub. L. No. No 5/2005 (2005).

UNESCO. CONVENTION CONCERNING THE PROTECTION OF THE WORLD CULTURAL AND NATURAL HERITAGE (1972). Retrieved from http://whc.unesco.org/archive/convention-en.pdf

Yang, Z., Becerik-Gerber, B., & Mino, L. (2013). A study on student perceptions of higher education classrooms: Impact of classroom attributes on student satisfaction and performance. *Building and Environment*, *70*, 171–188. https://doi.org/10.1016/j.buildenv.2013.08.030