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Research Article

Lighting Enhancement of Classrooms in Heritage School Buildings Based on the Greenship Rating Tools

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Abstract: This study aims to suggest some strategies for improving the quality of lighting in adaptive reuse buildings. Recently, several concerns have been raised about the lighting environment of heritage buildings that have been adaptively reused for a different function. These changes may lead to a problem for the occupants of the building, particularly on the indoor lighting quality. It is regarded as one of the most affected variables in the building of heritage that is adaptively reused. Green Building Council Indonesia (GBCI) has been concerned about this issue, particularly to the requirements related to lighting power density and control, visual comfort, outside view, and daylight. The purpose of this research is therefore to suggest some strategies for improving the quality of lighting in the two classrooms of two heritage schools in Surabaya, Indonesia, based on the Greenship Interior Space rating tool. There are three credits for lighting power density and control, and one credit for visual comfort criteria. By performing light mapping measurements, calculations, and computer simulation, this analysis is qualitative. To capture the condition of the classrooms examined, building observation was also performed. The observation shows that the existing condition gains four credits only. If adopted, the strategies proposed could achieve eight credits, which is covers 80% of the assessment points. The higher credits achieved reflect a better lighting environment and better value for energy efficiency and conservation.

Keywords: Adaptive Reuse, Energy Efficiency, Green Building, Lighting Quality, Visual Comfort.

1. INTRODUCTION

Adaptive reusing a building is a common practice to prolong the lifespan of a building. The heritage building is a legacy from the past which could not be replaced once lost. It is also a source of reference for the next generation, therefore these highly significant value properties must be sustained. However, some buildings are not purposely built for the same purpose in the future. A problematic condition to the indoor environment could be created by these alterations. These alterations will significantly affect the occupants, particularly their well-being and productivity. According to Prihatmanti and Bahauddin [1, 2], there is a risk for occupants' dissatisfaction in an adaptively reused building. This is due to the limitation of the heritage conservation practice which must comply with the guidelines. One of the most affected factors found in the adaptively reused building is indoor lighting. An appropriate amount of light will lead to fewer work errors, better safety, and lower absenteeism level. Hence, it will significantly affect the work performance of the building occupants [3, 4].

Some green building organizations, including the Green Building Council Indonesia (GBCI), have the arising concern to this condition. Previously, green building rating tools are used as parameters to design green buildings. Since the paradigm of sustainability has shifted, these rating tools are currently used to assess non-green buildings as well, including heritage buildings. Greenship, which was developed by the Green Building Council Indonesia has six rating tools: Appropriate Site Development, Energy Efficiency and Conservation,

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Water Conservation, Material Resources and Cycle, Indoor Air Health and Comfort, Building and Environment Management. There are three criteria related to the lighting environment, which are placed under two rating tools, (i) Lighting power density and control is placed under Energy Efficiency and Conservation; (ii) Visual comfort, outside view and daylight, are placed under Indoor Health and Comfort.

Energy used for lighting systems consumes 20 % of whole-building energy consumption. The usage of an energy-saving lamp will give a significant impact on the environment as well as on the building's operational cost. An energy-saving lamp will lead to less renewable energy consumption and reduce environmental pollution. Based on previous research, a building that uses an occupancy sensor saves 20 % to 26 % of lighting energy compared to a building with a manual system [3].

Several studies about lighting in a learning environment have been conducted. According to Susan and Prihatmanti [6], the lighting environment has a crucial role in affecting students' contentment and academic performance. Research on student awareness of higher education classrooms explains that the learning environment is influenced by physical attributes, including temperature, acoustic, lighting, daylight, and air quality [7]. This is also emphasized by Samani, a learning environment must provide an appropriate lighting quality to increase the motivation to learn and enhance the students' learning performance [8]. Another previous study conducted by Axarli and Tsikaloudaki also stated that the pupil's academic performance and well-being are significantly depending on the quality of the luminous environment [9]. The student performance is significantly correlated with the lighting quality in their classroom [10]. Related to this, a good lighting environment is significant to motivate the students for a better learning process. This is also addressed by Bluyssen et al. that exposure to poor lighting could cause short and long-term health impacts [11].

Adaptively reused buildings, particularly heritage buildings, are being reused into different functioned which is different from their original purpose. This could create occupants' discomfort due to the inappropriate space planning for the new purpose [1]. The lighting condition must be adjusted to comply with the occupants' activity as well as the need of saving energy. Therefore, this paper focuses on investigating the lighting performance and proposes suggestions to enhance the lighting environment, based on the Greenship Rating Tools.

2. MATERIALS AND METHODS

Regarding the issue of lighting environment, the Green Building Council Indonesia has been highlighting this matter. The current rating tool has put lighting as an important factor that gives a significant chance to reduce operational cost, reduce

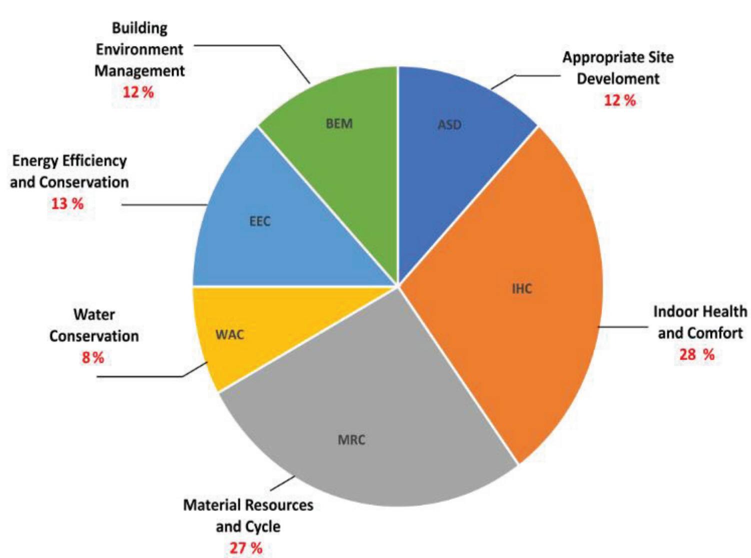

Fig. 1. Greenship Interior Space Rating Tools [5].

the greenhouse effect, and improve occupants' performance. As mentioned before, there are three criteria related to lighting performance, which are listed in Figure 2 [5]. Those are lighting power density and control, visual comfort, and outside view and daylight.

2.1 Lighting Power Density and Control Criteria

The Lighting Power Density and Control criteria aim to build an understanding regarding the consequence of energy saving on a built environment [9]. Based on the Greenship rating tools, the benchmark for these criteria is listed in Figure 3 [5].

Based on the Standard National Indonesia (SNI)/Indonesian National Standard, the maximum amount of lighting power density for a classroom is 13 W m^{-2} [12]. There are potential strategies that can be applied to achieve the targets: first, lighting power density can be reduced by applying interior finishes with high reflectance value; second, a daylighting system must be maximized to save energy; third, applying daylighting sensor that integrates with the building's artificial lighting system; fourth, option for lamps with higher efficacy, such as fluorescent and LED; fifth, the lighting armature must be selected based on the distribution characteristic, high efficiency, and the ability to reduce glare.

2.2 Visual Comfort Criteria

The lighting source on a working plane could be received from daylight and artificial light. In all circumstances, daylight is much-preferred compare to artificial light. However, if daylighting is insufficient to fulfill the building's requirement, artificial lighting must be provided. Daylighting and artificial lighting must be designed carefully, where excessive daylight could cause discomfort glare as well as disability glare [13]. On the contrary, the amount of artificial lighting which does not fulfill the standard could cause visual discomforts such as red-eye, eye irritation, blurred view, and difficulty in reading any objects. It is also has been studied by Lee, Moon, and Kim that visual comfort is strongly affecting the mood [14].

According to the GBCI, the main objective of the Visual Comfort criteria is to provide a suitable lighting quality in the designated workplace to enhance the productiveness and well-being of the users [5]. Based on the standard given by the local agency, any classroom should provide 350 lx as its illumination standard [10]. The benchmark for these criteria according to the Greenship rating tool is listed in Figure 4 [5].

2.3 Outside View and Daylight Criteria

Eye fatigue can be reduced by providing an outdoor view for the occupants. Those who have access to the outdoor view show symptoms of reduced stress level, less frustration, more patient, and higher performance [15, 16]. Meanwhile, maximizing the daylight could give good impacts such as improve occupants' health, provide better lighting quality, as well as saving cost and energy for artificial lighting. Hwang and Kim also agreed that daylight is proven for improving the occupants' comfort in an indoor environment [14]. Hence, the Outside View and Daylight criteria are required to be calculated. These criteria aim to reconnect the indoor to the outdoor area by providing an outside view as well as daylight into the indoor space. This will increase the occupants' satisfaction, in terms of comfort and productivity. The benchmark based on the Greenship rating tool for the outside view and daylight is listed in Figure 5 [5].

3. RESULTS AND DISCUSSION

3.1 Observation

There are two heritage schools selected for this study. The selection criteria are based on the heritage significance of the studied buildings. Those schools are Santa Maria Senior High School and

Code	Criteria	Credits
EEC 3	Lighting Power Density and Control	5
IHC 6	Visual Comfort	3
IHC 7	Outside View and Daylight	2

Fig. 2. Greenship criteria for lighting system and environment [5].

No.	Benchmark	Credits	
1A	Save 20 % in lighting systems with more efficient lighting power or total lighting power, as described in Energy Conservation Lighting System SNI 03-6197-2000.	1	5
	or		
1B	Save 40 % in lighting systems with more efficient lighting power or the total lighting power, as described in SNI 03-6197-2000 (Energy Conservation Lighting System).	2	
	or		
1C	Save 60 % in lighting systems with more efficient lighting power or the total lighting power, as described in SNI 03-6197-2000 (Energy Conservation Lighting System).	3	
2A	Use 100 % electronic ballast	1	
	or		
2B	Meet the 2A benchmark and save energy using an integrated lighting sensor and/or a built-in occupancy sensor and/or person power.	2	

Fig. 3. Benchmark for lighting power density and control [5].

No.	Benchmark	Credits	
1	Utilizing a lighting system with illumination in compliance with SNI 03-6197-2000 of Energy Conservation in Lighting System.	1	3
2	Provide at least 90 % of individuals, with individual reachable lighting settings (switch), and or provide all users in multi-occupant room/area with a lighting control system.	1	
3	Provide integrated automatic curtains/blind to the natural lighting control system.	1	

Fig. 4. Benchmark for visual comfort based on the Greenship rating tool [5].

No.	Benchmark	Credits	
1	75 % floor area used is oriented horizontally to outside view, limited by transparent wall and if drawn a straight line, then the transparent wall with a lower threshold is at a maximum of 0.90 m above the floor.	1	2
2	Optimal use of natural light to meet a minimum of 75 % of floor area used to achieve the natural light intensity for at least 300 lx.	1	

Fig. 5. Benchmark for outside view and daylight based on the green ship rating tool [5].

St. Louis Senior High School. Due to the historical significance. These schools are classified by the Surabaya City government regulation No. 5/2005 as national heritage buildings. Currently, both schools consist of the original heritage building and the newly built annex building. The annex building is newly built to accommodate the increasing number of students enrolled annually.

The first case study is the Santa Maria High School. The location of this school is Raya Darmo Street Surabaya. The studied classroom is 56.88 m^{-2} in size and facing to the South. According to the site observations conducted, there are four windows in total (1.8 m × 1.0 m in size; 1.8 m above the ground) which are located two in the North and two in the South wall. The second case study is the St. Louis Senior High School. Its location is in Polisi Istimewa street Surabaya. According to the observation, the studied classroom is 82.96 m^{-2} in size, facing North, located in the front part of the original building which is facing the main road as well as the parking area. High openings were also present and located in the North, East, and South wall.

The assessment which is applied based on the lighting criteria from Greenship Interior Space showed that the existing classrooms only obtained four credits from a total of 10 credits listed in lighting-related criteria.

Buildings can contribute energy savings from the lighting system. There are six lamps in each studied classroom. The lamps on the studied buildings are general fluorescent lamps 36 W for Santa Maria Senior High School and 58 W for St. Louis Senior High School. This proposed lighting system will create brighter classrooms, with 3.8W m^{-2} and 4.2 W m^{-2} lighting power density, as well as saving energy up to 71 % and 68 % respectively. This strategy will give the classrooms three credits. However, the current lighting system does not use 100 % electronic ballast as well as the integrated lighting sensor, and/or integrated occupancy sensor, and/or individual control by the means of saving energy. This decision has made both buildings lose another credit provided in these criteria.

Illuminance level was also measured, both for daylighting and artificial lighting conditions. According to the measurements taken, the illuminance level at Santa Maria Senior High School falls between 10 lx to 45 lx on daylighting and between 42 lx to 91 lx for artificial lighting conditions. While at St. Louis Senior High School, it falls between 26 lx to 105 lx and 47 lx to 150 lx respectively. Unfortunately, the illuminance levels in both schools were below the standard of SNI, which has to be 350 lx. This means that the buildings studied do not comply with the first benchmark of visual comfort. According to the GBCI, a lighting control system on a multi-occupant room or area should be provided which is accessible to all users. This resulted in the buildings obtained another one point from the second benchmark of visual comfort.

According to the building observation conducted, the high openings in Santa Maria Senior High School were made from a wooden frame and glazed by tinted glass. The openings were at 1.8 m above the floor and located on eye level. This resulted in a restricted view to the outside. However, due to the glare and thermal concerns, the openings are covered by an internal shading device. An internal shading device also restricts the occupants to access the outside view. These conditions have prevented the buildings from obtaining another credit provided on the criteria of the outside view. Thus, both buildings could not obtain credit from the daylight criteria as well. As explained previously, daylight illuminance levels in both classrooms are ranged between 10 lx to 105 lx. There is no optimal use of natural light to reach 75 % of the floor area to obtain the intensity of light for at least 300 lx. The natural light intensity for 100 % area is below 300 lx.

3.2 Analysis and Design Proposed

3.2.1 Lighting Power Density and Control

Based on the SNI, the maximum lighting power density for a classroom is 13 W m^{-2}. To achieve the optimum savings on lighting power density, the studied classrooms require lamps with higher efficacy. Philips TL-D 36W/33-640 1SL/25 with 100 % electronic ballast (eco passport: certified with energy efficiency label B) is proposed to be used in both classrooms. This research also proposes to add the numbers of lighting points, to make better lighting distribution. The number of lighting points

Fig. 6. The classroom condition and site plan of Santa Maria Senior High School.

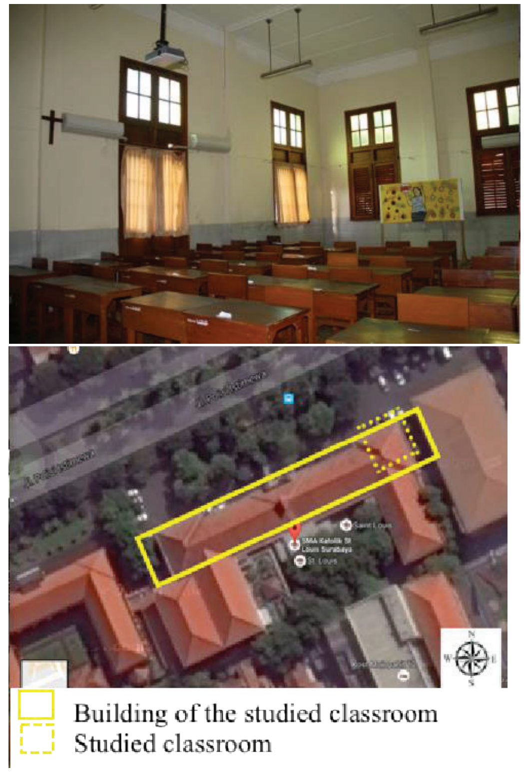

Fig. 7. The classroom condition and site plan of St. Louis Senior High School

at Santa Maria Senior High School was adjusted from 6 points to 12 points. Meanwhile, at St. Louis Senior High School, the numbers of lighting points were adjusted from 6 to 18. The lighting power density after the adjustment is tabulated in Table 1.

The treatment conducted to the classrooms at Santa Maria Senior High School and St. Louis Senior High School are 7.59Wm^{-2} and 7.81Wm^{-2} lighting power density, as well as saving energy 42 % and 40 % respectively. This system contributes three credits to the Lighting credit from each classroom. Another 1 credit is targeted to be achieved by using an integrated lighting sensor and/or integrated occupancy sensor and/or individual control to save energy. The planning for this system can be seen in Figure 9 and Figure 10.

3.2.2 Visual Comfort

In this study, the illuminance level is calculated by using the equation in Equation (1) [17]:

$$F = E \times A / Uf \times LLf \quad (1)$$

Where: F = Flux (lumens)
E = Illuminance (lx)
A = Area (m2)

Table 1. Lighting Power Density proposed

School Name	Lighting points numbers	Lighting power (W)	Area (m^2)	Lighting power density (W m^{-2})
(a)	(b)	(c)	(d)	(e) = (bxc)/(d)
Santa Maria	12	36W	56.88	7.59
St. Louis	18	36W	82.96	7.81

Code	Criteria	Credits
EEC 3	Lighting Power Density and Control	3
IHC 6	Visual Comfort	1
IHC 7	Outside View and Daylight	0

Fig. 8. Lighting credits for the classrooms

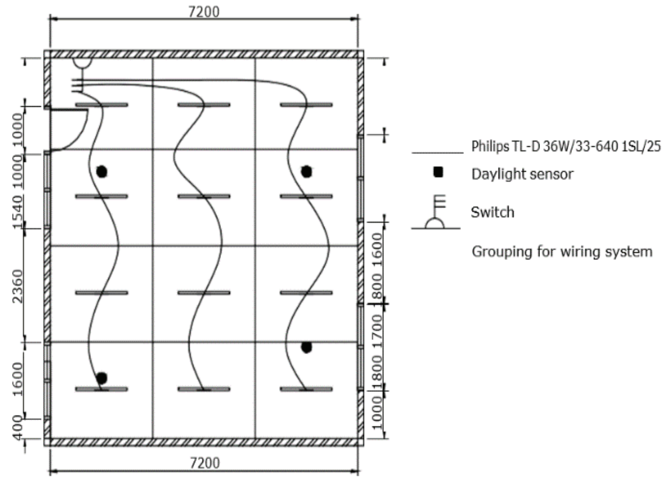

Fig. 9. Sensor and lighting plan for Santa Maria Senior High School

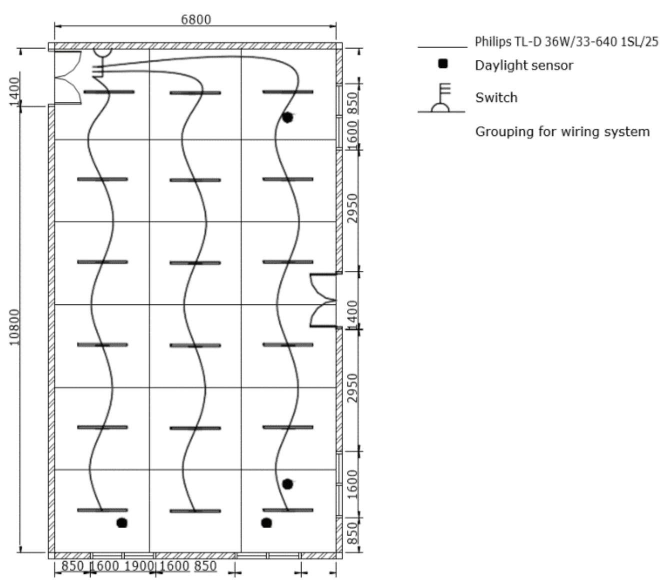

Fig. 10. Sensor and lighting plan for St. Louis Senior High School.

Table 2. Illuminance level proposed

School Name	F (lumens)	Lighting points numbers	Area (m^2)	Uf	LLf	E (lx)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Santa Maria	2850	12	56.88	0.75	0.8	361
St. Louis	2850	18	82.96	0.75	0.8	371

Uf = Utilization factor (0.75)
LLf = Light Loss factor (0.8)

According to the SNI, the illuminance level in both classrooms must reach 350 lx. In this study, Philips TL-D 36W/33-640 1SL/25 with 2 850 lx was proposed to be applied. After the treatment, the illuminance level in both classrooms is above 350 lx, which is 361 lx for Santa Maria Senior High School and 371 lx for St. Louis Senior High School (refer to Table 2). Based on the proposed strategy, as much as one credit is achieved from this treatment.

Another two credits were achieved by providing a lighting control system on multi-occupant room/ area for all users and an automatic curtain to the natural lighting control system. The placement of the lighting control system (switch) can be seen in Figure 9 and Figure 10. The switch must be reachable by all the users. An automatic curtain is also suggested to be applied since it can keep them perfectly aligned to control natural lighting.

3.2.3 Outside View and Daylight

As mentioned previously, the lighting enhancement based on Greenship rating tool is connected to access of outside view. The observation conducted at the Santa Maria Senior High School showed only 34 m^2 (59 %) area can get the access to the outside view (Fig 11), while at the St. Louis Senior High School only 56 m^2 (68 %) area (Fig 12). Nevertheless, there is no treatment proposed for this benchmark, since the building is a heritage building that has certain limitations to conduct major alterations on its façade.

Another credit could be achieved by optimizing the natural light. It has to reach at least 75 % of the total floor area. This will be used to obtain the natural light intensity of at least 300 lx. As mentioned previously, both classrooms have high openings. Theoretically, it could be a good treatment for daylight penetration. Unfortunately, due to glare and thermal problems, the openings are glazed with tinted glass and covered by internal blinds, which are usually closed on daily activities. The minor treatment is to propose a higher illuminance level. Tinted glass could be replaced by low-E glass. Based on the previous benchmark, an automatic curtain is suggested. To overcome glare and thermal problems when the window is opened, reflective light shelves are proposed. The treatments proposed are then simulated by using the software Velux 3.0.22. The result is illustrated in Figure 13 and Figure 14. The red area showed a higher illuminance level which could reach 600 lx and gradually decreasing towards the center of the room, reaching 300 lx.

3.2.4 Proposed Methods and Recommendations

Table 3 shows the enhancement strategies and the comparison between the previous and proposed methods, which indicates the advantages of the proposed methods to create energy efficiency and comfortability to the users. The Lighting Power Density and Control and Visual Comfort criteria can be achieved to improve the lighting condition of the studied buildings. However, the Outside View and Daylight criteria could not be fulfilled due to no proposed treatment conducted since both buildings are heritage-listed.

To show the difference between before and after the proposed treatment, the credit comparison of the previous condition and the proposed methods is shown in Table 4.

This research provides the suggestion for the Greenship rating assessment. Figure 15 shows the process flowchart that is developed as a reference for lighting designers as well as for the lighting assessors.

The practical application of this research is not only for heritage buildings but can also be applied with suitable modifications in campus buildings, assisted by a good energy management system. [17, 18]. That way, the future research direction will be easier to develop into the concept of ICT-based energy security for smart cities with the support of smart-grid technology.

4. CONCLUSION

The adaptive reusing building is a common practice to preserve a building with high significant value. However, there are many considerations and limitations when it comes to change to a new purpose. This research was conducted in two heritage schools which also adaptive reused

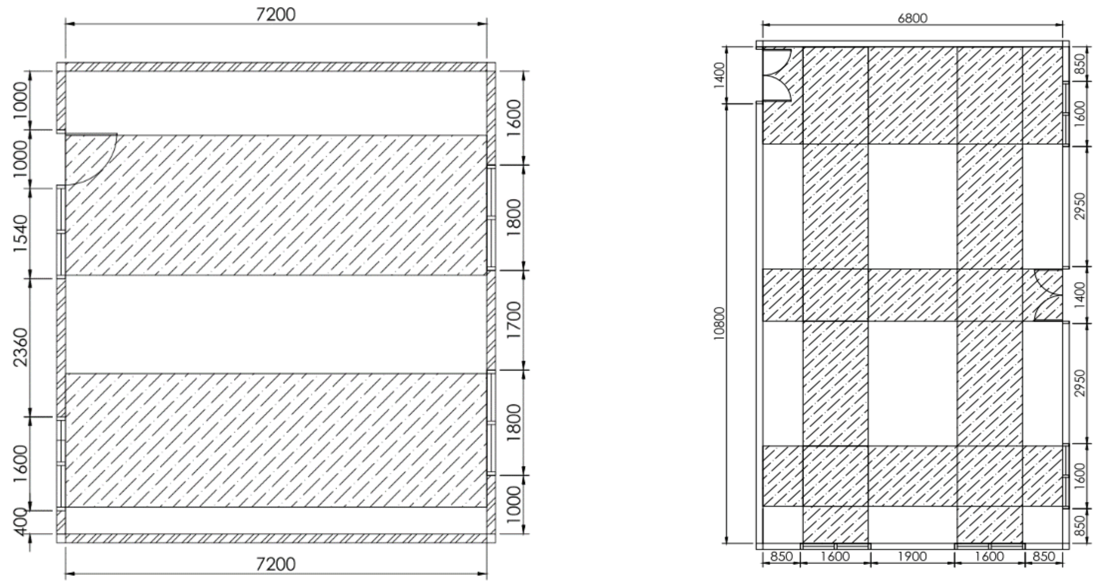

Fig. 12. The area with outside view access at St. Louis Senior High School.

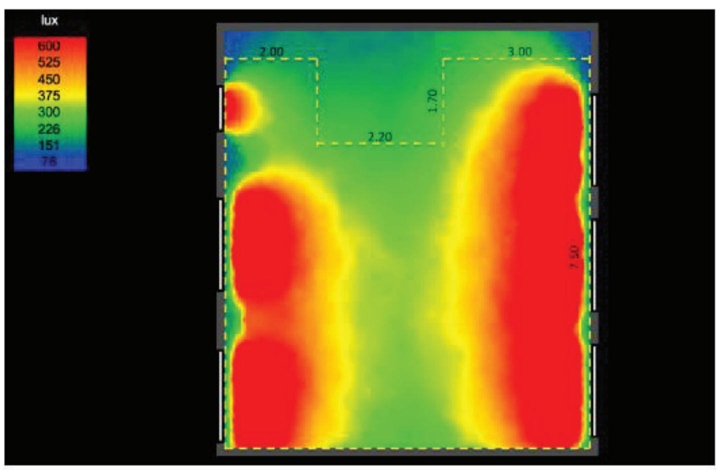

Fig. 13. Daylight simulation result for Santa Maria Senior High School.

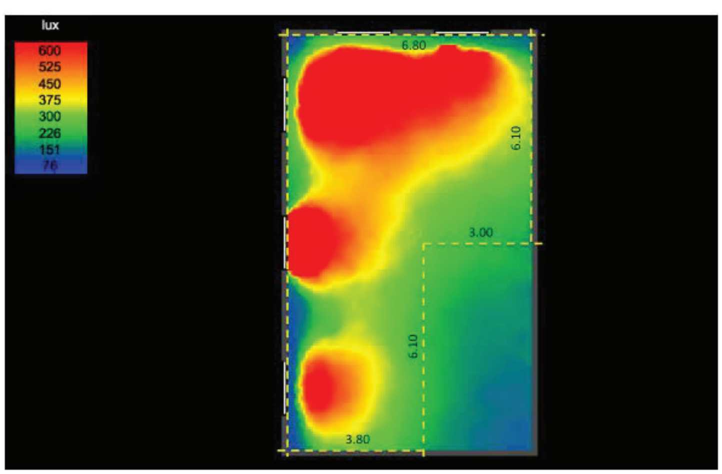

Fig. 14. Daylight simulation result for St. Louis Senior High School.

Table 3. Strategies Comparison of previous condition and the proposed methods

	Before	After	
Criteria	**Strategies**	**Strategies (Proposed Methods)**	**Application in this Research**
Lighting Power Density and Control	Based on SNI, low wattage lamp types	20 % to 60 % savings in lighting systems (low wattage, high flux, high efficacy), 100 % electronic ballast, integrated lighting sensor and/or integrated occupancy sensor, and/or individual control to save energy.	40 % to 42 % savings in the lighting system, 36 W, 2 850 lumens, 100 % electronic ballast, integrated lighting sensor and/or integrated occupancy sensor and/or individual control to save energy.
Visual Comfort	< 150 lx	Based on SNI	Combination of artificial lighting and daylighting, produce illuminance level 361- 371 lx (SNI standard for classroom = 350 lx)
Outside View and Daylight	59 % to 68 % floor area directed horizontally to the outside view and 100 % area has illuminance level <105 lx in daylighting condition.	Additional opening using low-E glass, an automatic curtain.	No treatment is proposed since the studied buildings are heritage-listed.

Table 4. Credit Comparison of previous condition and the proposed methods

	Before		After	
Criteria	**Strategies**	**Credits**	**Strategies**	**Credits**
Lighting Power Density and Control	Based on SNI, low wattage lamp types	3	40 % to 42 % savings in the lighting system, 36 W, 2 850 lumens, 100 % electronic ballast, integrated lighting sensor and/or integrated occupancy sensor and/or individual control to save energy.	5
Visual Comfort	< 150 lx	1	Combination of artificial lighting and daylighting produce illuminance level 361- 371 lx (SNI standard for classroom = 350 lx)	3
Outside View and Daylight	59 % to 68 % floor area directed horizontally to the outside view and 100 % area has illuminance level <105 lx in daylighting condition.	0	No treatment is proposed since the studied buildings are heritage-listed.	0
	Total credits on the previous condition	4	Total Credits on proposed methods	8

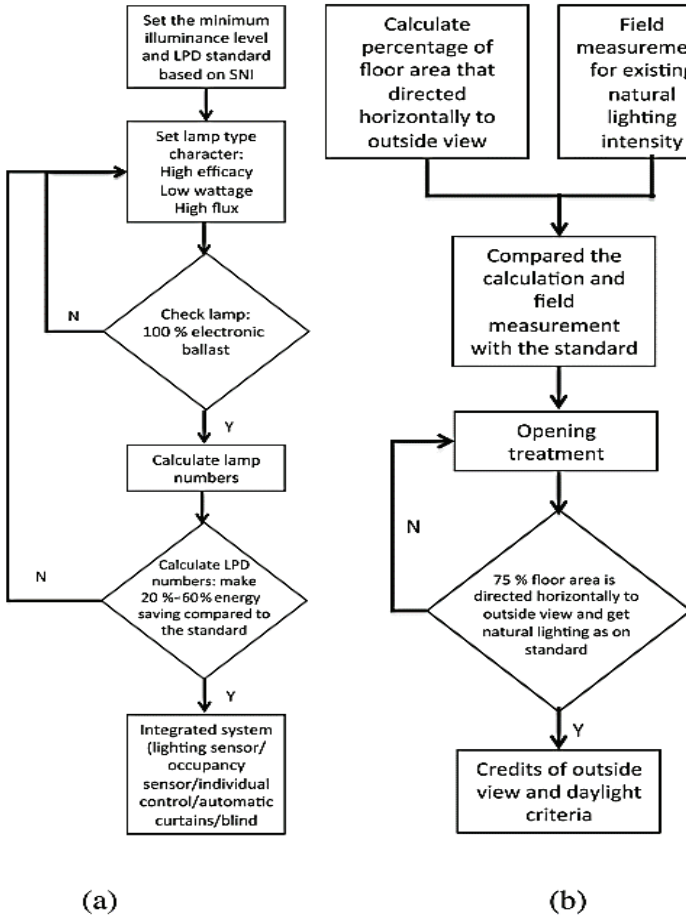

Fig. 15. (a) Lighting Power Density and Visual Comfort assessment flowchart; (b) View and Daylight assessment Flowchart.

from the previous purpose. Two classrooms were assessed based on the lighting quality according to the Greenship Rating Tools. From the measurement conducted, it showed that the amount of light in the studied buildings was inadequate. The indoor light level was below the standard (350 lx). Moreover, according to the Greenship Interior Space lighting criteria, both classrooms only obtained 4 credits from the total 10 credits listed. Several strategies could be implemented in these buildings to obtain more credits on the criteria for lighting systems and the environment. Although the studied buildings are heritage-listed, the occupants' visual comfort should not be neglected.

Further research can be applied by using the whole parameters of Greenship - Indoor Health and Comfort rating tool. The alterations of heritage building's function will affect the occupants, particularly on their well-being and productivity. Further research on comprehensive criteria of Indoor Health and Comfort will reduce the risk for occupants' dissatisfaction in an adaptively reused building, not only for indoor lighting but also for overall conditions related to indoor health and comfort.

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6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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