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Optimization of Design and Planing VHS Building Using Chronolux

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A B S T R A C T

Gedebage integrated vocational high school (SMK) is a school which accommodates the concept of technopolis. The school has four programs: building engineering, family welfare education (PKK/food service), mechanical engineering, and tourism - which produce skilled and ready-to-work graduates. This article aims to recommend the sun exposure toward the building of the school, which is related to site planning and design strategies based on the duration of solar radiation on vegetation, and building facades as well as the distance between buildings through the use of Chronolux plug-in on Sketch-up Software. From the measurement, it is found that vegetation can reduce sky view factors (SVF) from 76.4 to 38.87%. For the building façade, it is able to reduce sun exposure from 4 hours 51 minutes to 3 hours 19 minutes with SVF from 47.26 to 38.11%. Meanwhile, the building distance of 9 m receives sun exposure from 9:00 am to 3.42 pm.

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1. INTRODUCTION

Vocational senior high school, namely SMK is a secondary education level which aims at producing ready-to-work graduates. The SMK requires specific building performance related to the level of daylighting and thermal comfort, linked to the demands of vocational subjects given to students. Therefore, the building orientation, distance, facades or even vegetation are significant to perform the microclimate surround the building. (Wang, 2008)

The tropical climate consists of wet and dry tropics. A prominent feature of a tropical climate is the high average daily temperature compared to other climates. (Permatasari *et al.*, 2016) The length of maximum sunlight exposure can reach 90% depending on the season, latitude, geographical conditions, and cloud density. (Jones & Condit, 1948) Tropical areas have short dim morning and afternoon areas from the equator, the longer the duration of the dim morning and afternoon. (Chilibroste *et al.*, 2015) This condition causes the outdoor area continuously exposed to sunlight, which means the increasing the insolation throughout the surface area, such as building facade and ground area. (Wang & Liu, 2002) Meanwhile, it is suggested that buildings are exposed to sunlight at least for 4 hours, so that the buildings are protected from humidity. (Shameri *et al.*, 2011) Further, vegetation is placed only on the remaining area.

Since the school activities are most of in outdoor area, when the teaching-learning started from 7:00 am then continue to practice its theory, practically from 9:00 am to 2:00 pm, then continue to extracurricular activities from 4:00 pm. Thus, this period then, becomes the justification to calculate the sun exposure that is from 9:00 am to 4:00 pm.

Thus, the study of solar exposure toward the site also façade important to understand the insolation (sun radiation toward. Here, the purpose of this study was to optimize planning and design of SMK buildeing in Gedebage Bandung, Indonesia.

The use of Chronolux, a plugin tool for Sketchup is to optimize the planning and design stage that are justification for skin façade, distance between building and the vegetation spot. The feature of Chronolux for sun exposure period and SVF value then is describe specific time, and spot to reduce the solar radiation.

1. THEORETICAL REVIEW

2.1. SVF (Sky View Factor)

Sky View Factor (SVF) is a dimensional parameter with a value that represents the visible part of the sky in the hemisphere, which puts the analysis location as the center (Unger, 2008). Some researchers described SVF as the radiation ratio received by the planar surface compared to the radiation received by the whole hemisphere environment. (Watson & Johnson, 1987) In the urban environment, SVF is predominantly determined by buildings as the main element of the urban environment. Thus, some part of the sky is blocked by buildings and some other part is visible. Through a unified perfectly flat approach, barriers such as buildings and trees will proportionally reduce the SVF, indicating the sky openness for the radiation transportation with regard to certain locations.

The closedness of SVF reduce the impact of the solar heat. Closedness is due to the presence of buildings or vegetations closing the roof of segments. Vegetation which have the ability to cover segments are trees with wide canopy. Theoretically, the element of particular surfaces – part of the sky covered by buildings – can be determined by projecting buildings in the hemisphere, representing the sky with a projecting line. Twenty five geometries of urban canyons (having a variation of limiting height, length, and building distance/space) have a significant impact on the energy exchange and temperature of the urban areas (Oke, 1918; Oke, 1988). In general, SVF is determined through an analysis or photography. The analysis uses equations based on the geometry of the location to calculate ψs, particularly the height (H) and width (W) of canyons. The photography method employs a camera with a fish eye lens to project the hemisphere environment on a round planar image (Barring *et al.*, 1985). The traditional way to measure SVF is by taking a 180^{o} fish-eye image. The camera is set on a tripod with a height of 1 m and the fish eye lens is facing the sky. Pyranometers measure the global radiation received by the horizontal surface. The estimation of the effect of the slope on the irradiation is obvious and has been explained in many studies. The irradiation difuse on the slope has been estimated by multiplying irradiation spreading horizontally, known as Sky View Factor (SVF).

Later, there are several methods to measure SVF based on computational program. Chronolux is one of the applications that its goal is to test insolation duration and SVF, this application is an extension for SketchUp written on Ruby. These features are including: (See http://extensions.sketchup.com/en/content/lss-chronolux)

a. interactive real-time duration of insolation testing and SVF calculation at a pointer position
b. graphical representation of duration of insolation and SVF testing results
c. duration of insolation of an area defined by a face or surface testing

2.2. Solar radiation (Insolation)

Solar radiation is the energy radiation from the thermonuclear process that occurs in the sun. It is in the form of light and electromagnetic waves. It reaches the earth, warming the surface. Solar radiation will make building rooms warmer. The radiation that reaches the earth surface is called insolation.

Insolation is solar radiation which reaches a planet or the extension of any objects exposed to sunlight, such as spacecrafts or buildings. It is the exposure of objects to the sun or the intensity of solar radiation on horizontal surface units at certain levels. In construction, insolation is an important factor to consider in the design of buildings in certain climates (climates and micro climates). It is one of the most important climate variables which determines human comfort and the efficiency of buildings. Insolation depends on some factors: (1) the distance of the sun – changes of the distance result in the variation of solar energy acceptance, (2) the intensity of solar radiation – the angle of the sunlight coming to the earth; the amount received by the earth is proportional to the angle of sunlight coming to the earth. Sunlight with an oblique angle gives less energy to the surface of the earth, because the energy spreads over large surfaces and the sunlight has to go through farther atmospheric layers compared to sunlight with a perpendicular angle, (3) the length of day (sun duration) – the distance and duration between sunrise and sunset, and (4) effects of the atmosphere – some light going through the atmosphere will be adsorbed by gases, dust, and water vapor, reflected back; some goes to the surface of the earth.

Solar radiation has certain effects. During the day, abundant solar radiation will increase temperature in buildings. In contrast, solar radiation is minimal during

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the night, causing low temperature. Long and strong exposure of sunlight will cause eye damages or skin cancer. Therefore, a building design which can accommodate the advantages and disadvantages of the effects of solar radiation is needed.

2.3. Human activities

Human activities generally produce heat that will be released to the environment. For each activity, the level of heat is different. Heavy activities such as exercising, weight lifting, and other heavy activities require great energy, which in turn produce greater heat. Meanwhile, such activities as resting or sleeping produces minimum heat.

Human activities done in schools, both indoor or outdoor activities, should be evaluated as they are related to the quality of the activities in terms of comfort factor. The comfort factor should also consider the way sunlight affects the human activities in the schools.

2.4. The design of shader element

These are placed horizontally in front of the window, in various ways. Their, shape, type, depth and height all differs, all depending on the sun conditions. A window overhang is a (usually) horizontal surface that juts out over a window to shade it from the sun. This is desirable in order to reduce glare or solar heat gain. Purpose of the shape of shader element such as: cantilever, louver overhang, panels and horizontal louver as seen at **Figure 1**. The shading system itself is affected by some factors:

(i) the orbit of the sun;
(ii) local environmental conditions;
(iii) building forms;
(iv) building functions.

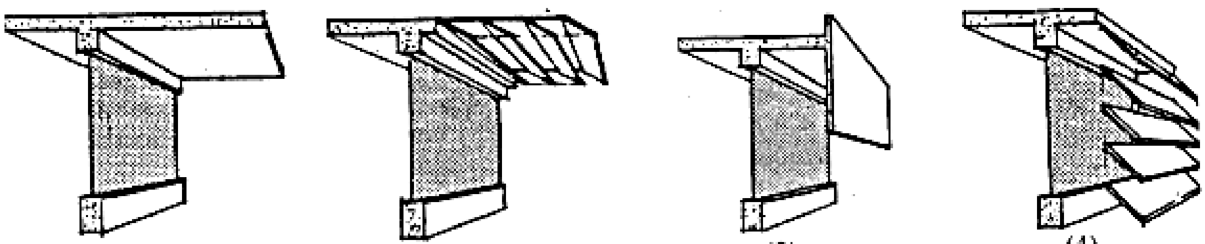

Figure 1. Shader element. Adopted from reference (Olgyay, 1963)

The function of shading in architecture is not only for anticipating problems caused by the sun, but also for forming the characteristics of buildings, visual communication, and creating psychological effects. The most optimum building orientation in all climates is extending from east to west. For humid tropical areas, the most optimum proportion of width and length as 1:1.7.

Window opening or ventilation is permanent because it is inseparable part of the building design, while flexible conditioning in accordance with individuals' activities requires shading elements. The shading elements can be permanent or adjustable. Permanent shading elements are usually overhang outside buildings or louver and light-shelves above building windows, while adjustable shading elements could be tents or gondola outside buildings or rollers and curtains inside buildings.

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2.5. Distance

The relationships between sky condition, latitude, surface reflectivity, building spacing, continuity, building shape and height are complex. Therefore, the spacing distance between buildings may be more restrictive than necessary, as low-latitude climates may be dominated by clear skies. The percentage of annual hours between 9am and 5pm is 95%. The latitude on 0 - 8° N/S required daylight factor 1.0 with H/W range is Tg α = 1.7-2.0. Thus, the minimum spacing angle requires 60° - 70°.

2.6. Vegetation

Vegetation acts as a filter absorbing sunlight and heat radiation, in which 5-30% of residual heat radiation from the biological process affects buildings' internal climate. Berry *et al.* have experiment with building shaded by tall Angophora trees, smaller Fraxinus trees and one was unshaded. (Berry *et al.*, 2013) Tree shade reduced wall surface temperatures by up to 9^{o}C and external air temperatures by up to 1^{o}C. The smaller trees did little to reduce external wall surface temperatures, and moving the tall trees further away from the building wall eliminated their cooling benefits. Further, city-scale studies have suggested that deposition to vegetation can make a very modest improvement (<5%) to urban air quality. This study shows that increasing deposition by the planting of vegetation in street canyons can reduce street-level concentrations in those canyons by as much as 40% for NO_2 and 60% for PM.

Vegetation planting is aimed at obtaining more fresh air in and around buildings. Lush vegetation will create shading effect which could improve comfort. Vegetation should be placed facing the sun so that the vegetation photosynthesize optimally and produce more oxygen. Considering the functional attribute and structural variable of leaves is a way to utilize the efficient quanta obtained in a natural community with a width variable in the environment parameter. In an environment with adequate sunlight, individual species will generally have leaves with higher capacity per unit area under bigger radiation due to the positive effect of the light on the mass of dry leaves per unit area.

3. CASE STUDY

3.1. Masterplan Site

The location for this SMK is at Cimincrang Street, Ujung Berung, Bandung as shown in **Figure 1** and divided into four blocks as seen. The northern part of the site is bordered by local community houses; the eastern part is bordered by Panyileukan Highway; the southern part is bordered by local community houses; and the western part is bordered by rice fields.

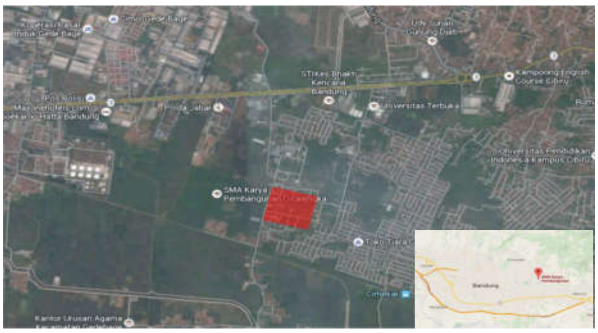

Figure 2a. Location of SMK in Ujung Berung, Bandung

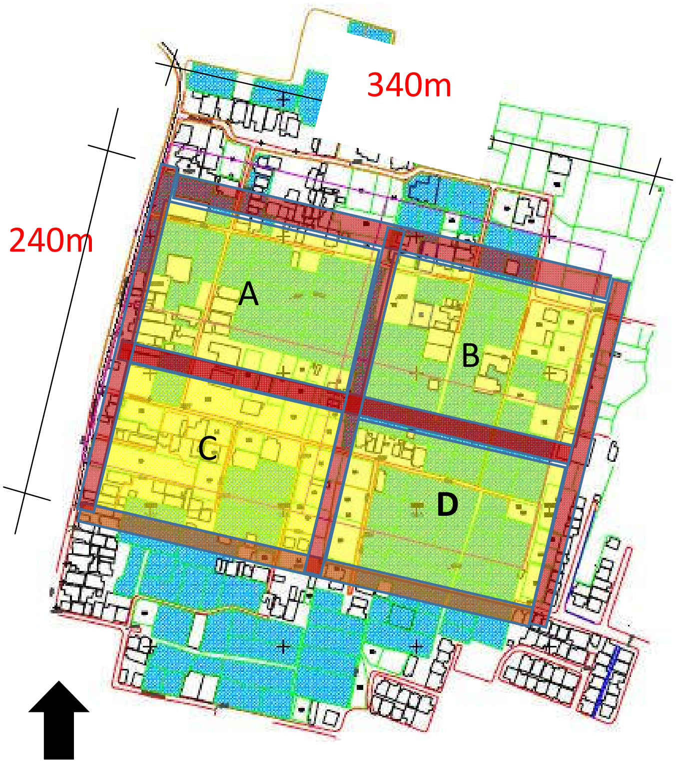

Figure 2b. Location of SMK in Ujung Berung, Bandung

3.2. SMK's Masterplan

Figure 3 explains the building block. In short, the discussion in this figure shows

A. Building Technology (BT)
B. Family welfacre education (FWE)
C. Tourism (T)
D. Mechanical Engineering (ME)

Total area of this SMK is 81.600 m2, which has building coverage 51%, and floor area ratio = 2.4, in which maximum floor allowed are 5 floors. Meanwhile, its green coverage area is 20%.

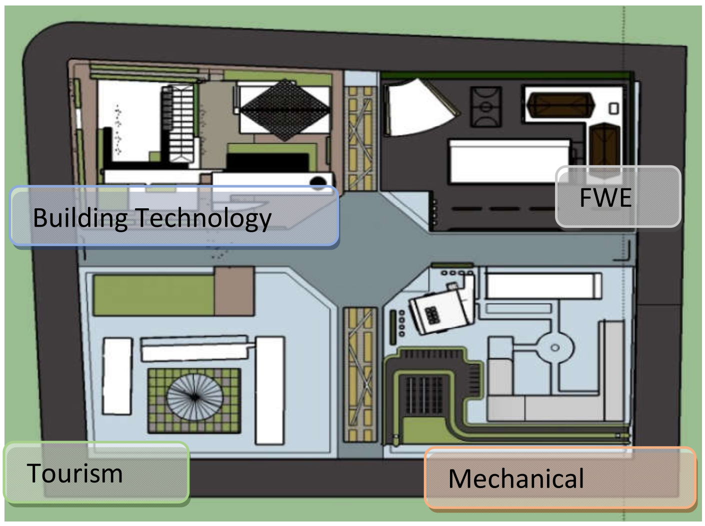

Figure 3. SMK's siteplan.

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3.3. Measurement for site plan's isolation

As shown in **Figure 4**, there are four building blocks, which are based on the based on the specifications of the majors. The next analysis is site plan's isolation which most of the ground area are colored by dark red that means it radiated more than 9 hours.

The figure indicates that each site plan has more than one building; yet, sunlight exposure has not been minimized significantly. Therefore, adequate vegetation needs to be added to reduce sunlight radiating to the site. However, the vegetation could not be spread evenly because of the presence of circulation which must be free from obstructions/barriers.

3.4. Vegetation Analysis

Figure 5 shows the vegetation has been dropped at the edge of the blocks. The vegetation should be laid on areas that are not used for circulation. So, radiation could be reduced. Furthermore, the area around the vegetation could be used for students' activities as the vegetation buffer from direct sunlight. After the plantation, the color of the ground plan has changed into orange to yellow from the dark red, showing a reduction for ground area isolation.

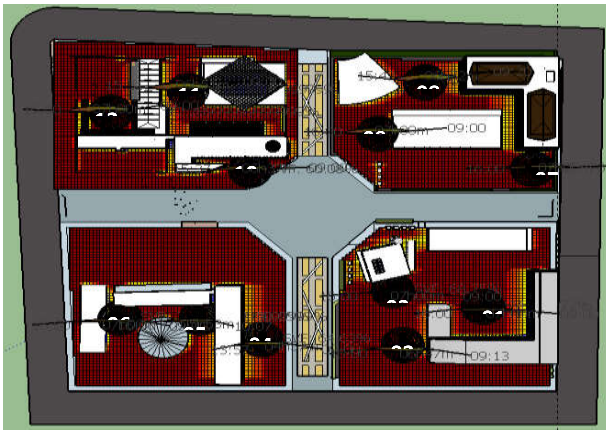

Figure 4. Siteplan's Insolation.

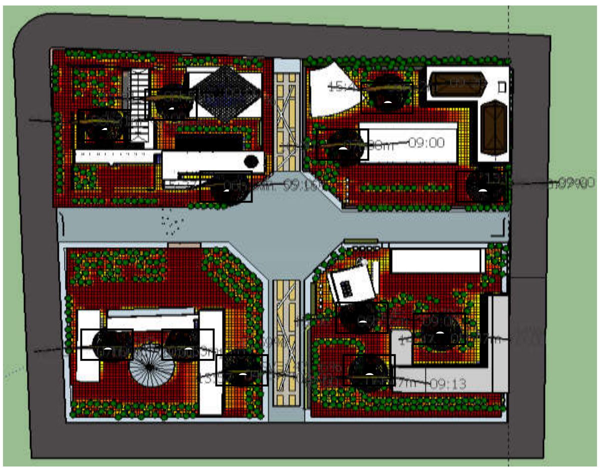

Figure 5. Vegetation Analysis

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4. Measurement results

4.1. *Chronolux Data from the Eksisting Site*

Table 1 explains the measurement on the eksisting site found that almost all of the SVF of each measurement point is above 55%. On average, the SVF for exixting site is 67.2%. The point with the highest SVF is point 7, which is 76.4% since there is no shadowing toward the point of measurement.

Table 2 shows the SVF value after vegetation on the site. As shown in the table, point 7 is able to reduce from 7 hours of insolation into 4 hours 1 minute (with SVF value = 38.87%).

Table 1. Eksisiting Insolation.

0	Point	Interval	Starts	Ends	Duration	SVF (%)
1	1	1	9:00	16:00	5h 47m	55.72
	2	1				55.72
2	3	1	9:00	16:00	6h 56m	68.75
	4	1				68.75
3	5	1	9:13	16:00	6h 47m	78.33
	6	1				78.33
4	7	1	9:00	13:57	4h 57m	64.63
	8	1				64.63
5	9	1	10.07	16:00	5h 53m	50.25
	10	1				50.25
6	11	1	9:00	16:00	7h 0m	71.39
	12	1				71.39
7	13	1	9:00	16:00	7h 0m	76.40
	14	1				76.40
8	15	1	9:20	15:42	6h 22m	73.44
	16	1				73.44
9	17	1	9:00	16:00	7h 0m	72.10
	18	1				72.10
10	19	1	9:00	15:37	6h 37m	60.08
	20	1				60.08
11	21	1	9:00	15:51	6h 51m	62.96
	22	1				62.96
12	23	1	9:00	16:00	7h 0m	72.29
	24	1				72.29

4.2. BUILDING FACADE

Description

Site : Mechanical Engineering

Area : 1.6ha (123m x 135m)

Buildings : 3 buildings

Mechanical Engineering's building block is one of the four blocks in the masterplan of SMK Gedebage (**Figure 6**). The main building that is going to observe is the classroom as seen at **Figures 7** and **8**. The measurement was done from 07:00 am to 02:00 pm due to the teaching-learning activities in the classroom. The aim of measurement is to know the direct sunlight exposure to the facade.

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Table 2. Insolation after vegetation plantation

Loc	Point	Interval	Starts	Ends	Duration	SVF (%)
	1	1	9:00	14:47	5h 47m	55.72
1	2	1				55.72
	3	1	9:00	15:56	6h 56m	50.97
2	4	1				50.97
	5	1	9:13	16:00	6h 47m	52.97
3	6	1				52.97
	7	1	9:00	13.57	4h 57m	47.26
4	8	1				47.26
	9	1	10.07	16:00	5h 53m	48.59
5	10	1				48.59
	11	1	9:00	16:00	7h 0m	68.90
6	12	1				68.90
	13	1	9:00	13:01	4h 1m	38.87
7	14	1				38.87
	15	1	9:20	15:42	6h 22m	66.02
8	16	1				66.02
	17	1	9:00	16:00	7h 0m	62.64
9	18	1				62.64
	19	1	9:00	15:37	6h 37m	55.15
10	20	1				55.15
	21	1	9:00	15:51	6h 51m	62.55
11	22	1				62.55
	23	1	9:00	15:31	6h 31m	45.85
12	24	1				45.85

Based on chronolux simulation, SVF measurement in the classroom lasted for 4 hours 51 minutes with the SVF value of 47.26%. The long exposure of SVF will bring negative effects to users of the classroom. Therefore, treatments need to be done to reduce the duration and the SVF value. One of the treatments is by adding canopy above the windows of the classroom, measured 1.2 meters in wide and 50 cm in height as shown in **Figure 9**. The existing condition of façade has shown at figure 8, with chronolux result in **Table 3** below.

Based on the data obtained by using Chronolux in the facade of the designed building of mechanical engineering, there are changes of duration and SVF value after the addition of canopy on the facade. Treatments as buffers need to be added to the facade to reduce sunlight. After the addition of the canopy, there is a significant change of SVF received by the point. The duration of sunlight becomes 3 hours 19 minutes and the SVF 38.11%. Therefore, there is a decrease of the duration, which is 1 hour 32 minutes, and a decrease of SVF, 9.15%.

Figure 6. Perspective situation of SMK Gedebage

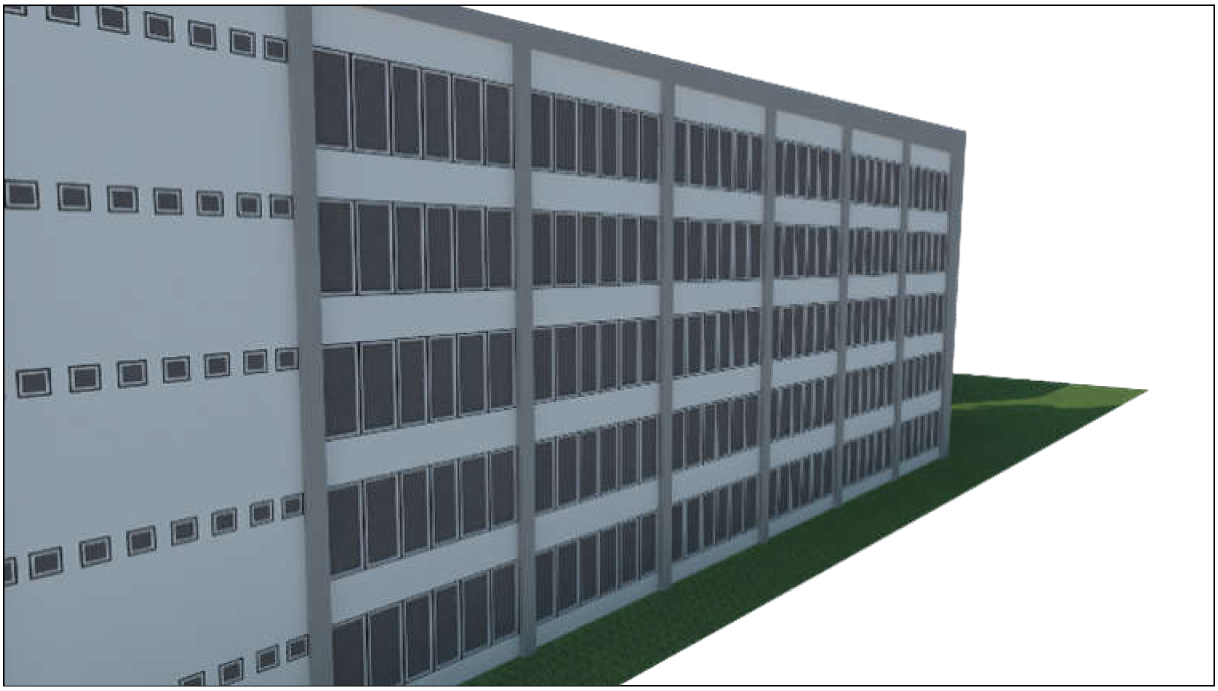

Figure 7. Sequence of façade of classroom

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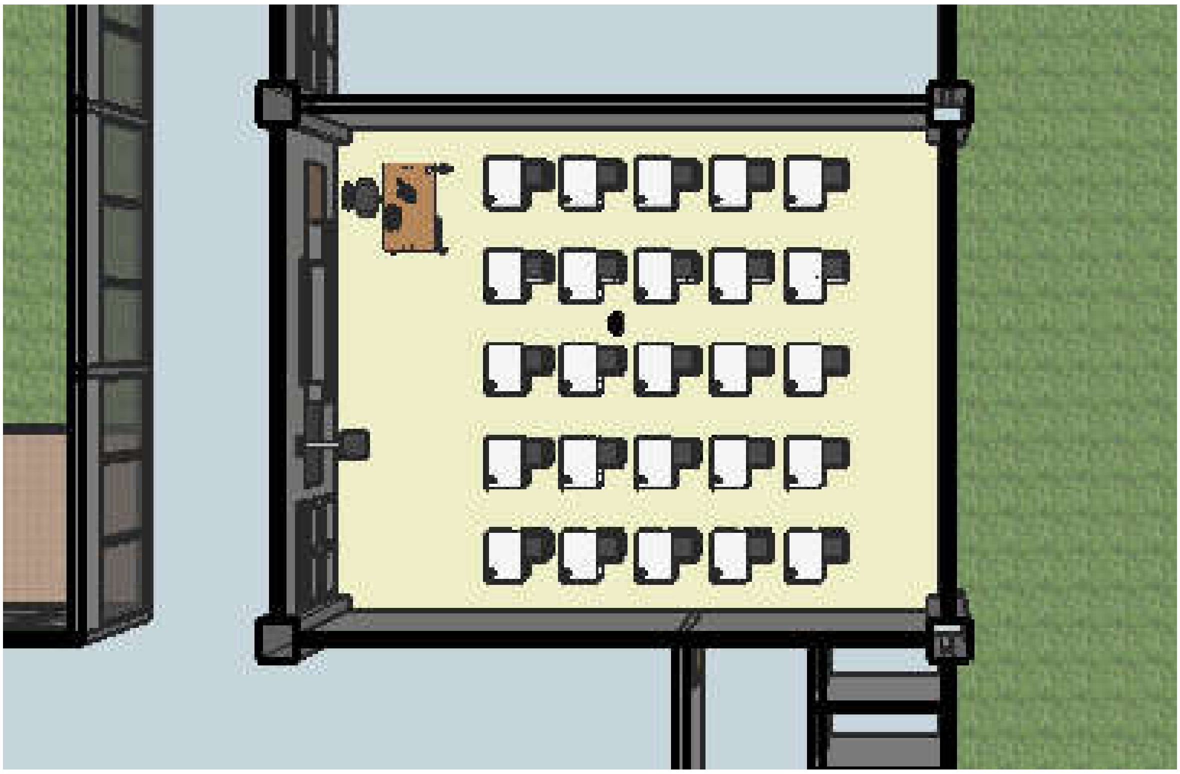

Figure 8. Classroom layout

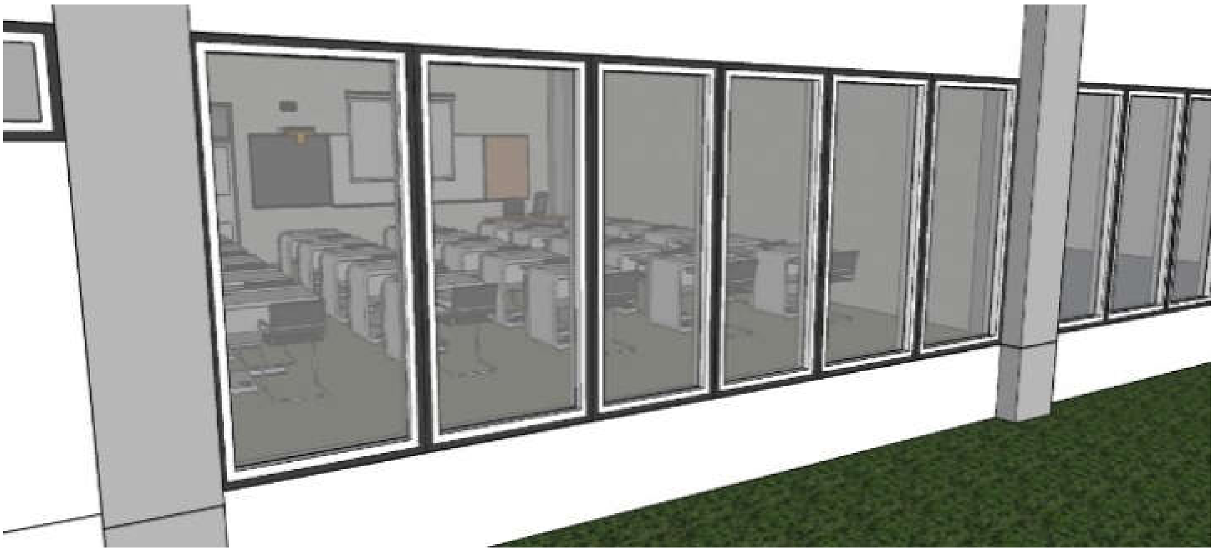

Figure 9. Eksisting façade of classroom

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Figure 10. Eksisting façade of classroom

Table 3. Direct exposure to existing façade

Interval	Starts	Ends	Duration	SVF, %
1	07:00	11:51	4h 51m	47.26

Table 4. Direct exposure to the façade after adding the canopy

Interval	Starts	Ends	Duration	SVF, %
1	07.00	10.19	3h 19m	38.11

4.3. DISTANCE BETWEEN BUILDINGS

Description

Site : Family welfare education (PKK/food service)

Area : 1.6 ha

Buildings : 3 building facades

The building of family welfare education (PKK/food service) program has two building blocks, which are the main building with L shape for administration room, classrooms and workshops. This building contains five floors and each floor has different vocational laboratory, which are: restaurant, patiseri, fashion, hairstyling, and skin treatment. The other buildings have one floor for auditorium. PKK program's building as seen in **Figure 10**. The measurement has done from 9:00 am to 4:00 pm.

The distance between the main building and the auditorium is 9 meters. The SVF value for this distance is 73.44% as shown in **Figure 11**. The building distance (between main building and auditorium) requires such a distance to allow students do their activities. So that, it does not interfere the main building that is close to classrooms.

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With such a distance/space, there is not so much sunlight as it is blocked by the high buildings.

Since the value of SVF is too high, the building distance then reduced into 6m, which then giving the SVF value into 66.02% as seen at figure 12. This distance is given since in the main building, there is a practice room which should be close to the workshop so that students can do their activities comfortably, such as moving tools or materials in the restaurant. Furthermore, the sunlight available from such a distance does not hamper the student activities

Figure 11. PKK program's Building block

Figure 12. Main Building distance to auditorium : 9 meters

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After the distance measurement, the SVF decreases from 73.44 to 66.02%, which is still above 50.00. However, in the area there is an open-area (field) which must be free from any barriers/canopies, and far from the buildings.

Figure 13. Main Building distance to auditorium : 6 meters

5. CONCLUSION

Chronolux has been proved as the simple tool to optimize the planning and design to accommodate the solar exposure to the site and façade. By knowing the period of exposure, architect or planner is able to assess the building performance and optimizing the building element, such as: window, facade and vegetation. Furthermore, by adding the vegetation on site, it is found that the insolation is able to reduce 7 hours into 4hours 1minute with SVF value from 76.40 into 38.87%. Meanwhile by adding the shaded element, the sun exposure from 07:00 am to 11:51 am (4 hours 5 minutes) is able to reduce into 07:00 am to 10:19 am (3 hours 19 minutes). The 9 meters distance between building has SVF 74.44%, by reducing the distance into 6 meters, the SVF value decrease into 66.02%.

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7. AUTHOR'S NOTES

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. Authors confirmed that the data and the paper are free of plagiarism.

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