## Research Article
# Estimation Daylight to Find Simple Formulate Based on the Ratio of Window Area to Floor Area Rule of Thumb for Classroom in Malaysia

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**Abstract:** The impact of ratio of window area to floor area rule of thumb on the performance of day lighting was investigated using computer simulation by Radiance in IES <VE>. The purpose of this research is to find simple formulate based on window area to floor area ratio for small classroom located in Malaysia and asses the influence of variables design on their day lighting and energy consumption. The simulation was carried out for various window areas to floor area percentage in two models of classrooms. Majority of architects prefer to use the quick reference resources instead of simulation tool to evaluate the amount of day lighting. Comparative simulation were done to determine which ratio of glazing area to floor area have optimum result on visual comfort and energy consumption. In addition, correlation between results of average illuminance on size of the window to find a new rule of thumb formulate in Malyasia. This simple formulate can help architect to calculate the optimum size of window to develop day lighting in small classrooms.

**Keywords:** Formulate, rule of thumb, simulation, window to floor area

## INTRODUCTION

Day lighting is an important issue in acquiring a more effective architecture which is integrated with the climate of building (Ramos and Ghisi, 2010). The estimation of energy efficiency and visual comfort due to natural lighting requires an accurate evaluation of the amount of illuminance in the space (Li *et al*., 2006) and also the other research confirm that adequate day lighting not only reduce energy using but also increasing learning of students. Heschong Mahone Group (1999) confirmed that the researched more than 20,0000 elementary students and 100 schools in the USA approved the effect of sufficient day lighting in classrooms increased 26% faster in reading and 20% quicker in mathematics (Abdelatia *et al*., 2010). US Department of Energy explained that 25% of the costs on energy using in classrooms can be saved by designing better building (Perez and Capeluto, 2009). Scartezzini (1991) indicated that using artificial lighting in non-domestic buildings can be represented 50% of the energy consumption in Europe. It also has been demonstrated that it can be decreased this utilization with 30 to 70% by using natural lighting (Abdelatia *et al*., 2010).

The penetration of natural lighting into the room depends on many parameters of design, among them the ceiling height, internal reflectance's, depth of room, shape and size of glazing area (Capeluto, 2003). The question of size of classroom and the relation of Window area to Floor area (WFR) was also researched which confirm that classroom can provide a visual comfort for students and decreasing energy consumption in tropical area. The purpose of this research was to find formulate of rule of thumb calculation of average internal illuminance and average daylight factor in 8 models with different window area to floor area ratio in classroom. Many efforts have been studied to improve the design of classroom on specific design of guideline in terms of the size of glazing area; however, there is inadequate information on strategy design of classrooms in hot-humid climate to understand these advantages and to develop the classroom into minimizing the electric energy consumption as well as comfortable studying environment (Perez and Capeluto, 2009). Majority of the architects prefer to use the quick reference recourse and check list instead of simulation tool to evaluate the amount of energy using (Van Den Wymelenberg and Meek, 2011; Reinhart and Fitz, 2006). It seeks to provide the formulated based on rule of thumb to estimate the average daylight factor by changing the ratio of window area to floor area.

## LITERATURE REVIEW

**Window area to floor area ratio rule of thumb:** The ratio of window area to floor area rule of thumb was

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often cited in literature of architecture and building codes. The percentage of window area to floor of 10 to 12.5% is also recommended in Neufert (2000) Architecture's Data. Gutherie (1995) prescribed that the ratio of glazing area to floor area for day lighting must be 10 to 25%. British Local Goverment Board by laws in 1920s and the London Building Acts of 1894-1909 suggested that a window area to floor area ratio of 10% was also requirement. However, these rules are occasionally associated to the room depth and type of building. For instance, Smith (2005) explained that window area to floor area ratio 20% can provide sufficient day lighting up to a depth of approximately 1.5 times the height of room in non-domestic buildings (Ibrahim, 2009).

Robson advised that the ratio of window area to floor area 20% can provide adequate lighting in the classroom (Wu and Ng, 2003). Perez and Capeluto (2009) States that overall size of window area to floor area was 12% in the east and west orientation where as window area 10% to floor area is a minimum for adequate natural lighting. Nevertheless, European countries with cooler climate recommended that 20% of window area to floor area. The percentage of 20 to 25% window area to floor area has not only connected with classrooms but also the other type of building. Hopkinson (1964) Claimed that these percentage can supply a 2% daylight factor or 100 lux ( as explain by the British Building Code) to a depth of 6 m from a window wall. It is likely that these researchers are replying to the extensive use of this rule of thumb (Ibrahim, 2009).

**Classroom's specification:** Model 1 was a rectangle classroom 8 m width, 6 m length; 3 m height where as the dimension of Model 2 was 6 m width, 8 m length, 3 m height as represented in Fig. 1. Researchers believe that the length to width of the classroom should be approximately 3:2 and ceiling height should be at least 3 m for small classrooms (Neuman, 2003). According to standard of classroom design, space per students require 1.9 to 2 m space in the classroom (Neufert, 2000), hence, there are approximately 20 students in the Model 1 and 2. The both classrooms, Model 1 and 2 have a standard ceiling height (3 m), a window head height (1.8) and average room surfaces reflectance of 0.5. All classrooms have a standard window sill height of 0.8 m in a north facing facade; however, the window facade in a long side (8 m) in Model 1; whereas, the window facade in a short side (6 m) in Model 2. In addition, Model 1 and 2 consist of small classrooms with a same area as shown respectively in Fig. 2 and 3. In addition, Both Models have a varying ratio of window area to floor area ranging 5 to 20% by gradually increasing the window width Model 1 and 2.

## METHODOLOGY

The objective of this study is to find the ratio of window area to floor area which can provide adequate
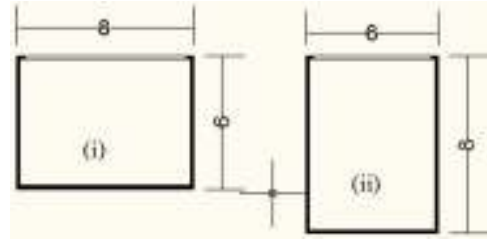


Fig. 1: (i) Model 1, (ii) model 2



Fig. 2: Model 1 with various ratio window areas to floor area
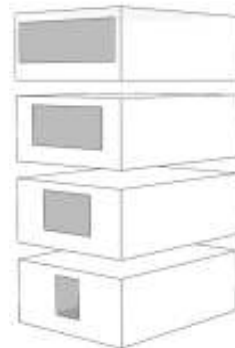


Fig. 3: Model 2 with various ratio window area to floor area

daylight illuminance inside the classrooms. This study was carried out in two phases, the first based on a comparison average illuminance between Model 1 and 2 as well as increasing window area to floor area from 5 to 20% for both Models. In second phase, the correlation between average illuminance and glazing area to floor area percentage by calculation of simulation to find new formulates based on climate of Malaysia in small classrooms.

**Simulation:** The simulation was performed using Radiance in Integration Environment Solution <Virtual Environment> (IES <VE>) software for lighting analysis. The time and data of simulation were set on July 21st at 12 pm. Researchers obtained that Radiance is a ray-tracing software to estimate illuminance that the ability to accurate account for daylighting design and

Table 1: Internal and external conditions of classrooms

| Sky condition | CIE standard overcast sky intermediate without sun sky |
|---|---|
| Latitude | 3.12°N |
| Longitude | 101.55°E |
| Altitude | 22 m |
| Obstruction | No |
| Ceiling reflectance | 80% |
| Wall reflectance | 50% |
| Floor reflectance | 20% |
| Glazing type | Clear, 80% transmittance |
| Date | 21st July |
| Time | 12 pm |

Table 2: Illuminance level according to Malaysian standard 1525 (Zain-ahmad *et al.*, 2002)

| Illuminance type | Activity | Illuminance (lux) |
|---|---|---|
| Working interiors | General offices, reading and writing | 300-400 |
| | Drawing office | 300-400 |
| Exacting task | Proof reading | 500 |
| | Exacting drawing | 1000 |
| | Detailed and precise work | 2000 |

physically valid lighting. In addition, Radiance is obtained from Lawrence Berkeley Laboratory-Berkeley, USA (Shahriar and Mohit, 2007). As shown in Table 1. The conditions of simulation were set to the condition of Kuala Lumpur, Subang. The latitude f the classrooms, Model 1 and 2 was 3.12°N, longitude was 101.55°E and altitude 22 m. Two sky conditions were assumed:

- Standard CIE Overcast sky
- Intermediate without sun sky

Zain Ahmad *et al* found that the sky of Malaysia is generally intermediate which means it is neither overcast sky. Moreover, the result of hourly illuminance showed that the type of sky was 85.6% usually intermediate, 66% intermediate mean, 16.3% intermediate blue and 14% overcast sky (Zain-Ahmed *et al.*, 2002). The Standard CIE overcast sky shows greatest low the level of daylight. Thus, it was used for simulation of day lighting on characteristic day for the minimum amount of daylight (Shahriar and Mohit, 2007). According to IES (1984) the effective surface reflectance for floor, wall and ceiling are 20, 50 and 70%, respectively.

## RESULTS AND DISCUSSION

According to the CIBSE, provision is made for the design of illuminance for types of classroom within the range from 300 to 500 lux (CIBSE, 1999). Malaysian standard code of practice on energy efficiency and use of renewable energy for non-residential buildings had recommended between 300 to 400 lux as range of the illuminance level for drawing office, however, it suggested that for exact drawing, the value must be around 1000 lux (MS 1525, 2007) in Table 2.

The average value of illuminance were compared in order to verify between the model 1 and 2 calculated by Radiance in IES <VE> program. As shown in Fig. 4, the level of average illuminance on horizontal work plane occurred in the Model 1 was higher than Model 2 which has a deeper plan under both of sky. Figure 5 and 6 Illustatre the day lighting distribution from the ratio of glazing area to floor area between 5 to 20% with the
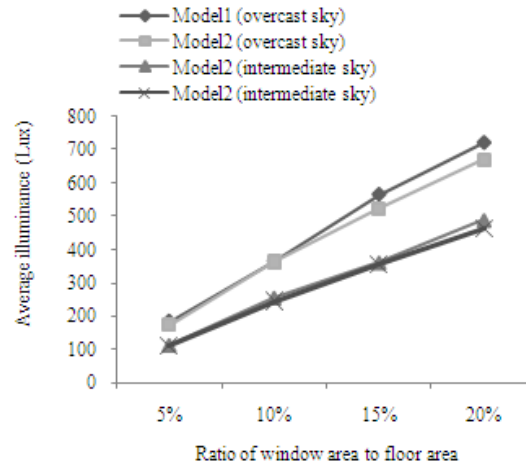
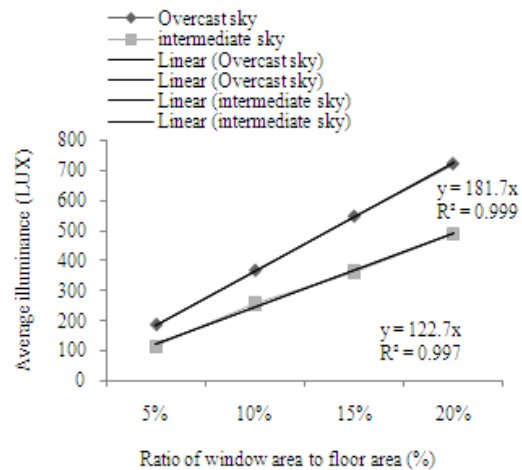Fig. 4: Comparison average illuminance between Model 1 and 2 to increasing window area to floor area

Fig. 5: Comparison average illuminance was increasing window area to floor area between overcast and intermediate sky in Model 1

step 20 and 15% for intermediate sky and overcast sky were increased respectively in the Model 1 and 2. Furthermore, it seems obvious that CIE Standard overcast sky results higher value of illuminance than intermediate sky without sun in both of Model 1 and 2. The Malaysian guideline for energy efficiency in buildings recommends that minimum interior lighting for classroom should be 300 lux. For this study, it was used the allowable interior illuminance between 300 to 100 lux.
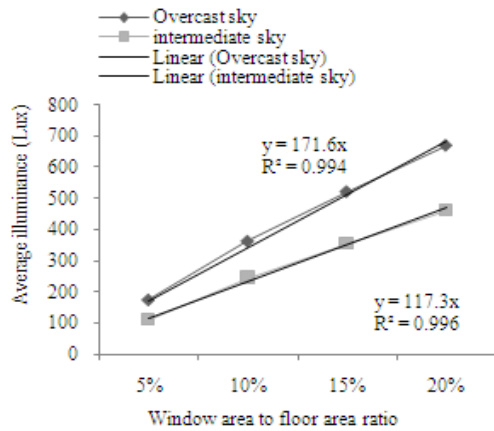
Fig. 6: Comparison average illuminance was increasing window area to floor area between overcast and intermediate sky in Model 2

**Average illuminance in model 1:** As shown in Fig. 2, average illuminance enhanced with an increasing ratio of window area to floor area. As well as, the average illuminance under an intermediate sky without sun was less than CIE Standard overcast sky in this research. The average illuminance for 5 and 20% the glazing area to floor area were 185 and 723 lux under overcast sky and also, 115 and 490 lux under intermediate without sun sky. according to standard (Malaysia, (MS1525) 2007), the ratio of glazing area to floor area more than 10% was acceptable under an overcast sky, whereas, the window area to floor area more than 15% was adequate under an intermediate sky without sun. Therefore, the result suggested that the ratio of opening area to floor area between 15 to 20% were accepted according to Malaysian standard and CIBSE in the Model 1 (CIBSE, 1999; MS 1525, 2007).

There was a strong important correlation between the ratio of glazing area to floor area and average illuminance to provide optimum day lighting in the small classroom with window façade in long side. (Deep 6 m). The linear correlation between average illuminance and the window area of floor area in Fig. 5 can be represented by the simple equation of rule of thumb below:

$$E_{ave} = 180 \ A_g/A_f \text{ (overcast sky)} \qquad (1)$$

$$E_{ave} = 120 \ A_g/A_f \text{ (intermediate sky)} \qquad (2)$$

where,
$E_{ave}$ : Average illuminance
$A_g$ : Glazing area
$A_f$ : Floor area

**Average illuminance in model 2:** As shown in Fig. 3, the design of window façade classroom was in the smaller side and also the different window area to floor area size from 5 to 20%. Therefore the Fig. 6 indicated the results of the simulation from the model 2 as shown

in Fig. 3. Average illuminance enhanced with a increasing ratio of window area to floor area. Figure 6 showed that a window to floor area ratio of 10% was seemed to satisfy the cheerfully average illuminance 360 lux under an overcast sky whereas, 15% the ratio of window to floor area was adequate 350 lux under an intermediate sky. Therefore, the window area to floor area ratio between 15 to 20% were provided optimum natural lighting in classroom according the standard of Malaysia. In addition, the percentage of window area to floor area less than 10 and 15% cannot provide sufficient minimum day lighting inside the classroom under an overcast and intermediate sky respectively on horizontal working plane in Model 2 of classroom which has a little deeper plan with comparison of Model 1. The result indicated a significant instance of correlation between the ratio of glazing to floor area and the average illuminance in Model 2 which $R^2$ were almost close to 1 for both type of sky in Model 2 (deep 8 m). The linear correlation between average illuminance and WFR can be represented by the simple equations of rule of thumb in deeper classroom:

$$E_{ave} = 180 \ A_g/A_f \text{ (overcast sky)} \qquad (3)$$

$$E_{ave} = 120 \ A_g/A_f \text{ (intermediate sky)} \qquad (4)$$

**CONCLUSION**

Applying the methodology explained herein, in this study performed Radiance in IES <VE> simulation program to investigate the adequate average illuminance in the small classrooms in Malaysia by day lighting with different window area to floor area percentage under overcast sky and intermediate sky in classroom's Malaysia. The first analysis done compared small classrooms under overcast and intermediate sky. It was observed that the average illuminance under intermediate sky was lower than overcast sky.

The result indicated that the strong correlation between percentages of window area to floor area was found in Model 1 with a window façade in a long side (8 m) and Model 2 with a window façade in short side (6 m) in the same area.

Through the analysis of average illuminance, it was estimated that the ratio of window area to floor area between 15 to 20% was adequate day lighting in small classrooms in north window façade in Malaysia.

Equation (1), (3), (2) and (4) showed that the result of value average illuminance in Model 1 and 2 under overcast sky were approximately same Equation.

**Equation 1 and 3:** $E_{ave} = 180 \ A_g/A_f$ (overcast sky)

**Equation 2 and 4:** $E_{ave} = 120 \ A_g/A_f$ (intermediate sky)
The result of this research can also be useful for architect to design of energy efficiency in educational buildings in estimation the value of illuminance by changing window area to floor area ratio.

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