**DESIGN AND ARCHITECTURE**

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# EVALUATION OF DAYLIGHTING PERFORMANCE IN EXISTING STUDENT RESIDENTIAL BUILDING WITH INTERNAL PARTITION


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***Abstract –*** The Polytechnic Ungku Omar residential college building was designed with an internal partition to accommodate six (6) people per room. However, the installation of an internal partition has resulted in lowering the illumination level inside the building. While the rooms are designed with internal partition, the layout of the internal partition may influence the indoor daylighting distribution. Therefore, this study is intended to evaluate the impacts of several internal partition layout on indoor daylighting performance in residential college rooms. The field measurement was conducted in a typical student residential room under a tropical sky to validate the result of the simulation under Climate Based Daylight Modelling (CBDM). Then several options of internal partition were simulated using DIVA for Rhino to suggest the possible partition layout that is effective to overcome low daylighting level in student residential rooms. The finding indicates that by changing the internal partition layout in a student residential room in the tropics have a robust impact on daylight sufficiency. It is revealed that the highest annual daylight sufficiency values belong to those internal partitions oriented perpendicular to the window. These improvements could provide a comfortable, productive and healthy environment for occupants as well as savings in annual energy consumption.



***Keywords -*** Illuminance, Tropical climate, Simulation


## 1 INTRODUCTION

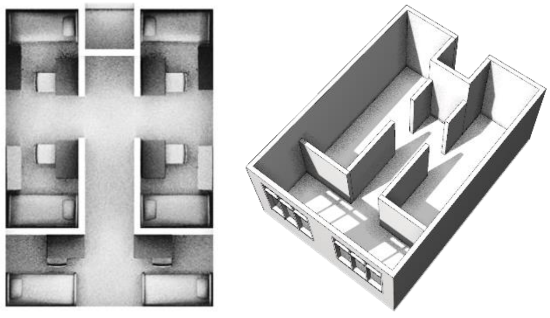
Polytechnic education was introduced in Malaysia with the funding from the World Bank and a collaboration with the Colombo Plan in 1969. Currently, there are 33 polytechnics in the country which can be divided into three categories - premier, conventional, and metro. These polytechnics provide skilled semi-professionals in the fields of engineering, commerce, and hospitality at diploma and advanced diploma levels to meet the demand of the public and private sectors. The increasing number of students leads to the booming of multi-storey student residential buildings on the campuses. However, there is a lack of studies performed at the student residential building, especially in the tropical climate region, as compared to the office or commercial buildings in the temperate climate region (Jamaludin, Hussein, Keumala, Rosemary, & Ariffin, 2015).

The use of daylighting as a passive design strategy can contribute to the reduction of energy consumption if it is effectively used (Mousavi, Khan, & Wah, 2018; Lim, 2014; Mahdavi et al., 2015; Nikpour & Kandar, 2016). Based on the previous studies (Zomorodian et al., 2016; Rena, 2017; G. Lim et al., 2017), the effective use of daylighting can contribute a healthy indoor environment, produce energy-saving, and provide good visual comfort to the residents. For multi-storey buildings, the most appropriate zones for active human activities should be located within the daylight zone, typically about 5m deep from the window wall or the top floor of a building with skylight (Leslie, 2003).

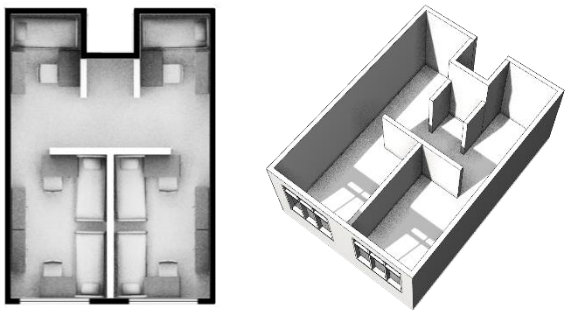
Usually, typical multi-storey hostel room layout has an open planning layout, and students stay in a shared accommodation with at most four students at one time. However, in this new hostel building, the rooms are designed with an internal partition and can accommodate six students at one time which has resulted in lowering the illumination level inside the room. This scenario has increased the dependence on artificial lighting, especially during daytime and consequently will increase energy consumption. This is converse to the previous study that merely focuses on student residential room with an open plan (Kumar, 2014; Pejic´, Petkovic´, & Krasic´, 2014; M. Al-Tamimi, Syed Fadzil, & Wan Harun, 2011). According to the New Buildings Institute (2015), the height, orientations, and materiality of partitions (reflective surfaces of partitions) can affect the amount of transferred daylight from windows and the lighting conditions of space. Higher partitions that are greater than 48” should be used perpendicularly to the perimeter glazing in providing privacy, a sense of enclosure, and unobstruction of the daylight direction (New Buildings Institute, 2015). The selected building is a new student residential building located in Ipoh, which is designed with internal partitions. This study aims to investigate the impact of several internal partition layout on annual indoor daylighting performance in student residential room as a sustainable approach to energy saving in a tropical climate.

## 2 METHODOLOGY

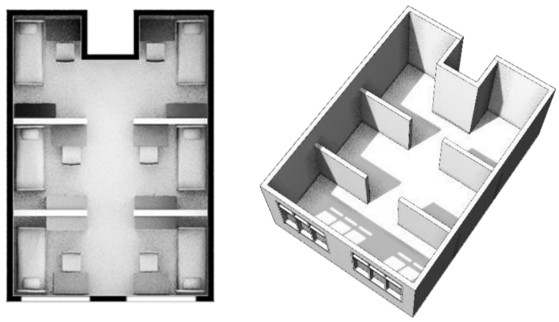
There are two methods involved in this study, which are field experiment and computer simulation method. The methodology was carried out in three phases. The first phase is the data collected from the field experiment. The second phase is the verification and validation process, which included a model of the case study room similar to the real one used in a student residential building. The results of the field measurement were then compared with those of the simulations. The last stage involves simulating the four proposed internal partitions. Figure 1 shows the existing condition of the room and proposed different types of internal partitions to be tested using simulation software. The description of each type of internal partitions is described in Table 1.



Existing Condition



Type A



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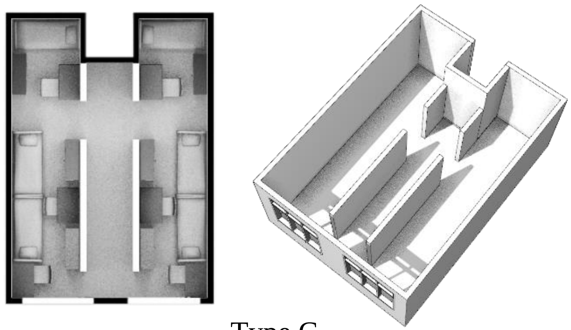
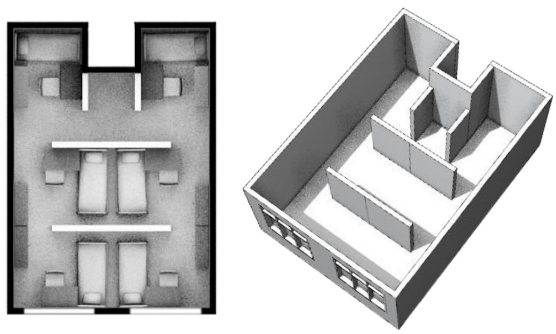


Type C



Type D

Figure 1 The existing condition of the partition inside a room and proposed types of Internal Partition Layout to be tested using simulation software

Table 1 The Internal Partition Design Description

| Type | Description |
|---|---|
| **EC** | Existing condition internal partition with 2.1 m height. The partition layout is the combination of parallel and perpendicular to a window that can accommodate six students at one time. |
| **Type A** | Internal partition with 2.1 m height. The partition layout is the combination of parallel and perpendicular to a window that can accommodate six students at one time. |
| **Type B** | Internal partition with 2.1 m height. The partition layout parallel to a window that can accommodate six students at one time. |
| **Type C** | Internal partition with 2.1 m height. The partition layout perpendicular to a window that can accommodate six students at one time |
| **Type D** | Internal partition with 2.1 m height. The partition layout parallel to a window that can accommodate six students at one time. |

## 2.1 Field Measurement

Before running the daylighting simulation study, an actual field measurement should be conducted under the Malaysian tropical sky to ensure the accuracy of the simulation results. Several studies suggested that simulated results must be compared with measured data and several input parameters affecting the simulation discrepancies that were tuned (Al-Tamimi & Fadzil, 2011; Mousavi *et al*., 2018). This procedure is usually known as the calibration of the simulation model. In order to calibrate, the building simulation results need to be compared with fieldwork data. Due to the security reason, field measurement was done during semester break from 18 until 22 May 2018.

## 2.2 Specification of the Case Study Room

The case study room was located at Politeknik Ungku Omar, Ipoh, Perak (4.57 N/ 101.10 W) Perak facing Nort East. The window has a head height of 2.7 m, and the sill is at 0.9 m, thus making the height of the window at 1.8 m. The case study room was modelled using Rhinoceros 5.0 programme with the same specification as shown in Figure 2 (a-b) that shows the room's geometry.

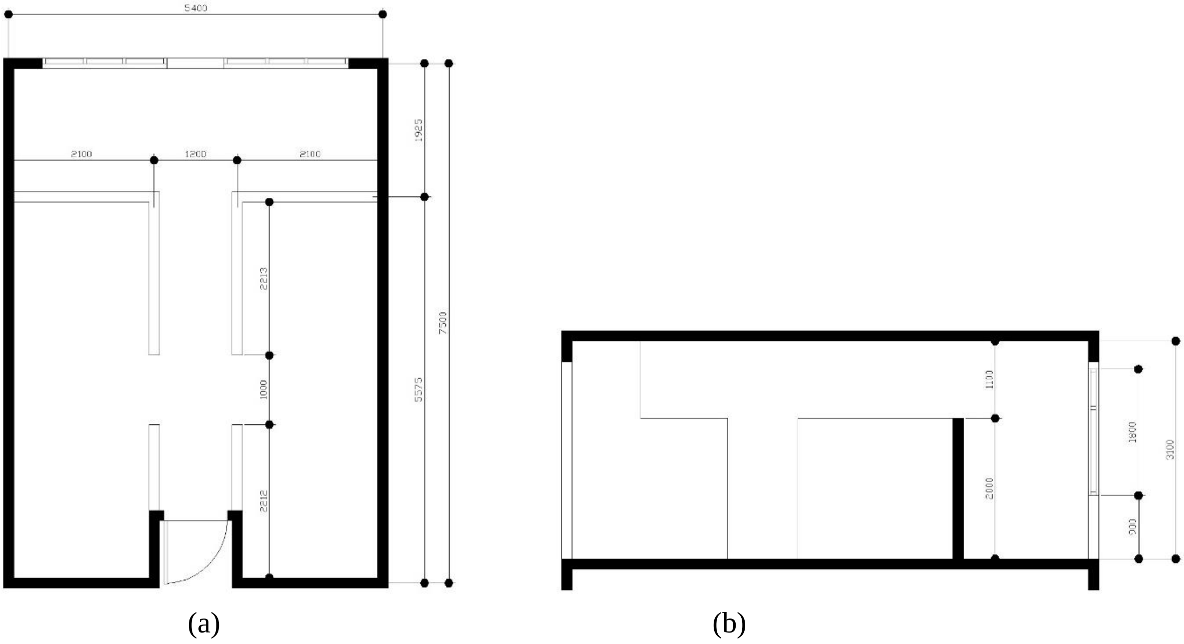



Figure 2 Plan (a) and Section (b) of the case study room

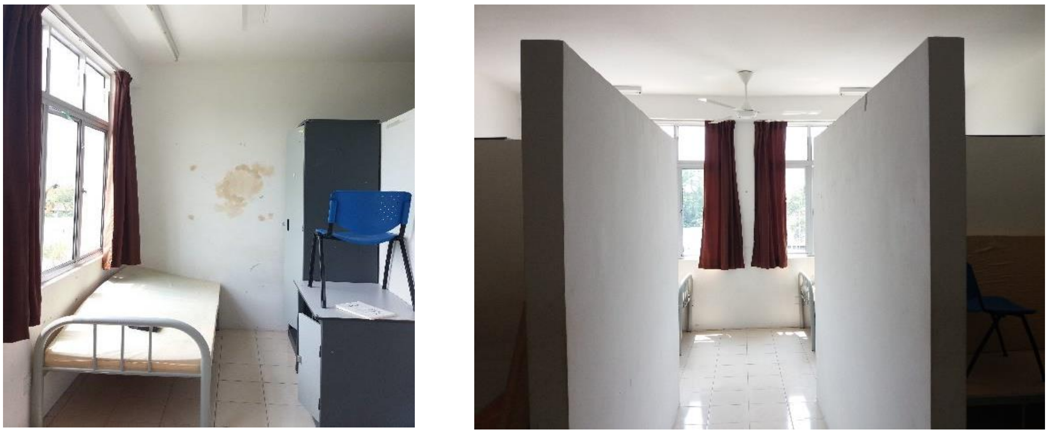


Figure 3 Existing condition of the case study room

## 2.3 Experiment Setting

As shown in Figure 4, six (6) positions of reference point were placed at the working plane height (75cm) in the case study room to calculate the work plane illuminance (WPI) by using lux meter. The measurement was carried out from 9.00 am to 4.00 pm during a five-day period where the rooms had been exposed without any curtain (Table 2). Based on an indoor daylighting experiment conducted by Mousavi et al., (2018), the time interval of taking measurement was set every five minutes by using data logger. However, in this experiment, the time interval of taking the measurement was set at 15 minutes because it was impractical to set the time for every five minutes when using the lux meter. Mousavi et al. (2018) also set the simulation time interval at one hour because to simulate every five minutes is time-consuming. Some daylighting performance indicators were used in this study for the validation exercise of daylighting performance in Radiance DIVA-for-Rhino under the Malaysian tropical climate. WPI was employed to compare the measured illuminance values with the simulated ones at six internal positions. However, it is questionable to use CIE intermediate sky types, which are used in the radiance based software. The reason is that the value of outdoor illuminance in the tropical climate of Malaysia could be as big as 120000 lux, whereas simulated value was up to 20000 lux under the CIE sky (Lim *et al.*, 2017). Therefore, for the significance of this study, the illuminance value was derived from Ipoh Typical Meteorological Year (TMY) data value in the proposed simulated rooms under tropical sky. Table 3 shows the mean value difference between CIE intermediate sky and tropical sky under TMY in Diva for Rhino.

Table 2 Summary of the measurement in the case study room.

| Day | Date | Start Time | End Time | Time interval |
|---|---|---|---|---|
| 1st | 18 May 2018 | 9 am | 4 pm | 15 min(Measured), 1 hour (Simulated) |
| 2nd | 19 May 2018 | 9 am | 4 pm | 15 min(Measured), 1 hour (Simulated) |
| 3rd | 20 May 2018 | 9 am | 4 pm | 15 min(Measured), 1 hour (Simulated) |
| 4th | 21 May 2018 | 9 am | 4 pm | 15 min(Measured), 1 hour (Simulated) |
| 5th | 22 May 2018 | 9 am | 4 pm | 15 min(Measured), 1 hour (Simulated) |

Table 3 Mean value of the simulated and global illuminance data in Ipoh during four days of the field measurement.

| Time | Mean Outdoor Illuminance of CIE intermediate sky (lux) | Mean Outdoor Illuminance taken from Ipoh Typical Meteorological Year (TMY) |
|---|---|---|
| 9:00 AM | 19690 | 65873 |
| 10:00 AM | 21793 | 80810 |
| 11:00 AM | 20768 | 88827 |
| 12:00 PM | 19745 | 70835 |
| 1:00 PM | 20119 | 85299 |
| 2:00 PM | 21609 | 73354 |
| 3.00 PM | 21019 | 55515 |
| 4.00 PM | 16612 | 31784 |

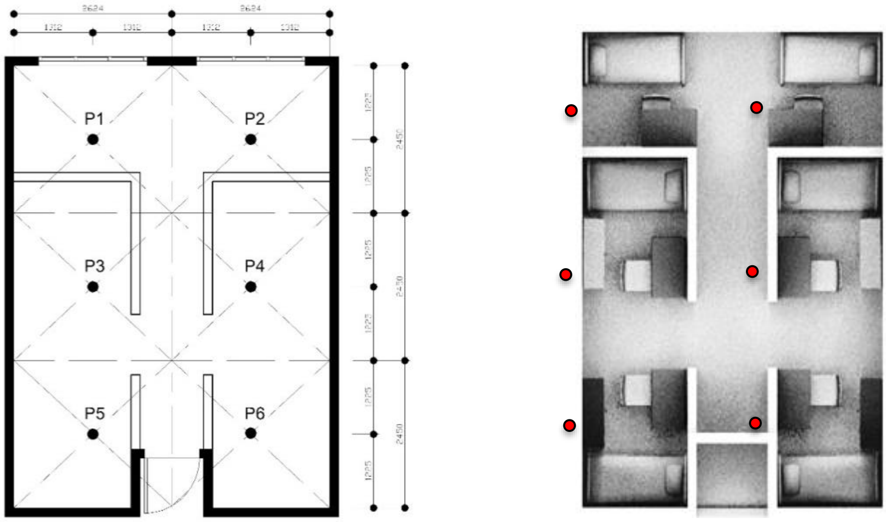



Figure 4 Location of a reference point in the case study room

## 2.4 Simulation of Internal Partition Layout

DIVA-for-Rhino simulation software was used in this study to evaluate daylight performance in the student residential room with internal partition. According to a survey, among 185 participants from 27 countries, nearly 50% chose Radiance-based software among more than 40 daylight softwares that were introduced (Galasiu; Reinhart, 2016). Radiance is known to provide a higher level of accuracy in predicting the levels of daylight illuminance compared with several other daylighting software packages. It is beneficial for determining whether or not there is sufficient light to accomplish different activities. Here, DIVA-for-Rhino software is used because of the progressive facilities and accessibility to a comprehensive collection of daylight and visual comfort analysis (Jakubiec; Reinhart, 2011). The typical configuration of case study room (Figure 2) with four typologies of internal partition layout (Figure 1) in the existing student residential building in Politeknik Ungku Omar, Ipoh, was modelled through Rhinoceros 5 software. The reflectance values of the materials are based on the previous study done by Moazzeni and Ghiabaklou (2016). However, due to the limitation in measuring the surface reflectance of the furniture, furniture layout is not taken into account in this study. Table 4 shows the specification of the case study room.

Table 4. Specification of case study room

| Materials Surface | Reflectance Value (%) |
|---|---|
| Wall | 70 |
| Ceiling | 90 |
| Floor | 20 |
| Glass | Double glazing, 80% light transmission |

(Source: Moazzeni & Ghiabaklou, 2016)

## 2.5 Simulation Procedure.

Climate Based Daylight Modelling (CBDM) for dynamic daylight metric in the DIVA-for-Rhino programme was simulated to demonstrate the indoor daylight performance for different internal partition conditions. In this experiment, the use of hourly time steps to describe the relevant climate variables as recorded by meteorological stations (Sultan Azlan Shah airport), allows for understanding the daylight distribution in a space under tropical sky and times of the year. For analysing daylight, the illuminance grids were placed 0.75m above the floor according to MS 2680:2017 for residential building. There were 228 sensors placed with 0.38 x 0.39 reference grid.

### 2.6 Simulation Output

In this experiment, Useful Daylight Illuminance (UDI) was used as a daylight metric. In MS 2680:2017 for residential building, the Useful Daylight Illuminance (UDI) is another approach which draws on a range of useful levels. It is defined as the annual occurrence of illuminances across the work plane where all the illuminances are within 100 lux to 2000 lux. It is a dynamic daylight performance. UDI aims to determine when the daylight levels are 'useful' for the occupants. According to Costanzo et al., (2018), climate based daylight modelling is potentially more accurate than the Daylight Factor (DF) assessment. It combines the quality of the light assessed during the year which is based on annual weather information and changing conditions, compared to the conventional Daylight Factor approach that only involves overcast sky condition and is assessed in a special time and fixed conditions. DIVA uses TMY weather data to calculate climate-based results (Moazzeni & Ghiabaklou, 2016). For this study, daylight illuminance in the range of 100-2000 Lux is considered as 'useful' for the occupants, while daylight that is greater than 2000 Lux will cause glare and thermal discomfort.

## 3 RESULTS AND DISCUSSION

### 3.1 Validation Test of the Case Study Room Under a Tropical Sky

In order to carry out successful computerised building simulations, accurate and reasonable input data for the buildings and climate are essential. Several studies suggested that simulated results must be compared with the fieldwork data and several input parameters affecting the simulation discrepancies should be tuned (Al-Tamimi & Fadzil, 2011).

An average of five days of data for six points from 9.00 am until 4.00 pm in a case study room was analysed and compared to the simulation data. The result shows that the average values between the measured and simulated data are quite similar, as demonstrated in Figure 5.

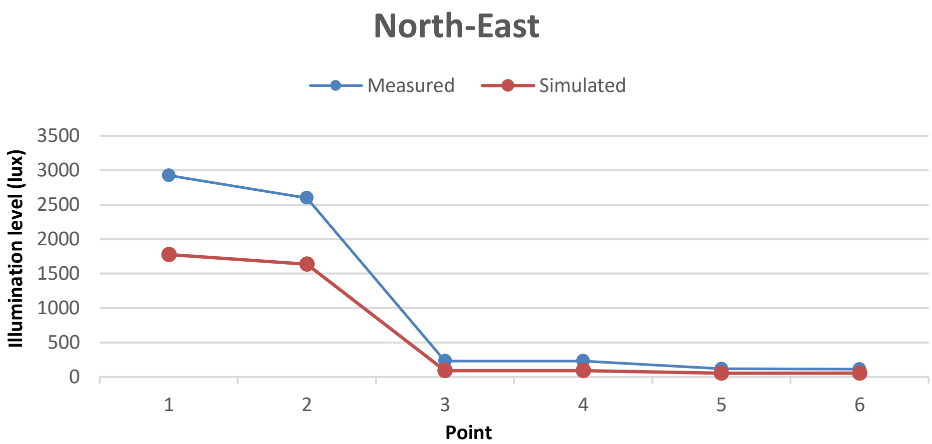



Figure 5 Mean simulated and measured results of the illumination level at 6 points in the case study room from 9.00 am until 4.00 pm for five-days measurement.

Statistical analysis was used to assess the value of the Pearson correlation for simulated and measured values in the case study room. The analysis revealed that the Pearson correlation coefficient with the value of 0.944 is very close to 1, which indicates that the field measurement data and the simulated data are normally distributed and there is a strong and linear association between them under the Malaysian tropical sky as shown in Table 5.

Table 5 Pearson correlation for simulated and measured values under Malaysian tropical sky

| Pearson Correlation | Sig. (2-tailed) | N |
|---|---|---|
| .944** | 0.000 | 6 |

**Correlation is significant at the 0.01 level (2-tailed)

### 3.2 Simulation Results and Discussion

The simulation software simulated and analysed daylight based on Radiance and Daysim. The discussion was only focusing on the comparison between the existing condition (EC) and the most effective partition for daylight penetration, which is Type C. Type A, B and D demonstrated the uneffective daylight penetration compared to type C, but better than the existing condition for all orientation. The overall data of UDI for all types of partition configuration are shown in Figure 6.

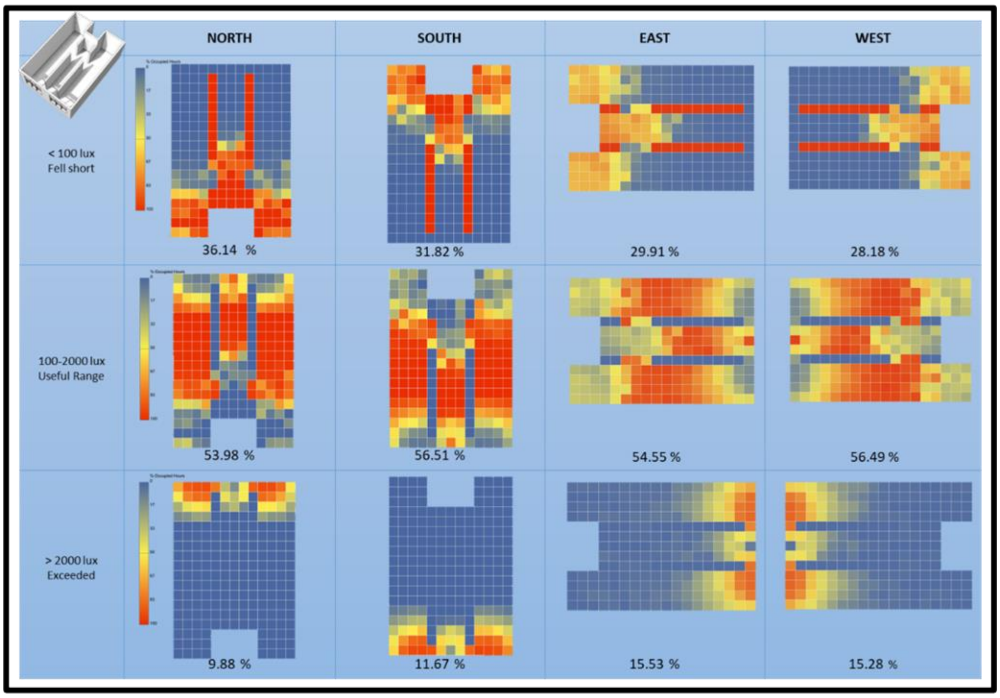



Figure 6 The overall data of UDI for all types of partition configuration

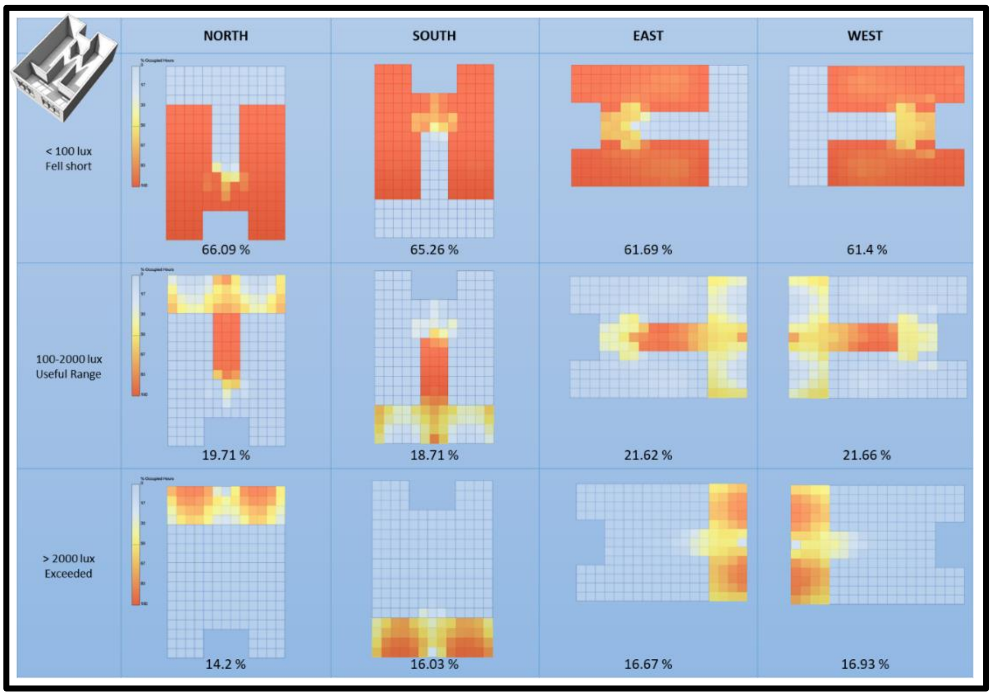



Figure 7 UDI pattern of Existing Condition (EC) internal partition.

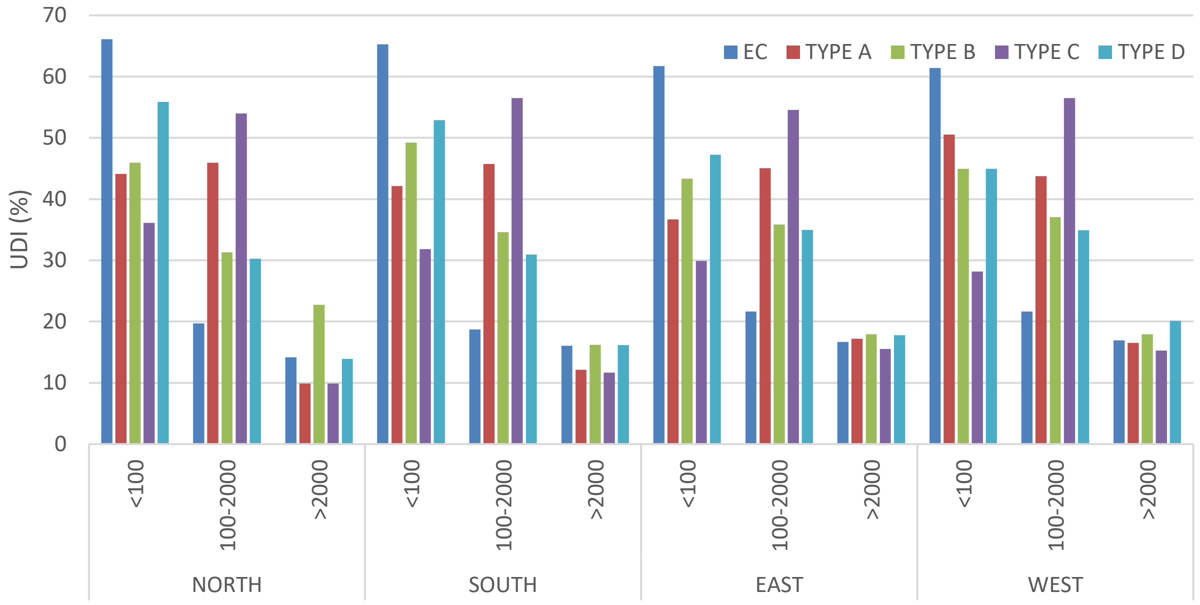



Figure 8 UDI pattern of Type C internal partition.

### 3.2.1 Northern Orientation

As shown in Figure 7, the UDI exceeded (>2000 lux) values were relatively low in Existing Condition (EC) and Type C partition at a location near the window. It shows that the North orientation side has a lower amount of glare compared to the other orientations. The internal partition Type C recorded the highest percentage of useful daylight (100-2000 lux) and the lowest UDI fell short (<100 lux) due to the positioning of internal partition perpendicular to the window that allows more daylight to enter the room. It is obvious that in the EC type, about 66% of the time during a year the daylighting level is below 100 lux. This is because, the parralel side of the internal partition which is located near the window blocks the daylight from penetrating inside the room. It will increase the dependence on artificial lighting and be very challenging to provide visual comfortable indoor environment. Therefore, the internal partition needs to be arranged from blocking the daylight and the partition height needs to be reduced to allow more daylighting.

### 3.2.2 Southern Orientation

In the southern orientation, UDI exceeded area is almost the same in EC and Type C partition. Type C recorded about 56.51% range of useful daylight (100-2000 lux) over the year, but as expected the existing condition type has the highest percentage of below useful range (<100 lux) for about 65.26%. This is because of the small amount of daylight penetrates inside the room due to the positioning of internal partition that parallels to the window. The experiment reveals that the existing condition internal partition will result insufficient daylight level in the southern orientation and require modification. Therefore, using the internal partition that parallels to the window is not preferable. The combination of parallel and perpendicular internal partition can be used if the parallel side is located at the back of the room as demonstrated in Type A (see Figure 6).

### 3.2.3 Eastern and Western Orientation

The UDI results in EC and Type C internal partition on the east and west facades recorded nearly the same amount of percentage as the sun movement is symmetrical. As shown in Figure 7 and 8, the area near the window experienced a higher level of glare compared to the north and south orientations. The results reveal that the internal partition Type C has a high percentage of UDI useful range in the east (54.5%) and west (56.5%) respectively. The worst condition of internal partition belongs to EC type with UDI fell short around 66% in both eastern and western orientation. At the east and west side, the amount of sunlight is quite high and can cause disturbing glare in the area near the window. However, by using a combination of window and light shelf that act as both light controller and shading might reduces overlit area and increases the daylight distribution.

## 4 CONCLUSION

This research was conducted to evaluate the impact of several internal partitions on indoor lighting performance in a student residential building room. The results reveal that the partition layout considerably has impacts on annual daylight performance. Based on the finding of the daylight performance analysis of five (5) types of internal partition layouts through simulation, the internal partition that is positioned perpendicular to the window (Type C) has the highest annual daylight sufficiency values, whereas the internal partition that is positioned parallel to the window has the worst annual daylight performance. It is also found that high partitions provide privacy and a sense of enclosure, but at the same time, they block more sunlight. Therefore, the author suggests the best layout is the internal partition in a perpendicular position to the window as it allows more daylight penetration inside the room as compared to the partition with the parallel position. In addition, reducing the partition height and installing light shelf might improve the daylight level inside the room. Further studies are required to improve the current design in terms of height and materiality, and the impact of furniture layout.

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