

# Occupants Interaction with Window Blinds in A Green-Certified Office Building in Putrajaya, Malaysia

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One of the key features of green office buildings is the proper utilization of daylight in order to ensure a good visual indoor environment which can potentially increase the occupant's productivity. However, poor daylight condition inside office buildings can occur due to improper positioning of window blinds by the occupants. Previous studies have shown that fully lowered window blinds and the use of the artificial lightings during daytime have caused many office buildings in Malaysia to have high rates of electricity consumption. Yet, the operation of window blinds is rarely considered during the calculation of building's daylight performance in the tropics. Therefore, this paper aims to investigate the frequency of window blind operations by office occupants and the driving factors behind their window blind operations. A GBI Gold-certified office building was selected for the study. The specific objectives of this paper are, 1) to find out the correlation between window blind operations with different orientations of the building, sky conditions, time and floor levels; and 2) to gauge the occupants' views on their window blind operations and also their satisfaction level with their visual working environment. This study used time-lapse photography to record the blinds positions and a questionnaire survey among the occupants. Results of the ANOVA and Pearson Correlation tests from the photographic analysis found a strong correlation between window blind occlusion values with the building orientations and floor levels, but not with time. The survey results revealed that most of the participants seldom adjusted their window blinds and, in most cases, excessive brightness or glare was the main issue. These results indicate that the occupants make a little effort in changing their blind positions, which may lead to a poor daylight condition. It is expected that the results of this study will serve as the initial steps in considering occupants' behaviour in window blinds usage during the calculation process of a building's daylight performance in order to ensure a better indoor visual environment.

**Keywords:** *Window Blind Operation, Occupants' Behaviour, Indoor Visual Environment, Green Office Building*

## 1. INTRODUCTION

According to the fifth assessment report of the Intergovernmental Panel on Climate Change, energy use in building sector was responsible for 8.8 GtCO<sub>2</sub>-eq emissions, which was 32% of the total global energy-related emissions (IPCC, 2014). In line with this realisation, a plethora of rating tools have been developed all over the world to assess the sustainability performance of buildings (Papargyropoulou, Padfield, Harrison, & Preece, 2012). In Malaysia, the first environmental rating tool called Green Building Index (GBI) was introduced in 2009 by the Malaysian Institute of Architects (PAM) and the Association of Consulting Engineers Malaysia

(ACEM) (Mun, 2009; Papargyropoulou et al., 2012). As of 31 March 2019, 484 buildings were certified as green buildings, 51% of which were non-residential buildings (Greenbuildingindex Sdn Bhd, 2019). The specific GBI rating tool for office buildings is called GBI Non-Residential New Construction (GBI NRNC) tool. GBI NRNC consists of 51 credits grouped under six assessment categories. A total of 100 points are available and distributed in these six categories (see Table 1). After going through the detailed assessment process, buildings are awarded Platinum, Gold, Silver or Certified rating depending on their achieved scores (Greenbuildingindex Sdn Bhd, 2018).

Table 1: Assessment categories of GBI NRNC tool

No.	Categories	Maximum points
1	Energy Efficiency	35
2	Indoor Environmental Quality	21
3	Sustainable Site Planning and Management	16
4	Material and Resources	11
5	Water Efficiency	10
6	Innovation	7
Total Score		100

For those GBI-certified buildings that scored high or maximum points for Indoor Environmental Quality (IEQ) category, there is a high probability that the buildings were designed to optimise daylighting while minimising the glare in order to create an ideal visual environment for the occupants and reduce the electricity consumption by cutting down the dependency on artificial lightings. The assessments of daylight and glare control in GBI are included under the main assessment category of IEQ, specifically under the credits EQ8 and EQ9 (for GBI NRNC) respectively. Under to daylight credit EQ8, points are awarded based on the percentage of coverage of the Net Lettable Area (NLA) that achieves the daylight factor (DF) of 1.0- 3.5%, measured at the working plane which is 800 mm from the floor level. Daylight factor is the ratio of indoor and outdoor available daylight at a reference point. Credit EQ9 requires glare from all direct sunlight to be eliminated and the horizontal workspace daylight luminance to be kept below 2,000 lux (Greenbuildingindex Sdn Bhd, 2018). Besides DF, other common indices used worldwide to measure daylight intensity and glare include useful daylight illuminance (UDI), daylight glare index (DGI), daylight glare probability (DGP) and visual comfort probability (VGP).

The utilization of daylight is an integral part of green building design, which comes along with the proper use of shading devices; size of the windows and glazing materials; as well as appropriate finishing and reflectance of interior spaces (Ander, 2003). As a tropical country, Malaysia receives a vast amount of daylight over the course of the year which can be utilized as an alternative to artificial lightings; thus, reducing the electricity consumption. A better visual environment can also increase the productivity level of the occupants (Dubois, 2001; Lim, Ahmad, & Ossen, 2013). However, the proper use of daylight in office buildings is still

problematic in Malaysia. Malaysian office buildings are often found with poor daylight condition either due to poor façade designs or occupants' behaviour of operating the window blinds. A study by Kandar et al. (2011) on five government office buildings found that all these buildings are fully dependent on artificial lightings even though there is sufficient daylight outside. Lim and Mohd Hamdan (2010) conducted a survey on thirteen existing high-rise office buildings and concluded that these buildings do not optimize daylight and most of their occupants keep their window blinds fully closed to avoid glare from the sun. They asserted that the behaviour of building occupants in operating their window blinds can play a vital role in the buildings' daylight performance. Another study on existing high rise office buildings in Malaysia conducted by Lim et al. (2013) found that many of these buildings are having poor daylight condition because of poor façade designs. Furthermore, occupants of these buildings do not bother to adjust their window blinds and most of the time, artificial lights are turned on during the daytime.

Typical Building Energy Intensity (BEI) in Malaysia is ranging between 200-250 kWh/m<sup>2</sup>/year (Iman, Mohd, Royapoor, Wang, & Roskilly, 2017; Saidur, 2009; Xin & Rao, 2013), which can be saved up to 30% with the proper use of internal shading devices (Hong, 2012). The properties of window blinds and their usage during daytime can greatly affect the penetration of daylight inside the buildings; however, they are not being included in the calculation of daylight performance such as the calculations of DF, UDI, DGI, DGP and VCP. Therefore, this paper aims to investigate the frequency of window blinds operation actions by office building occupants and the main factors affecting the blind positions, using a GBI-certified office building in Putrajaya, Malaysia as a case study.

## CLIMATE OF MALAYSIA

Malaysia lies between the geographical coordinates of 1° to 7° north and from longitude 100° to 119.5° east (Aziah & Ariffin, 2004). This tropical country consists of two main lands: the peninsular Malaysia in the west and Sabah and Sarawak in the East. Being in the tropical region, the climate is hot and humid throughout the year. An average temperature of 23°C to 33°C can be experienced throughout the year as shown in Figure 1 (Weatherspark, 2018). The country receives around 400-600 MJ/m<sup>2</sup> of solar radiation every month (Figure 2) (Mekhilef et al., 2012).

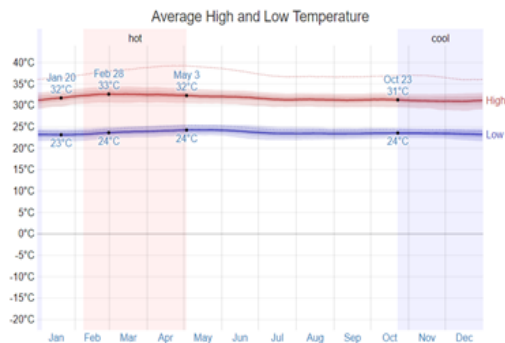


Fig. 1: Average temperature of Malaysia  
Source: (Weatherspark, 2018)

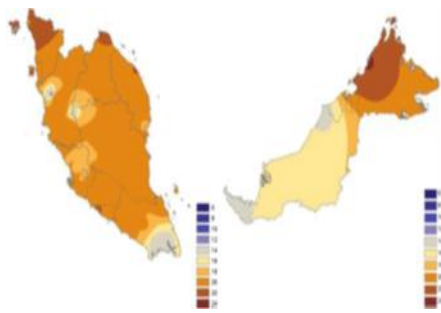


Fig. 2: Monthly solar radiation received by Malaysia  
Source: (Mekhilef et al., 2012)

An overcast sky can be seen most of the time during the Northeast monsoon which occurs during November to March and it is very difficult to have a completely clear sky during the drought season (Mirrahimi et al., 2016). The sky has an average cloud coverage of 6-7 Oktas, where the sky remains intermediate 85.6% of the time and the rest 14% of the time it is overcast (Ahmed, 2000; Zain-Ahmed, Sopian, Abidin, & Othman, 2002)

The sun altitude does not change dramatically throughout the year because of the geographical positioning of Malaysia. The months of November till January experience the lowest altitude angle of 65° to 60° in the South

orientation and 68° to 71° of sun altitude angle in the North orientation during the month of June (Fadzil & Sia, 2003). The North facing windows receive direct radiation from the sun from 22<sup>nd</sup> September till 20<sup>th</sup> March and direct solar radiation is received by the South facing windows for the rest of the months. The sun comes over the equator during the month of March and September and goes to the furthest distance from the equator during the months of December and June (Ahmed, 2000; Djamila, Ming, & Kumaresan, 2011). As a result, the windows facing northeast, northwest, southeast and southwest receive direct solar radiation from the sun during the month of March and September. Windows oriented to the East and West gain most of the solar radiation during the month of June and December.

## PREVIOUS STUDIES ON DAYLIGHT CONDITION IN OFFICE BUILDINGS

A great deal of research has been conducted on occupants' behaviour towards window blind operations in Europe, the USA, Canada and the Republic of Korea (Correia da Silva, Leal, & Andersen, 2013; Day, Theodorson, & Van Den Wymelenberg, 2012; Escuyer & Fontoynt, 2001; Foster & Oreszczyn, 2001; H B Gunay, O'Brien, Beausoleil-Morrison, & Huchuk, 2014; Inkarojrit, 2005; Rea, 1984; Reinhart & Voss, 2003; Rubin, Collins, & Tibbott, 1978; Sanati & Utzinger, 2013; Sutter, Dumortier, & Fontoynt, 2006; Zhang & Barrett, 2012). The first study on the blind operation was conducted by Rubin et al. (1978) and it was found that the occupants of the study preferred to keep their window blinds at certain positions and blind occlusion was higher in the South orientation than the North orientation. This study was then extended further by Rea (1984) and the findings indicated that the occlusion values of the window blinds significantly differed for different orientations and sky conditions. Also, the occlusion values were higher when the sky was clear than on a cloudy day. According to a study by Inoue et al. (1988), window blind operation was correlated with the time of the day and the East facing window blinds had higher occlusion values during the morning period, whereas those facing West had higher values during the afternoon period. Foster and Oreszczyn (2001) concluded that the actual energy consumption in their study buildings were higher than the initially predicted energy consumption during the design stage due to the problems of over glazing and high rate of occluded window blinds. Another study by Escuyer and Fontoynt (2001) revealed that occupants mainly changed their window blinds

because of the reflections on their computer screens. They further argued that the ideal lighting system should change with the daylight intensity and should come with manual control systems for the occupants. Inkarojrit (2005) further added that glare from the sun and computer screen were the main two reasons behind the occupants' blind operation and the values of blind occlusion were highly dependent on sky conditions. Zhang and Barrett, (2012) studied the factors influencing the blind operation and found that, most of the window blinds were opened on the North orientation and solar altitude had a strong correlation with the blind occlusion value. Sanati and Utzinger, (2013) came to the result that, easily accessible window blinds for the occupants can play an important role in saving electricity consumption.

However, these issues remain unclear in the context of equatorial regions with hot-humid climatic condition. Furthermore, none of these studies established any correlation between window blind occlusion and floor levels. As quoted by Lim et al. (2013), "lots of efforts are needed to further develop the knowledge of tropical daylighting and future research can be done on the impact of human behaviour on tropical daylighting." Therefore, this paper fills this gap by presenting results of window blind usage by the occupants of a case study building in Putrajaya. The specific objectives of this paper are, 1) to find out the correlation between window blind operations with different orientations of the building, sky conditions, time and floor levels and 2) to gauge the occupants' views on their window blind operations and their satisfaction level with their visual working environment.

## 2. METHODS

The study used time-lapse photography and questionnaire survey methods to collect data from a case study building, as explained below.

### 2.1 ABOUT THE STUDY BUILDING

Menara Putrajaya Holdings (PjH) was selected as a case study building for this study. Completed on 30 June 2012, PjH is a GBI Gold-certified office building. PjH is located in the main commercial boulevard at Precinct 2, Putrajaya, Malaysia. With a total gross floor area of 575,721 square feet, the building consists of 3 low-rise office 'fingers' linked by 12-storey tower block (see Figure 3).

The facades are generally made of aluminium spandrel panels with high performance glass. All 'fingers' are basically facing north-south to avoid heat gain and glare. Although the tower is facing east-west, a unique shading system was employed. The external shading systems used for the low-rise 'fingers' and the tower block are summarized in Table 2 and shown in Figure 4.

Internally, white coloured manually-controlled roller blinds are used for the windows. Semi-opaque blinds are used to facilitate outside viewing while blocking excessive daylight (Figure 5). This building is equipped with dimmable artificial lighting technology, which is centrally controlled by the Building Management System (BMS).

Table 2: Summary of external shading system used in Menara PjH

	N-S (low-rise)	E-W (low-rise)	N-S (tower)		E-W (tower)
Aluminium spandrel panels	✓	✓			
Aluminium louvers	✓				
Aluminium fins	✓				
Aluminium spandrel curtain walls			✓		
Aluminium framed fritted glass fins					✓

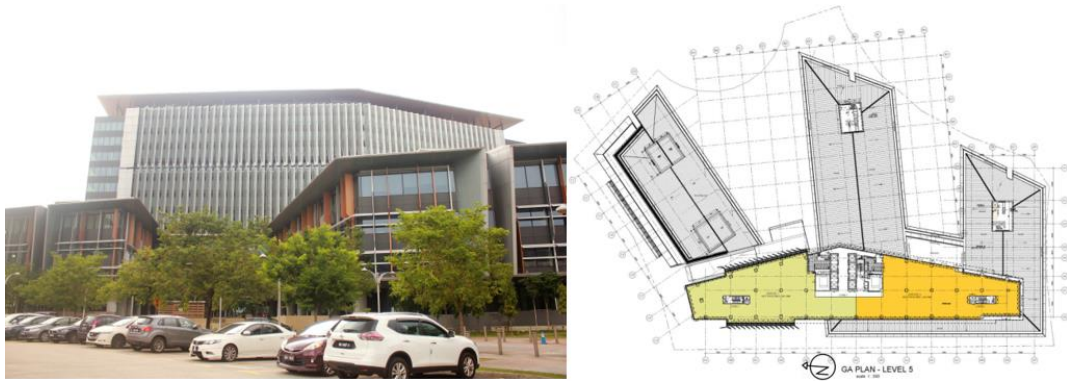


Fig. 3: Eastern view and floor plan of Menara PjH  
Source: Author



Fig. 4: Aluminium spandrel panels with horizontal aluminium louvers on N-S facades of low-rise (left), aluminium spandrel panels on E-W facades of low-rise (middle) and aluminium framed fritted glass fins on E-W facades of tower block (right)  
Source: Author

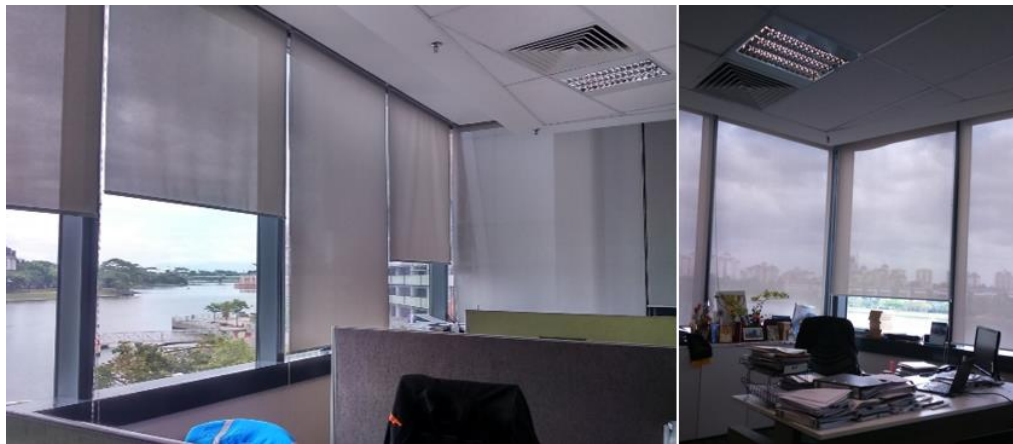


Fig. 5: Semi-opaque, manually-controlled window blinds of Menara PjH  
Source: Author

## 2.2 TIME- LAPSE PHOTOGRAPHY

This study used time-lapse photography in order to record the positions of the blinds from inside the building. It is a well-established method around to the world in the field of blind operation study (Correia da Silva et al., 2013; Day et al., 2012; Burak Gunay, O'Brien, & Beausoleil-

Morrison, 2013; Inkarojrit, 2005; Inoue et al., 1988; Lindsay & Littlefair, 1992; Mahdavi, 2009; Rea, 1984; Rubin et al., 1978; Sanati & Utzinger, 2013; Sutter et al., 2006; Zhang & Barrett, 2012). The field measurements were conducted in two different sessions: 1) from 15<sup>th</sup> of March till 31<sup>st</sup> of March 2017; and 2) from 21<sup>st</sup> until 28<sup>th</sup> of July 2017. The month of March was



selected for the first session of field measurement because Malaysia typically receives extreme solar radiation during this month (Zain, 2000). In the initial plan for conducting the second session of the field measurements, the month of June was chosen to cover the summer solstice days (Department of Standard Malaysia, 2014). However, the session had to be shifted to July 2017 due to long public holidays in Malaysia during the month of June. In order to analyse the blind occlusion, this study considered four different factors: time of the day, building orientations, floor levels and sky conditions. Photographs of the window blinds facing all four orientations were taken from inside the building on each working day at 9 am, 12 pm and 4:30 pm. A camera was set at 5 feet height from the floor level and placed at an appropriate distance from the windows to ensure that the captured images were the elevation views rather than the perspective views of the window blinds. The final set up of the camera was determined at the site after capturing some trial blind images before the final field measurement. At each time, a total number of 248 window blind positions were recorded for levels 1, 4 and 11. These three floor levels were selected to cover the lower, intermediate and upper floors of the building. After finishing two sessions of field measurements, there were

14,136 recorded images of the blinds. An overview of the field measurements is presented in Table 3. The outside sky condition was also captured with the camera in order to correlate them with window blind operation.

All recorded images were carefully resized and rated to obtain the “blind occlusion index.” As stated by Foster and Oreszczyn (2001), blind occlusion index is the percentage of an occluded blind. For example, 70% of blind occlusion index means the blind is 70% lowered at a specific time. After post-processing of the recorded images, each window blind was assigned with a number ranging from 0 to 10 (0 = fully opened and 10 = fully closed) and coded with a name which represents their number, orientation and floor level (Figure 6). The sky condition was categorized into three different types, namely sunny, partly cloudy and overcast. Then, ANOVA and Pearson Correlation tests were performed on the complete data sets of “average blind occlusion index” considering the four factors (i.e. time of the day, building orientations, floor levels and sky conditions) for both sessions of the field measurements. These tests aimed to find out the correlation of the window blind positioning with the above-mentioned factors.

Table 3: Overview of the field measurements (time-lapse photography)

Date	Floor levels	Orientation				No. of window blinds
		North	-	East	West	
15 <sup>th</sup> - 31 <sup>st</sup> March 2017	Level 1	North	-	East	West	30 nos
	Level 4	North	South	East	West	110 nos
	Level 11	North	South	East	West	108 nos
21 <sup>st</sup> - 28 <sup>th</sup> July 2017	Level 1	North	-	East	West	30 nos
	Level 4	North	South	East	West	110 nos
	Level 11	North	South	East	West	108 nos



Fig. 6: Coding of window blind position for occlusion index

Source: Author

### 2.3 QUESTIONNAIRE SURVEY

A questionnaire survey was conducted among the building occupants during the second session of field measurements. The questionnaire form had 27 questions in total which were divided into three main sections – Part A, Part B and Part C. Part A contained the questions about personal information of the participants. Questions related to window blind operations were included in Part B, whilst Part C was dedicated for questions about the visual satisfaction levels of the participants. The survey participants were requested to answer the questions based on their behaviour throughout their working period in the building so that the information of their average behaviour could be obtained. The survey also helped to understand the participants' satisfaction levels with their working environment throughout the years. The targeted

group of participants for the questionnaire survey were the occupants working on level 1, level 4 and level 11, where time-lapse photography was conducted. A total of 180 hard copies of questionnaire forms were distributed among all the occupants working on these three floor levels and 107 were returned, representing 59.4% response rate. The remaining 40.6% of the occupants did not respond to the survey. A total number of 57 males and 50 female employees (53.3% and 46.7% respectively) participated in the survey, majority of whom aged between 30 and 39 years (36.4%). Most of the participants (81.3%) had windows next to their workstation whereas the remaining 18.7% did not have any window. Around 21% of them worked near south facing windows (Figure 7), whilst 31.8% of them worked with windows on their back (Figure 8).

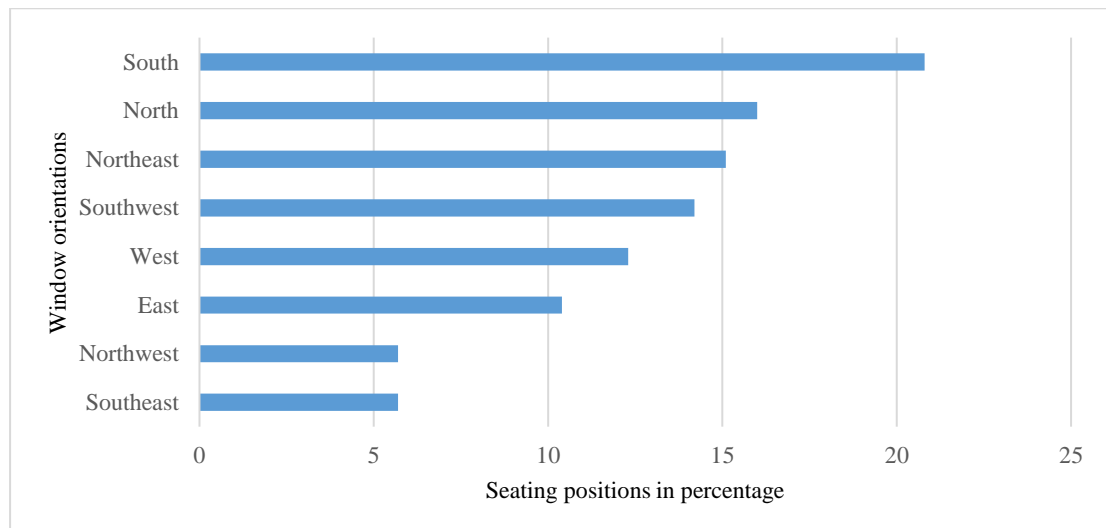


Fig. 7: Percentage distribution of window and occupants' seating positions

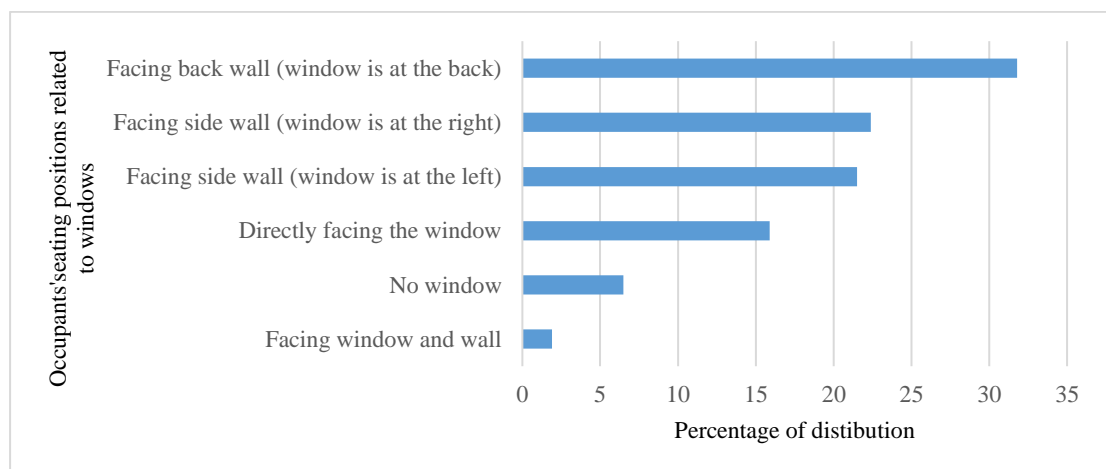


Fig. 8: Percentage distribution of occupants' seating positions in relation to windows

### 3. RESULTS

#### 3.1 WINDOW BLIND POSITIONS

Table 4 shows the results of the ANOVA test on the data set of “average blind occlusion index” from the first session of field measurements

(March). Results revealed that the change of window blind occlusion index was statistically significant with the building orientations, floor levels and sky conditions ( $p < 0.05$ ). The interaction between orientations and floor levels also had a high value for average blind occlusion index ( $F= 262.33$ ).

Table 4: ANOVA test on the data set of “average blind occlusion index” from the first session of field measurement (N= 429)

Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	87	1.053	40.272	.000	.911
Intercept	1	22995.498	879095.710	.000	1.000
Time	2	.065	2.498	.084	.014
Orientation	3	4.259	162.810	.000*	.589
Floor level	2	10.587	404.712	.000*	.704
Sky condition	2	.279	10.659	.000*	.059
Time X Orientation	6	.006	.244	.961	.004
Time X Floor level	4	.000	.007	1.000	.000
Time X Sky condition	3	.035	1.347	.259	.012
Orientation X Floor level	5	6.862	262.329	.000*	.794
Orientation X Sky condition	6	.017	.649	.691	.011
Floor level X Sky condition	4	.029	1.109	.352	.013

\*The mean was significantly different at the level of less than 0.05

Table 5 shows the Pearson Correlation test for the “average blind occlusion index” from the first session. Results indicated that the building orientations and floor levels were statistically correlated with average blind occlusion index,

which means that the positioning of the blinds varied at different orientations and floor levels. However, window blind occlusion index was not correlated with time and the sky condition.

Table 5: Pearson Correlation test on data set of “average blind occlusion index” from the first session of field measurement (N= 429)

		Time	Orientation	Floor level	Sky condition
Average blind occlusion index	Pearson Correlation	.018	-.207**	-.157**	-.032
	Sig. (2-tailed)	.709	.000	.001	.509
	N	429	429	429	429

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

The ANOVA test on the data set of “average blind occlusion index” from the second session of field measurements (July), revealed that the change of window blind occlusion value was statistically significant in relation to the building orientations and floor levels ( $p < 0.05$ ) only. There was no significant relationship between

blind occlusion index and the sky conditions this time. The interaction between orientations and floor levels are significant for average blind occlusion index ( $F= 334.68$ ). But interestingly, the Pearson Correlation test revealed that there was only one significant correlation which was between the window blind occlusions and the



building orientations. Floor levels, sky conditions and time of the day did not obtain the significant values. Tables 6 and 7 show the

results of ANOVA test and Pearson Correlation test respectively.

Table 6: ANOVA test on the data set of “average blind occlusion index” from the second session of field measurement (N= 198)

Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	87	.508	33.145	.000	.963
Intercept	1	13371.266	872399.357	.000	1.000
Time	2	.004	.233	.793	.004
Orientation	3	2.252	146.961	.000*	.800
Floor level	2	3.581	233.661	.000*	.809
Sky condition	2	.007	.427	.653	.008
Time X Orientation	6	.006	.405	.875	.022
Time X Floor level	4	.005	.334	.854	.012
Time X Sky condition	3	.003	.197	.898	.005
Orientation X Floor level	5	5.130	334.672	.000*	.938
Orientation X Sky condition	6	.019	1.209	.307	.062
Floor level X Sky condition	4	.009	.596	.666	.021

\*The mean was significantly different at the level of less than 0.05

Table 7: Pearson Correlation test on data set of “average blind occlusion index” from the second session of field measurement (N= 198)

		Time	Orientation	Floor level	Sky condition
Average blind occlusion index	Pearson Correlation	.013	-.346**	-.029	-.009
	Sig. (2-tailed)	.852	.000	.681	.898
	N	198	198	198	198

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

The ANOVA and Pearson Correlation tests on the combined data set from both sessions of field measurements also found a significant correlation between window blind occlusion values with the building orientations and floor levels, which is also an indication that the blind operations were largely influenced by these two factors.

### 3.2 QUESTIONNAIRE SURVEY

The questionnaire survey found that during the period of survey, majority of the participants rarely adjusted their window blinds (81.1%),

whereas 11.1% of them said they operated their window blinds at least once in a day, and 7.8% occasionally operated their window blinds (Figure 9). This result indicates that the occupants’ seating positions did not influence their blind operations. When asked about the preferred position of the window blinds, 38.9% of the participants said they preferred the blind positions to be at 50% closed. Around 36% enjoyed to keep their blinds at 25% open position and 10% kept their window blinds fully closed. Around 12% liked to have almost fully-opened blinds and only 3.3% fully opened their window blinds (Figure 10).

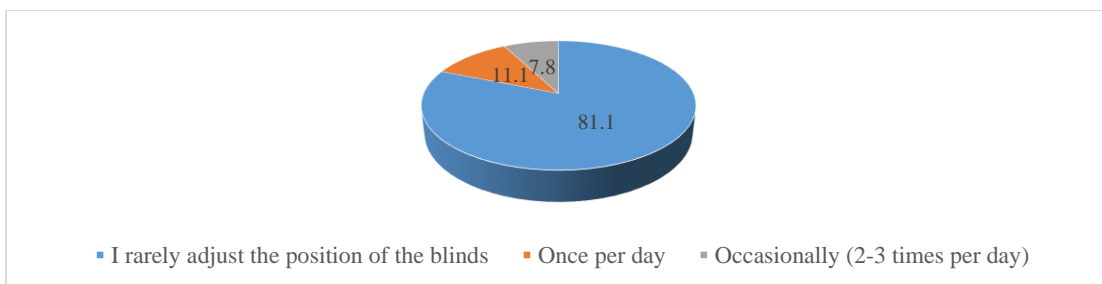


Fig. 9: Percentage distribution of blind adjustment by the occupants (N=107)

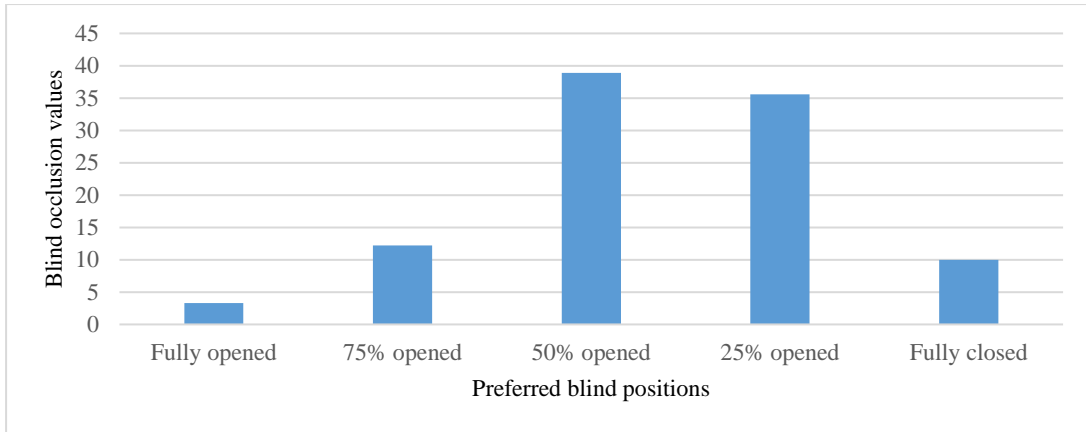


Fig. 10: Percentage distribution of preferred blind position (N=90)

Table 8 shows the main reasons behind their blind operations. It shows that the top five reasons cited by the respondents were “excessive daylight or glare”, “to have the outside view”, “to increase daylight level”, “to reduce heat gain”, and “to feel the warmth of the sun”, which represent 28.8%, 22.1%, 19.7%, 10.6% and 6.7% respectively. When asked about their

satisfaction level with the amount of daylight, majority (37.4%) were found satisfied, around 27% were slightly satisfied, whereas 23.4% rated moderate, as shown in Figure 11. Figure 12 shows that the top mostly cited negative aspects were “computer screen glare”, “too much electric lightings”, and “the indoor environment is too bright”, representing 25.4%, 21% and 20.3% respectively.

Table 8: Frequent distribution of the participants’ reasons behind the blind adjustment

Reason for blind adjustment		
	N	Percent
To reduce glare or brightness from daylight	60	28.80%
To have an outside view	46	22.10%
To increase daylight level	41	19.70%
To reduce heat from the sun	22	10.60%
To feel the warmth of the sun	14	6.70%
To increase visual privacy	8	3.80%
To increase room spaciousness	7	3.40%
To reduce visual stimulus	6	2.90%
Other	4	1.90%

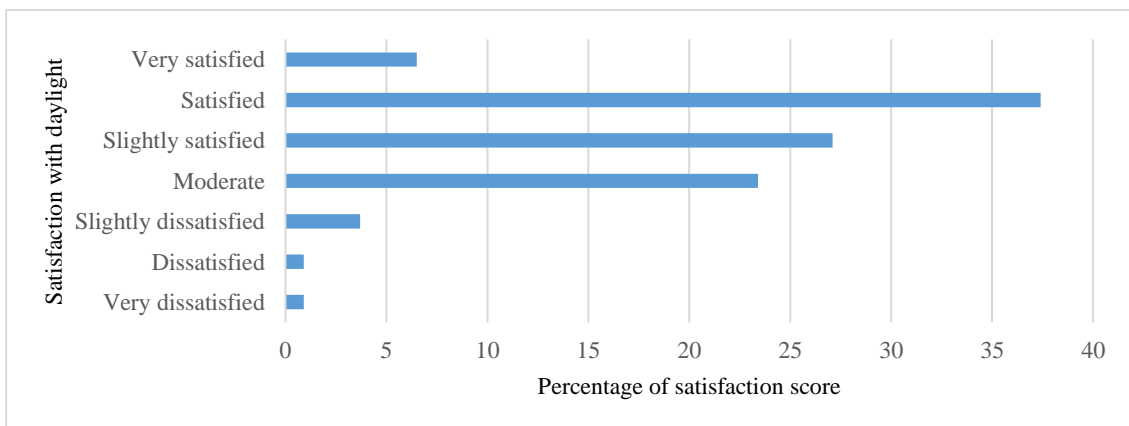


Fig. 11: Percentage distribution of participants’ satisfaction level with daylight (N=107)

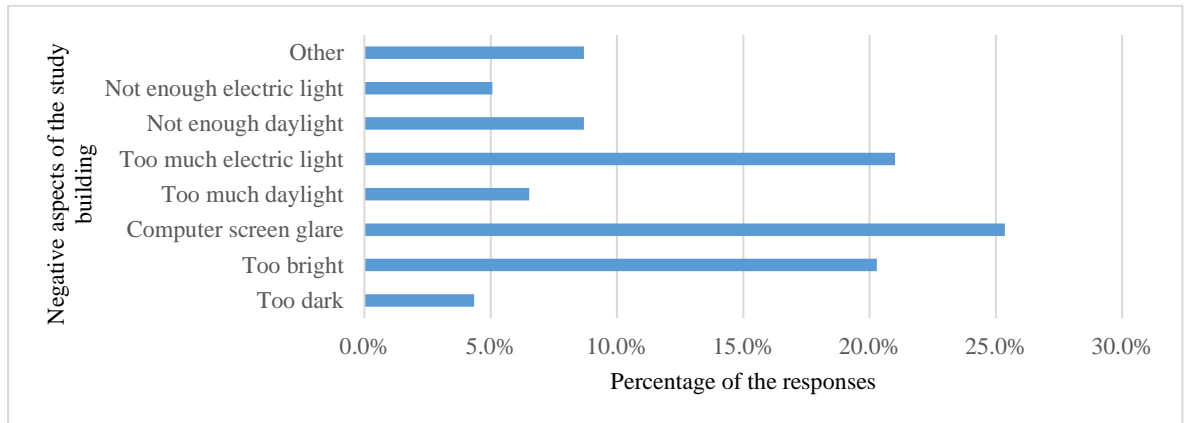


Fig. 12: Percentage distribution of participants' responses on the negative aspects of the building's visual environment (N=138)

#### 4. DISCUSSION

One of the objectives of this study was to find out the correlation between window blind operations with different orientations of the building, sky conditions, time and floor levels. It was found that a high correlation exists between window blind occlusion values and the building orientations. The results also demonstrated that the window blind occlusion values also depended on the floor levels and sometimes on the sky conditions, but not on the time of the day. Specifically, ANOVA test conducted on data set of "average blind occlusion index" from the first session in March showed a significant correlation between window blind operations and the building orientations, floor levels and sky condition. Similar results were observed for data set of "average blind occlusion index" from the second session in July with the exception of sky condition, which turned out to be a non-correlated factor. These were reinforced by result from Pearson Correlation test on data sets from both sessions: window blind occlusion index was highly correlated with the building orientations.

This result is echoed by previous studies done by Rea (1984) and Zhang and Barrett (2012). Interestingly, the Pearson Correlation test on both sessions revealed that window blind occlusion was not correlated with different sky conditions, which is denying the result obtained by Rea (1984) conducted in Ottawa, Canada. These contradicting results can be explained by the fact that tropical sky has different characteristics. Although floor levels had a significant correlation value during the month of March, there was no significant correlation between blind occlusion and floor levels during the second session in July. Neither was there a

significant correlation between blind occlusion and time for both sessions of field measurements. This indicates that the blind positions are rarely changed by the occupants. This seems to be inconsistent with Inoue (1988) who claimed that window blind operation was highly correlated with the time of the day. However, this study's result supports earlier result from Lim et al.'s (2013) study in the Malaysian context. They concluded that the occupants of their studied office buildings in Malaysia do not adjust their window blinds frequently. Excessive daylight or glare was found to be the main reason behind their blind operation, and this finding was previously proven by Inkarojrit (2005).

The survey also revealed that most of the occupants preferred to keep their blinds at half-closed or almost fully-closed positions although most of them were satisfied with the amount of daylight. Since this result is consistent with a similar finding by Lim and Mohd Hamdan (2010), it shows that the phenomenon in Malaysia has not changed since 8 years ago. Also, many of the participants claimed that they experienced computer screen glare and too much electric lightings, which supports the evidence by Escuyer and Fontoynt (2001) and Inkarojrit (2005). This result is predictable because the artificial lightings were turned on during daytime. The studied building is installed with daylight sensors to automatically turn off the artificial lights if sufficient amount of daylight comes inside the building. However, almost all of the lights remained on as the sensors could not capture the actual intensity of the daylight due to the lowered window blinds.

## 5. CONCLUSION

This paper has presented the occupants' behaviour towards the use of window blinds in a green office building in Malaysia. Office buildings in Malaysia are consuming a high rate of electricity due to poor daylight condition inside the buildings and improper blind usage among the occupants. A responsible behaviour of the occupants plays a vital role when a green building is occupied. It has well been proven that an office building with ideal visual environment has the potential to increase the productivity of the occupants. This study reveals that the occlusion level and frequency of adjustment of window blinds can affect the daylight condition and energy consumption of a building. Hence, it is high time for the designers, researcher and the authorities to take necessary steps to create awareness among the building occupants on the proper use of window blinds and daylight. Since window blind operation is rarely considered during the initial calculation of daylight performance of office buildings, it is sensible to suggest for an initial step to be taken to address the issue in the tropical context. Specifically, it is deemed necessary to conduct further studies on how to incorporate the calculation of average blind occlusion index in the GBI's assessment of daylight performance and discomfort glare. But beforehand, it is recommended for more similar studies involving more green buildings to be carried out in order to have a deeper and clearer understanding of occupants' behaviour in the tropics.

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## 6. REFERENCES

- Ahmed, A. Z. (2000). *Daylighting and shading for thermal comfort in Malaysian buildings*. University of Hertfordshire. Retrieved from <https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.323648>
- Ander, G. D. (2003). *Daylight performance and design*. New Jersey: John Wiley & Sons.
- Aziah, N., & Ariffin, M. (2004). The effect of orientation on energy efficiency potential for terraced housing in Malaysia, (November), 10–12.
- Correia da Silva, P., Leal, V., & Andersen, M. (2013). Occupants interaction with electric lighting and shading systems in real single-occupied offices: Results from a monitoring campaign. *Building and Environment*, 64, 152–168. <https://doi.org/10.1016/j.buildenv.2013.03.015>
- Day, J., Theodorson, J., & Van Den Wymelenberg, K. (2012). Understanding controls, behaviors and satisfaction in the daylight perimeter office: A daylight design case study. *Journal of Interior Design*, 37(1), 17–34. <https://doi.org/10.1111/j.1939-1668.2011.01068.x>
- Department of Standard Malaysia. (2014). MS 1525:2014 Energy Efficiency and Use of Renewable Energy for Non Residential Buildings Code of Practice. *Kuala Lumpur: SIRIM Berhad*.
- Djamila, H., Ming, C. C., & Kumaresan, S. (2011). Estimation of exterior vertical daylight for the humid tropic of Kota Kinabalu city in East Malaysia. *Renewable Energy*, 36(1), 9–15.
- Dubois, M. (2001). Impact of Solar Shading Devices on Daylight Quality. *Lund, Lund University*, 1–106. Retrieved from <http://www.grap.arc.ulaval.ca/attaches/Dubois/BOK-3061.PDF>
- Escuyer, S., & Fontoyont, M. (2001). Lighting controls: a field study of office workers' reactions. *Lighting Research and Technology*, 33(2), 77–94.
- Fadzil, S. F. S., & Sia, S. J. (2003). Recommendations for horizontal shading depths for vertical building facades in the tropic region with particular reference to Penang, Malaysia. *Architectural Science Review*, 46(4), 375–381.
- Foster, M., & Oreszczyn, T. (2001). Occupant control of passive systems: the use of Venetian blinds. *Building and Environment*, 36(2), 149–155.
- Greenbuildingindex Sdn Bhd. (2018). Retrieved June 29, 2018, from <http://new.greenbuildingindex.org/organisation/summary>
- Greenbuildingindex Sdn Bhd. (2019). Retrieved April 16, 2019, from <http://new.greenbuildingindex.org/organisation/summary>
- Gunay, H. B., O'Brien, W., & Beausoleil-Morrison, I. (2013). A critical review of observation studies, modeling, and simulation of adaptive occupant behaviors

- in offices. *Building and Environment*, 70, 31–47.  
<https://doi.org/10.1016/j.buildenv.2013.07.020>
- Gunay, H. B., O'Brien, W., Beausoleil-Morrison, I., & Huchuk, B. (2014). On adaptive occupant-learning window blind and lighting controls. *Building Research and Information*, 42(6), 739–756.  
<https://doi.org/10.1080/09613218.2014.895248>
- Hong, T. (2012). Occupant Behavior: impact on energy use of private offices. *ASim 2012 - 1st Asia Conference of International Building Performance Simulation Association*, (January). Retrieved from <https://escholarship.org/uc/item/6jp5w8kn#page-11>
- Iman, W., Mohd, W., Royapoor, M., Wang, Y., & Roskilly, A. P. (2017). Office building cooling load reduction using thermal analysis method – A case study. *Applied Energy*.  
<https://doi.org/10.1016/j.apenergy.2015.12.053>
- Inkarojrit, V. (2005). *Balancing comfort: Occupants' control of window blinds in private offices*. Chemistry & University of California, Berkeley.  
<https://doi.org/10.1017/CBO9781107415324.004>
- Inoue, T., Kawase, T., Ibamoto, T., Takakusa, S., & Matsuo, Y. (1988). The development of an optimal control system for window shading devices based on investigations in office buildings. *ASHRAE Transactions*, 94, 1034–1049.  
<https://doi.org/10.1007/s13398-014-0173-7.2>
- IPCC, W. I. (2014). Climate Change 2013 - The Physical Science Basis. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1–33.  
<https://doi.org/10.1017/CBO9781107415324>
- Kandar, M. Z., Sulaiman, M. S., Rashid, Y. R., Ossen, D. R., & Aminatuzuhariah, M. (2011). Investigating Daylight Quality in Malaysian Government Office Buildings Through Daylight Factor and Surface Luminance. *International Journal of Civil, Architectural, Structural and Construction Engineering*, 5(11), 52–57.
- Lim, Y.-W., Ahmad, M. H., & Ossen, D. R. (2013). Internal shading for efficient tropical daylighting in Malaysian contemporary high-rise open plan office. *Indoor and Built Environment*, 22(6), 932–951.
- Lim, Y. W., & Mohd Hamdan, A. (2010). Daylight and users' response in high rise open plan office: a case study of Malaysia. In *3rd International Graduate Conference on Engineering, Science, and Humanities, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia* (pp. 1–10).
- Lindsay, C., & Littlefair, P. J. (1992). Occupant use of venetian blinds in offices. *Building Research Establishment*. Retrieved from <http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Occupant+use+of+venetian+blinds+in+offices#0>
- Mahdavi, A. (2009). Patterns and Implications of User Control Actions in Buildings. *Indoor and Built Environment*, 18, 440–446.  
<https://doi.org/10.1177/1420326X09344277>
- Mekhilef, S., Safari, A., Mustaffa, W. E. S., Saidur, R., Omar, R., & Younis, M. A. A. (2012). Solar energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, 16(1), 386–396.  
<https://doi.org/10.1016/j.rser.2011.08.003>
- Mirrahimi, S., Mohamed, M. F., Haw, L. C., Ibrahim, N. L. N., Yusoff, W. F. M., & Aflaki, A. (2016). The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot-humid climate. *Renewable and Sustainable Energy Reviews*, 53, 1508–1519.  
<https://doi.org/10.1016/j.rser.2015.09.055>
- Mun, T. L. (2009). The Development of GBI Malaysia ( GBI ). *Pam/Acem*, (April 2008), 1–8. Retrieved from <http://new.greenbuildingindex.org/Files/Resources/GBI Documents/20090423 - The Development of GBI Malaysia.pdf>
- Papargyropoulou, E., Padfield, R., Harrison, O., & Preece, C. (2012). The rise of sustainability services for the built environment in Malaysia. *Sustainable Cities and Society*, 5(1), 44–51.  
<https://doi.org/10.1016/j.scs.2012.05.008>
- Rea, M. . (1984). Window blind occlusion : a pilot study. *Journal of Computing in Civil Engineering*, 15(1), 35–43.  
[https://doi.org/10.1061/\(ASCE\)0887-3801\(2001\)15:1\(35\)](https://doi.org/10.1061/(ASCE)0887-3801(2001)15:1(35))
- Reinhart, C. F., & Voss, K. (2003). Monitoring manual control of electric lighting and blinds. *Lighting Research and Technology*, 35(3), 243–258.  
<https://doi.org/10.1191/1365782803li0640a>
- Rubin, A. I., Collins, B. L., & Tibbott, R. L. (1978). Window blinds as a potential energy saver-a case study. *NBS Building Science*

- Series*, 112, 89. Retrieved from <https://www.ncjrs.gov/pdffiles1/Digitization/64368NCJRS.pdf>
- Saidur, R. (2009). Energy consumption, energy savings, and emission analysis in Malaysian office buildings. *Energy Policy*, 37(10), 4104–4113.  
<https://doi.org/10.1016/j.enpol.2009.04.052>
- Sanati, L., & Utzinger, M. (2013). The effect of window shading design on occupant use of blinds and electric lighting. *Building and Environment*, 64, 67–76.  
<https://doi.org/10.1016/j.buildenv.2013.02.013>
- Sutter, Y., Dumortier, D., & Fontoynt, M. (2006). The use of shading systems in VDU task offices: A pilot study. *Energy and Buildings*, 38(7), 780–789.
- Weatherspark. (2018). Average Weather in Putrajaya, Malaysia. Retrieved February 22, 2018, from <https://weatherspark.com/y/113804/Average-Weather-in-Putrajaya-Malaysia-Year-Round>
- Xin, H. Z., & Rao, S. P. (2013). Active Energy Conserving Strategies of the Malaysia Energy Commission Diamond Building. *Procedia Environmental Sciences*, 17, 775–784.  
<https://doi.org/10.1016/j.proenv.2013.02.095>
- Zain-Ahmed, A., Sopian, K., Abidin, Z. Z., & Othman, M. Y. H. (2002). The availability of daylight from tropical skies—a case study of Malaysia. *Renewable Energy*, 25(1), 21–30.
- Zain, A. (2000). Daylighting and shading for thermal comfort in Malaysian building. Ph. D. dissertation, University of Hertfordshire., UK.
- Zhang, Y., & Barrett, P. (2012). Factors influencing occupants' blind-control behaviour in a naturally ventilated office building. *Building and Environment*, 54, 137–147.  
<https://doi.org/10.1016/j.buildenv.2012.02.016>