UNIVERSITI PUTRA MALAYSIA

WINDOW BLIND OPERATIONS AND THEIR RELATIONSHIP WITH ENVIRONMENT FACTORS AND OCCUPANT'S BEHAVIOUR IN A GREEN-CERTIFIED OFFICE BUILDING IN MALAYSIA

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By

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June 2019

Chair : Associate Professor Zalina Binti Shari, PhD
Faculty : Design and Architecture

There is a need to understand the correlations between window blind operations with the environmental factors and occupants' behaviour to improve the indoor visual environment and daylight performance of office buildings in Malaysia. Improper positioning and seldom use of window blinds can hamper the penetration of daylight into office buildings, which may cause high electricity consumption and poor indoor visual environment. According to some studies, many of the existing office buildings in Malaysia are consuming high amount of electricity, partly because the occupants leave the window blinds fully lowered and depend on artificial lightings during daytime. Furthermore, the real reasons behind, and the influential factors of, occasional blind operation are still unknown for countries with hot and humid climatic condition. Therefore, this study aims to explore the behaviour of green office building's occupants regarding their control of window blinds as well as to investigate the manual blind use patterns and their correlations with the building orientations, sky conditions, floor levels and time of the day. The main objectives are, 1) to analyse how and why the office occupants operate their window blinds through a questionnaire survey among occupants; 2) to determine whether building façade orientations, sky conditions, different floor levels, and time of the day, influence the level of occlusion and the frequency of window blinds adjustment; and 3) to examine how window blinds are affecting occupants' visual comfort level. A GBI Gold-certified office building in Putrajaya was selected as a case study building for this study. This study used time-lapse photography to record the positions of the blinds. A questionnaire survey was also conducted among the building occupants to deepen understanding of their views on window blind operation. The Spearman's Correlation and ANOVA tests were conducted for the statistical analysis of the blind positions in relation to the different environmental factors. The responses obtained from the survey were analysed using descriptive and cross-tabulation analyses. The Spearman's Correlation and ANOVA tests revealed that the positioning and movements of the window blinds were correlated with the building orientations and floor levels and sometimes with the sky conditions. However, no relationship was found between the window blind operation and time of the day. The survey results revealed that most of the occupants did not operate their window blinds frequently, and glare from the daylight and outside views were the two main reasons for closing and opening their blinds respectively. The results indicate that there was a lack of willingness among occupants to operate their window blinds frequently throughout the day, which may result in poor daylight condition and high dependency on the artificial lightings. It is expected that findings of this study will contribute to further studies on window blind operation involving more office buildings in the tropics to ensure good indoor visual environment. It is hoped that this study will help to raise awareness among building occupants and encourage them to operate their window blinds frequently to better utilise the available daylight and to reduce the usage of artificial lightings.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

OPERASI TETINGKAP BUTA DAN HUBUNGAN MEREKA DENGAN FAKTOR PERSEKITARAN DAN SIKAP PEKERJA DALAM PERSEKITARAN KERJA HIJAU DI MALAYSIA

Oleh

S M JUBAER ALAM

June 2019

Pengerusi : Profesor Madya Zalina Binti Shari, PhD
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Terdapat keperluan untuk memahami korelasi di antara operasi tirai tingkap dengan faktor fizikal dan tingkah laku penghuni bangunan untuk meningkatkan persekitaran visual dalaman dan prestasi pencahayaan bangunan pejabat di Malaysia. Kedudukan yang tidak betul dan jarang menggunakan tirai tingkap boleh menghalang penembusan cahaya matahari ke dalam bangunan pejabat, dan boleh menyebabkan penggunaan elektrik yang tinggi serta persekitaran visual dalaman yang kurang baik. Menurut beberapa kajian, banyak bangunan pejabat yang sedia ada di Malaysia menggunakan jumlah elektrik yang tinggi; sebahagiannya kerana penghuni menurunkan tirai tingkap sepenuhnya dan bergantung kepada cahaya tiruan pada siang hari. Tambahan pula, sebab sebenar dan faktor yang mempengaruhi operasi tirai di negara-negara beriklim panas dan lembap masih tidak diketahui. Oleh itu, matlamat kajian ini adalah untuk mengkaji corak operasi tirai tingkap oleh penghuni pejabat dan bagaimana ianya berkaitan dengan persekitaran fizikal. Oleh itu, matlamat kajian ini adalah untuk meneroka kelakuan para penghuni pejabat bangunan hijau berkaitan pengawalan tirai tingkap dan untuk menyiasat corak penggunaan tirai tingkap dan hubungannya dengan orientasi fasad bangunan, keadaan langit, jumlah tingkat bangunan, dan masa. Objektif utama adalah, 1) untuk menganalisa bagaimana dan mengapa penghuni pejabat mengendalikan tirai tingkap mereka melalui kajian soal selidik; 2) untuk mengenal pasti sama ada orientasi fasad bangunan, keadaan langit, paras lantai, dan waktu mempengaruhi tahap oklusi dan kekerapan pelarasan tirai tingkap; dan 3) untuk memeriksa bagaimana tirai tingkap mempengaruhi tahan keselesaan visual penghuni. Bangunan pejabat hijau di Putrajaya yang mendapat anugerah GBI-Gold dipilih sebagai bangunan kajian kes untuk kajian ini. Kajian ini menggunakan fotografi *time-lapse* untuk mencatat kedudukan tirai. Kajian soal selidik juga dilakukan di kalangan penghuni bangunan untuk memperdalamkan pemahaman tentang pandangan mereka mengenai operasi tirai tingkap. Ujian korelasi Spearman dan ANOVA telah dijalankan untuk analisis statistik kedudukan tirai dan kaitannya dengan

faktor fizikal. Maklum balas yang diperoleh daripada tinjauan telah dianalisis dengan menggunakan analisis deskriptif dan *cross-tabulation*. Ujian korelasi Spearman dan ANOVA mendedahkan bahawa kedudukan dan pergerakan tirai tingkap berkorelasi dengan orientasi bangunan dan paras lantai bangunan dan kadang-kadang dengan keadaan langit. Walau bagaimanapun, tiada hubungan dijumpai di antara operasi tirai tingkap dan waktu. Hasil kajian menunjukkan kebanyakan penghuni tidak mengendalikan tirai tingkap mereka dengan kerap, dan silau dari cahaya matahari merupakan sebab utama tirai ditutup manakala pandangan luar merupakan sebab utama tirai dibuka. Keputusan menunjukkan bahawa terdapat kekurangan kesediaan di kalangan penghuni untuk mengendalikan tirai tingkap mereka secara kerap sepanjang hari, yang mungkin mengakibatkan keadaan pencahayaan dalaman yang kurang baik dan pergantungan yang tinggi pada cahaya tiruan. Adalah dijangkakan bahawa penemuan kajian ini akan menyumbang kepada lebih banyak kajian lanjutan mengenai operasi tirai tingkap dengan melibatkan lebih banyak bangunan pejabat di kawasan tropika untuk memastikan persekitaran visual dalaman yang baik. Diharapkan kajian ini akan membantu meningkatkan kesedaran di kalangan penghuni bangunan dan menggalakkan mereka untuk mengendalikan operasi tirai tingkap mereka dengan kerap untuk memanfaatkan penggunaan cahaya matahari dengan lebih baik dan mengurangkan penggunaan lampu tiruan.

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I certify that a Thesis Examination Committee has met on 13 June 2019 to conduct the final examination of S M Jubaer Alam on his thesis entitled "Window Blind Operations and their Relationship with Environment Factors and Occupant's Behaviour in a Green-Certified Office Building in Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
ACEM	Association of Consulting Engineers Malaysia
ANOVA	Analysis of Variance
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
Avg. B.O.I	Average Blind Occlusion Index
BEI	Building Energy Intensity
BMS	Building Management System
BREEAM	Building Research Establishment Environment Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CIE	International Commission on Illumination
DF	Daylight Factor
DGI	Daylight Glare Index
DGP	Daylight Glare Probability
GBI	Green Building Index
GBI NRNC	GBI Non-Residential New Construction
GHG	Greenhouse Gas
GreenPASS	Green Performance Assessment System
GreenRE	Green Real Estate
IEQ	Indoor Environmental Quality
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
K-S	Kolmogorov-Smirnov
LEED	Leadership in Energy and Environmental Design
MECM	Ministry of Energy, Communications and Multimedia Malaysia
MS	Malaysian Standards
MyCREST	Malaysian Carbon Reduction and Environmental Sustainability Tool
NI	Nebulosity Index
NLA	Net Lettable Area
PAM	Pertubuhan Akitek Malaysia
pH JKR	Penarafan Hijau JKR
PjH	Putrajaya Holdings
PVC	Polymerizing Vinyl Chloride
PWD	Public Works Department
SD	Standard Deviation
SHGC	Solar Heat Gain Coefficient
SPSS	Statistical Package for the Social Sciences
SR	Sky Ration
S-W	Shapiro-Wilk
UBBL	Malaysia Uniform Building By-Laws
UDI	Useful Daylight Illuminance
VCP	Visual Comfort Probability

CHAPTER 1

INTRODUCTION

1.1 Background

According to the report of the International Energy Agency, around 30% of the global energy is consumed by the building sector all over the world (IEA, 2018). The fifth assessment report of the Intergovernmental Panel on Climate Change indicated that building sector around the world is responsible for 32% of the total global energy-related emissions (IPCC, 2014b). Although a plethora of green building rating tools and passive design strategies have been developed globally to reduce buildings' energy consumption and to utilise renewable energy, many of today's buildings are still facing environmental issues and performing below the standards. One of the main reasons behind the poor performance of these buildings is the occupants' behaviour towards the use of energy and their lack of awareness. The use of natural resources like daylight can greatly reduce the electricity cost of the buildings if it is utilised properly by the occupants. The positive relationship between occupants' behaviour and different environmental factors, such as lighting and daylighting, can significantly enhance occupants' productivity as well as reduce energy consumption. Hence, organisation should pay more attention to the importance of daylighting and improvement of indoor daylight conditions (Horr et al., 2016; Yang & Nam, 2010).

In recent years, designers and researchers have given a lot of emphases on the buildings' design as well as the design of exterior and interior shading devices to ensure excellent daylight performance and comfortable indoor visual environment. In order to mitigate the negative impacts of the buildings on the environment, many green building rating tools have been developed all around the world to assess and certify the environmental performance of buildings. The utilisation of daylight is an integral part of green building design, which comes along with the proper use of shading devices; the suitable size of windows and glazing materials; as well as appropriate finishing and reflectance of interior spaces (Alam & Shari, 2019). Appropriately designed exterior shading devices can reduce solar radiation and thus minimising electricity and energy consumption (Sanati & Utzinger, 2013; Shen & Tzempelikos, 2012).

Furthermore, interior shading devices play a vital role to further block the excessive solar radiation, heat, and glare when the exterior shading devices are inadequate (Inkarojrit, 2005). The properties of window blinds can also affect the penetration of daylight inside the buildings and their proper use by the occupants can save up to 30% of the total electricity usage of a building (Hong, 2012). The daylight performance and visual comfort of a building are traditionally being calculated with the existing indices, such as daylight factor (DF), useful daylight illuminance (UDI), daylight glare index (DGI), daylight glare probability (DGP), visual comfort probability (VCP) and so on. Although the window blinds and their frequent operations can be an impact factor in the case of daylight performance, they are yet to be included in the process of calculating the daylight performance of a building.

In Malaysia, there is an abundant source of tropical daylight that can be utilised for energy conservation and higher productivity of building occupants (Lim, Ahmad, & Ossen, 2012). In 2009, the Green Building Index (GBI) was launched in collaboration with Malaysian Institute of Architects (PAM) and Association of Consulting Engineers Malaysia (ACEM) to assess buildings' environmental performance (Fauzi & Malek, 2013; Mun, 2009). Subsequently, a handful numbers of green building rating tools were developed by different organizations, such as Penarafan Hijau JKR (pH JKR) and Green Performance Assessment System (GreenPASS) in 2011, Green Real Estate (GreenRE) in 2012, and recently, Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) in 2013 (Kamaruzzaman, Lou, Zainon, Mohamed Zaid, & Wong, 2016; Zainol & Alauddin, 2016). However, many of existing office buildings in Malaysia do not meet the minimum standards for daylighting (Kandar, Sulaiman, Rashid, Ossen, & Aminatuzuhariah, 2011; Lim et al., 2013; Lim & Mohd Hamdan, 2010). According to a recent survey of discomfort glare by Hirning, Isoardi, & Garcia-Hansen (2017) in six office buildings including three GBI certified green office buildings, windows were found as the most common source of glare. The glare was experienced by 35% of the occupants in green buildings compared to just 7% in non-green buildings (Hirning et al., 2017). Occupants of these buildings use window blinds to block this excessive glare from daylight and work under artificial lighting environment during daytime. As a result, typical Building Energy Intensity (BEI) in Malaysia ranges between 200 and 250 kWh/m^2/year (Saidur, 2009; Wan Mohd Nazi et al., 2017; Xin & Rao, 2013). Whereas, office buildings in Singapore consume around 218 kWh/m^2/year (Building & Construction Authority Singapore, 2014). Interestingly, however, both of these countries have a lower average energy consumption rate than office buildings in Europe, which is 306 kWh/m^2/year (Dubois & Blomsterberg, 2011).

1.2 Research Problem

Research on shading devices and blind operations traditionally aim to reduce the buildings' energy consumption as well as increase the occupants' comfort and level of awareness. External shading devices can prevent solar radiation better than internal shading devices; however, interior shading devices and window blinds are more effective in controlling excessive daylight and glare (Sanati & Utzinger, 2013; Shen & Tzempelikos, 2012). Although many researchers have recommended automated window blinds and dimmable lighting systems as a solution for more comfortable indoor visual environment (Kim, Park, Yeo, & Kim, 2009; Reinhart & Voss, 2003), some studies have found that, automated shading systems may affect the occupants' sense of controlling the window blinds and can also cause dissatisfaction (Meerbeek, de Bakker, de Kort, van Loenen, & Bergman, 2016).

Occupants' control of interior shading devices vitally influences the daylight performance of a building. Many studies have been carried out in Europe, the

USA, Canada, the Republic of Korea and Japan to observe the occupants' behaviour in their control of internal shading devices. Findings from these studies indicated that occupants do not adjust their blinds frequently and once lowered, these blinds remain at the same position for weeks or even for months, which resulted in poor daylight performance in these buildings. (Correia da Silva, Leal, & Andersen, 2013; Day, Theodorson, & Van Den Wymelenberg, 2012; Escuyer & Fontoynont, 2001; Foster & Oreszczyn, 2001; Gunay, O'Brien, Beausoleil-Morrison, & Huchuk, 2014; Inkarojrit, 2005; Rea, 1984; Reinhart & Voss, 2003; Rubin, Collins, & Tibbott, 1978; Sanati & Utzinger, 2013; Sutter, Dumortier, & Fontoynont, 2006; Zhang & Barrett, 2012).

Many existing office buildings, including green buildings, are still having poor daylight performance inside the buildings, either due to inappropriate façade design or poor attitude among the occupants. Besides occupants' behaviour towards blind use, several environmental factors such as glare from daylight and sunlight, visual privacy and visual comfort, outside views, time of the day may also influence the blind use patterns. According to some previous studies, indoor air temperature and solar radiation were significant variables of occupants' interaction with window blinds (Sadeghi, Karava, Konstantzos, & Tzempelikos, 2016). Furthermore, occupants' characteristics and psychological aspects also play a vital role in occupants' use of window blinds. Some studies have reported that, non-physical factors, such as outside views, connection with outdoor spaces, privacy of the workstations, and perception of daylight, can be the main reasons behind occupants' use of window blinds (Inkarojrit, 2005; Inoue, Kawase, Ibamoto, Takakusa, & Matsuo, 1988; Ardeshir Mahdavi, Mohammadi, Kabir, & Lambeva, 2008; Zhang & Barrett, 2012). However, the real reasons that motivate the occupants in office buildings to operate their window blinds are still less known in the context of Malaysia.

Previous studies on Malaysian office buildings found that window blinds are not operated frequently by the occupants and most of the time, they are kept lowered during the daytime (Kandar et al., 2011; Lim et al., 2013; Lim & Mohd Hamdan, 2010). Windows are the most common source of glare in office buildings in Malaysia, including in green-certified office buildings (Hirning et al., 2017). Occupants may lower down their window blinds to avoid the glare. However, if these blinds are not operated frequently, they can cause poor daylight availability and visual condition inside office buildings (Sadeghi et al., 2016). However, findings from previous studies on blind operations cannot be applied to countries with a hot-humid climatic condition like Malaysia, as most of these studies were conducted in the regions within the temperate zone, such as Europe, the USA, Canada, Republic of Korea and Japan. Tropical countries have different solar geometries than cold countries, which may cause different window blind movement patterns. As stated by Galasiu and Veitch., (2006), systematic comparisons are needed for generalised recommendations of window blind operations for different orientations, weather conditions, times of day, latitudes, seasons, building and window types, cultures and individuals. Therefore, coordinated field studies are required to establish general recommendations for window blind control strategies.

1.3 Research Gaps

Several research gaps have been identified by reviewing the literature on window blind operations and existing standards and regulations for the building industry in Malaysia:

1. Previous studies have identified the environmental factors, such as building orientations, sky conditions, visual comfort as well as thermal comfort as the most influential factors for window blind operations (Lindsay & Littlefair, 1992; Rea, 1984; Rubin et al., 1978). However, occupants' behaviour can also be responsible for the poor use of window blinds, which may result in poor daylight condition inside the buildings. Therefore, subjective measurements are also crucial alongside the physical measurements to fully understand the patterns of window blind usage in the office buildings.

2. Although questionnaire survey of the occupants was conducted alongside field measurements in later years for studying the window blinds operations, all four orientations of the study buildings were not included in most of these studies (Day et al., 2012; Escuyer & Fontoynont, 2001; Inkarojrit, 2005; Inoue, Kawase, Ibamoto, et al., 1988; Moore, Carter, & Slater, 2002; Sanati & Utzinger, 2013; Sutter et al., 2006; Zhang & Barrett, 2012). Inoue, Kawase, Ibamoto, et al., (1988) only studied the east and the west facades of four office buildings, whereas Sutter et al., (2006) studied the southeast façade of eight individual office buildings. The north, south and the west orientations were included by Day et al., (2012) for understanding the occupants' behaviour towards their blind operations, but the east orientation was ignored. Sanati and Utzinger, (2013) only studied the window blind operations of the west façade of an open-planned architectural studio. The only two studies that considered all four orientations of the buildings were Inkarojrit, (2005) and Zhang & Barrett, (2012). However, no previous studies have measured the effect of floor levels on the use of window blinds. The use of window blinds can differ on different floor levels of a building because of privacy issues, solar heat gain, visual comfort and outside views. Therefore, studies on window blind operations should measure the effect of floor levels on the operations of window blinds.

3. In order to analyse the positions of the window blinds, previous studies used time-lapse photography or video recording, of which the positions of the window blinds were recorded from outside of the buildings. Although in recent years, high-resolution cameras have been used to record the blind positions, it was difficult to measure the actual positioning of the window blinds in the case of tall buildings. Therefore, more accurate measurements of the window blind positions are needed, which may involve close-range time-lapse photography from inside of the study buildings.

4. All of the previous studies on window blind operations have been conducted in the USA, Canada, Europe, Japan and the Republic of Korea. However, there are no studies on window blind operations in the context of equatorial regions with the hot-humid climatic condition. The different climatic condition may have different blind use patterns for the office buildings. Therefore, window blind operations in the tropical office buildings should be appropriately investigated.

5. The use of window blinds can significantly affect the penetration of daylight inside the buildings. The previous studies on Malaysian office buildings have also found that most of the window blinds were kept lowered during the day time, which may cause poor daylight performance inside these office buildings. However, the exact reasons why the occupants keep their window blinds as fully or partially closed and why they do not operate their blind frequently are still unclear for the tropics.

6. The existing green building rating tools in Malaysia calculate the daylight performance only by using daylight factor (DF), but not the other common indices, such as useful daylight illuminance (UDI), daylight glare index (DGI), daylight glare probability (DGP) and visual comfort probability (VGP). The effects of window blind operations on daylight performance and occupants' behaviour are still being ignored in these indices, rating tools as well as building and design standards. As stated 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."

1.4 Research Aim

The study aims to explore the behaviour of green office building's occupants regarding their control of window blinds as well as to investigate the manual blind use patterns and their correlations with the building orientations, sky conditions, floor levels and time of the day.

1.5 Research Questions

The main question related to this research is:

1. What are the main reasons for the occupants to operate their window blinds?
2. What are the correlations between window blind operations and-
   - building orientations;
   - sky condition;
   - floor levels and
   - time of the day
3. How does the occupants' use of window blinds affect their satisfaction level of visual comfort?

1.6 Research Objectives

The objectives of this study are:

1. To analyse how and why office occupants operate their window blinds through a questionnaire survey among occupants.

2. To determine whether building façade orientations, sky conditions, different floor levels, and time of the day, influence the level of occlusion and the frequency of window blinds adjustment.
3. To examine how window blinds are affecting occupants' visual comfort level.

1.7 Research Methodology

A case study method was used in this study to identify the existing problems and contribute to the existing knowledge. Specifically, this study used a correlation strategy to evaluate the correlations between window blind operations with environmental factors and occupants' behaviour. A green-certified office building in Putrajaya called Menara PjH was chosen as the case study building. The study was mainly conducted using two different methods for fulfilling the research objectives. Time-lapse photography was used for recording the position of window blinds of this building to obtain the average blind occlusion index (avg. B.O.I). A questionnaire survey was conducted among the building occupants to analyse their behavioural aspects.

Field measurements were conducted in two different phases: seventeen days in March 2017 and eight days in July 2017. During the first phase, window blinds from all four orientations were recorded from inside through time-lapse photographs. The sky condition was also recorded at the same time for analysing their relationship with the window blind operation.

The questionnaire survey was conducted during the second phase of field measurements. Hard copies of the survey form were distributed among the occupants of the building, which included questions related to their personal information, window blind operation and satisfaction levels with their indoor visual environment.

After finishing the field measurements, the obtained data were analysed using several statistical methods, such as the Spearman's Correlation and ANOVA test, descriptive analysis, and cross-tabulation analysis.

1.8 Scope of Study

This study focuses on the operation of window blinds in the office buildings and the influential factors that affect the blind operations and indoor visual environment. As the assessment of indoor visual environment is a vast and complicated process, this study is only limited to window blind operations and occupants' behaviour in office buildings (Figure 1.1). Several factors have been considered for this study:

1. Different environmental factors, such as building orientations, floor levels, sky conditions and time of the day.
2. Psychological aspects of the occupants, such as their preference of outside views and privacy of their workstations.

3. Occupants' preference for daylight and interior shading according to their age, gender, types of official tasks, and seating positions.

This study is expected to contribute to a clear understanding of occupants' behaviour in controlling their window blinds in office buildings in Malaysia. Even though this study was conducted in a green-certified office building, the findings may apply to other conventional office buildings in Malaysia or indirectly to other countries with the hot-humid climatic condition.

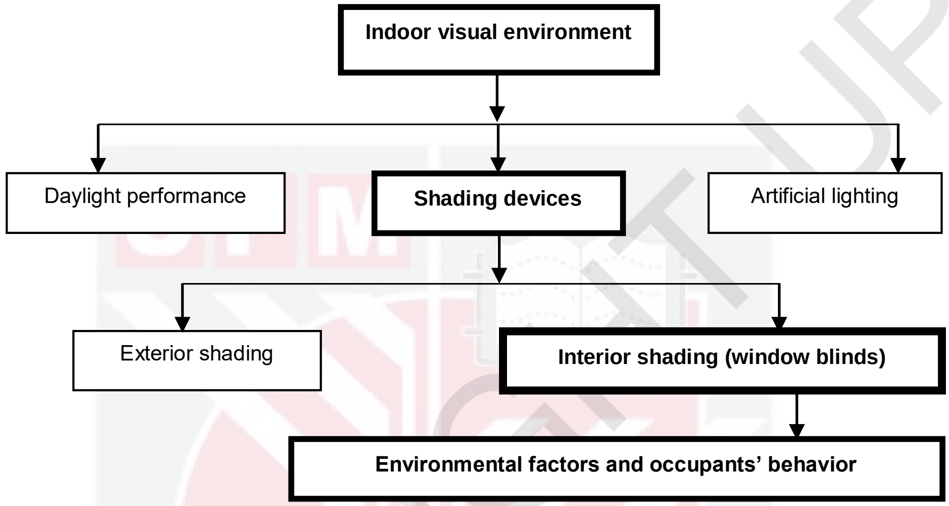

Figure 1.1 Scope of the study

1.9 Significance of Research

Reduction of energy consumption by the building sector is one of the sheer priorities around the world. The energy consumption by office buildings in Malaysia is comparatively high due to the lack of awareness among occupants regarding the proper use of window blinds and utilisation of available daylight. It is anticipated that the findings of this study will help architects, designers and management authorities to have a better understanding about occupants' behaviour in their use of interior shading devices and artificial lightings, which in turn will encourage them to promote awareness among the occupants. This research contributes to the knowledge of energy efficient practices within the commercial building sector, particularly in Malaysia.

1.10 Organization of Thesis

This thesis consists of six chapters. The organisation of the thesis is described below:

Chapter 2: Literature review

This chapter develops the theoretical foundation for this study. It reviews the climatic condition of Malaysia; the concept of daylighting design; building regulations in Malaysia; window blinds in office buildings; and previous studies on window blind operations. The chapter ends with the summary of the whole chapter.

Chapter 3: Research methodology

This chapter describes the methods used for this study. It explains the detail procedures of the selection of the study building, window blind movement measurements, questionnaire survey and processing of the obtained data from the field measurements and survey.

Chapter 4: Results

Chapter four interprets the results and findings from the data analyses so that the hypothesis of this research can be tested. This chapter includes the statistical analyses of the window blind movements and the questionnaire survey.

Chapter 5: Discussions

Chapter five discusses the results obtained from the data analysis. This chapter also explores the connections between the results from the previous studies and this study. Finally, this chapter concludes with the summary of the findings.

Chapter 6: Conclusions

Chapter six summarizes the findings of this study. It consists of research limitations, impacts of the study and knowledge contribution. Finally, this chapter concludes with the recommendations for future research on the window blind operations.

1.11 Research Methodological Framework

Figure 1.2 illustrates the graphical representation of the methodological framework of this study. The model demonstrates the sequential phases in this study, which started with the identification of the research problem, research aim followed by the formulation of the research objectives. Then, the previous literature on window blind operations was reviewed to establish the main methods for data collections and the procedures of data analysis. The study concludes with a discussion, conclusions, and future recommendations.

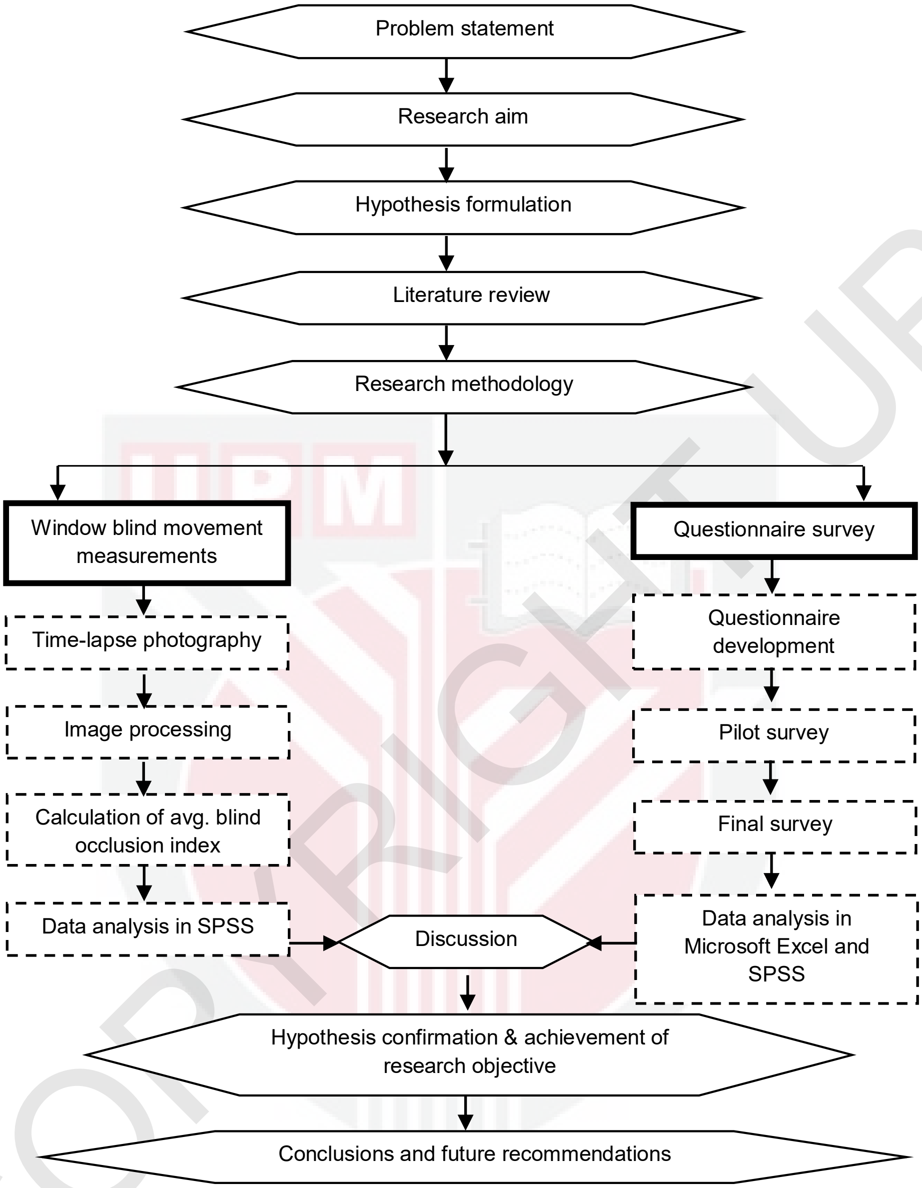

Figure 1.2 The research methodological framework

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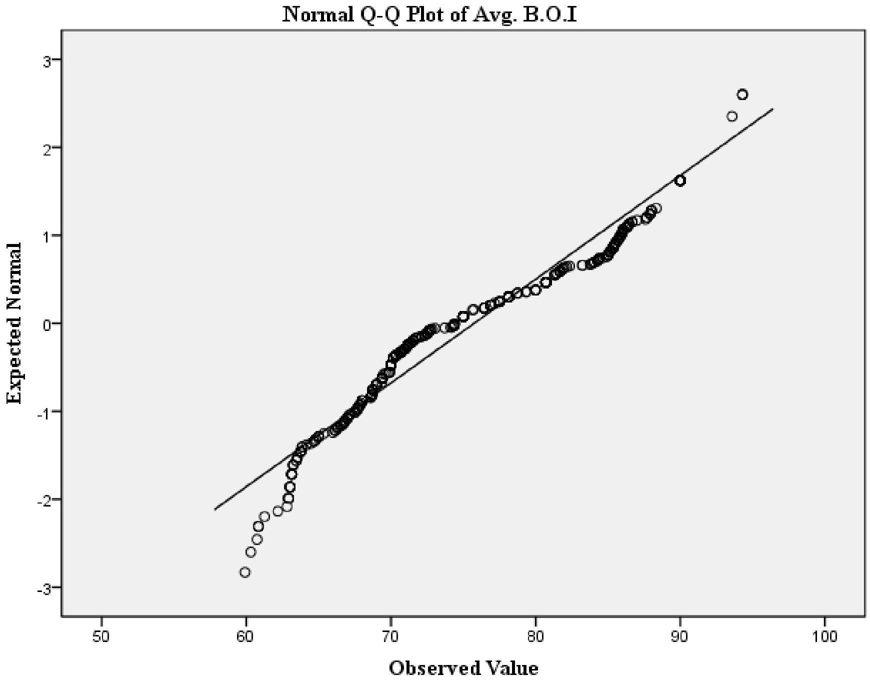
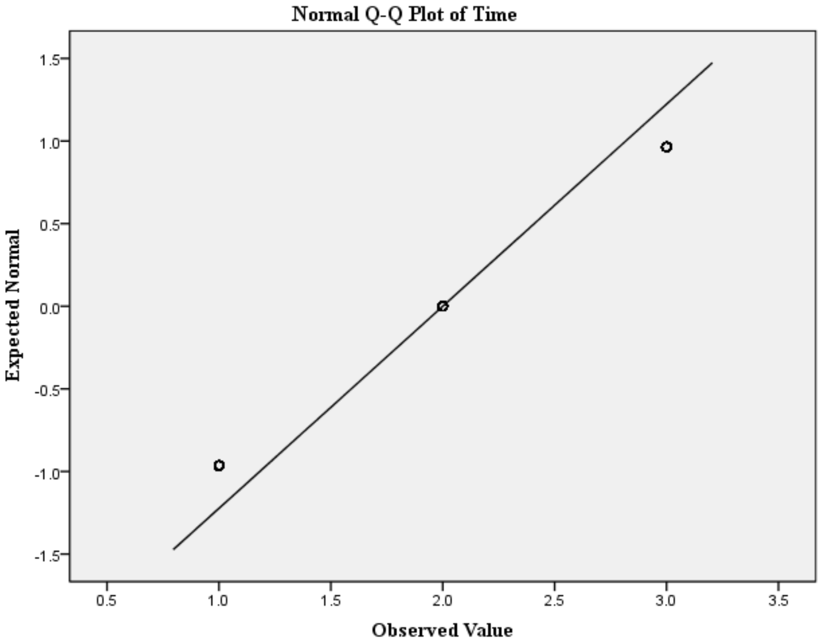
APPENDICES

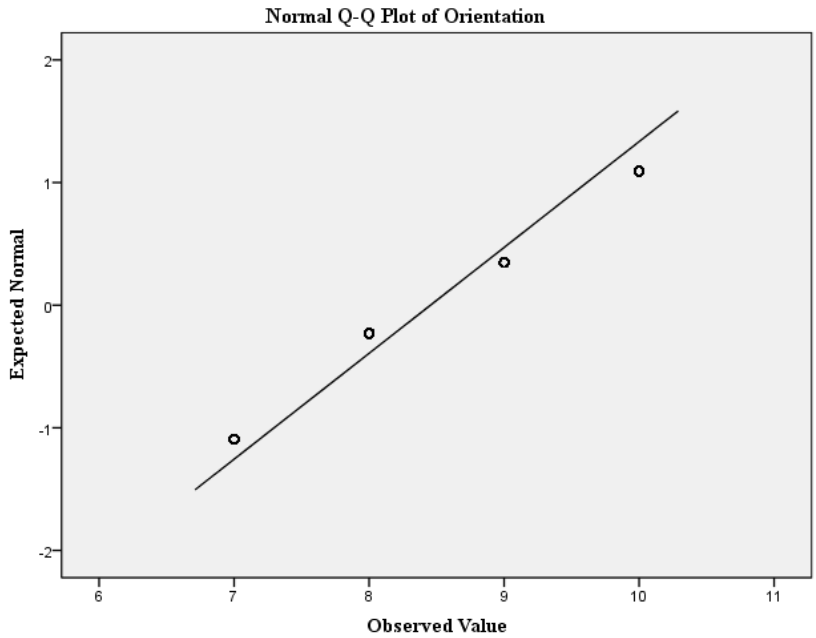
Appendix A
Visual analysis of Q-Q plots



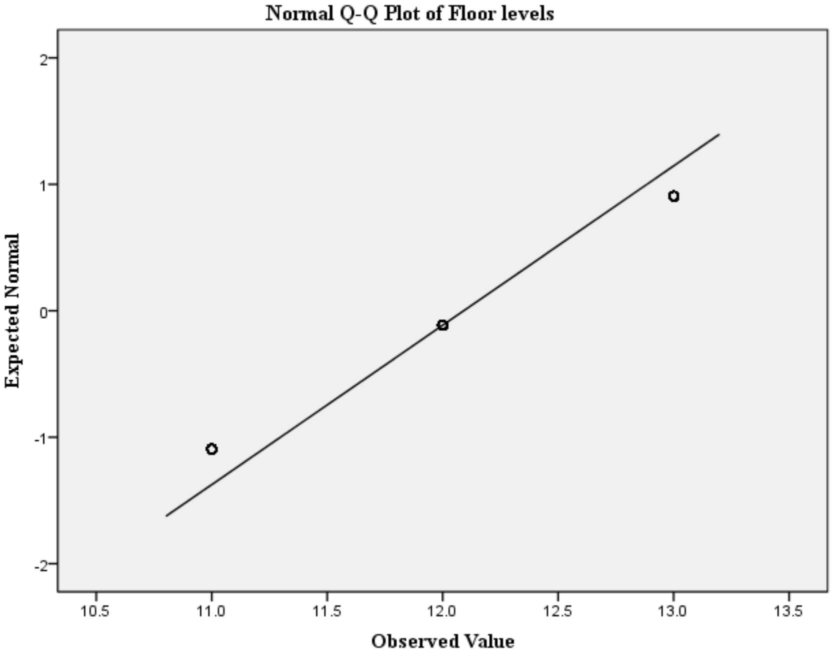
Q-Q plot for the data set of avg. B.O.I from the first session of the field measurements



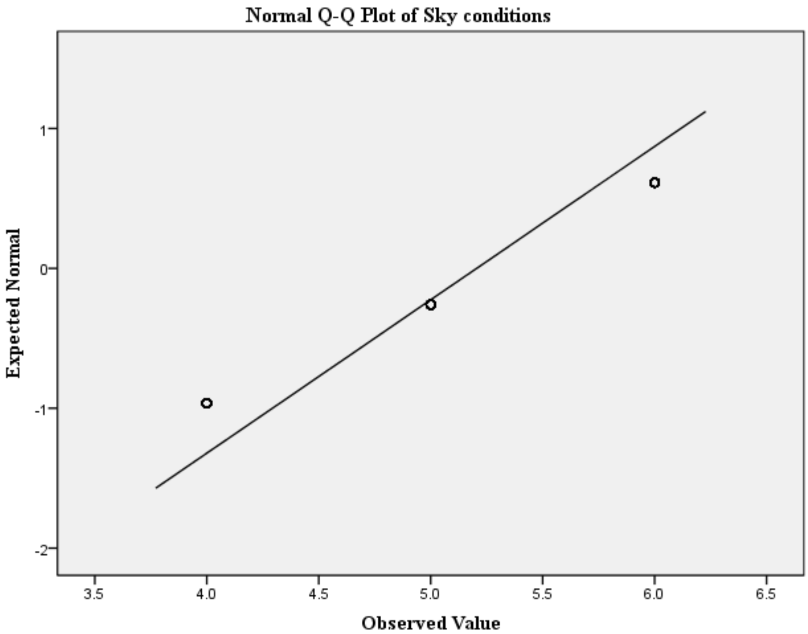
Q-Q plot for the data set of time from the first session of the field measurements



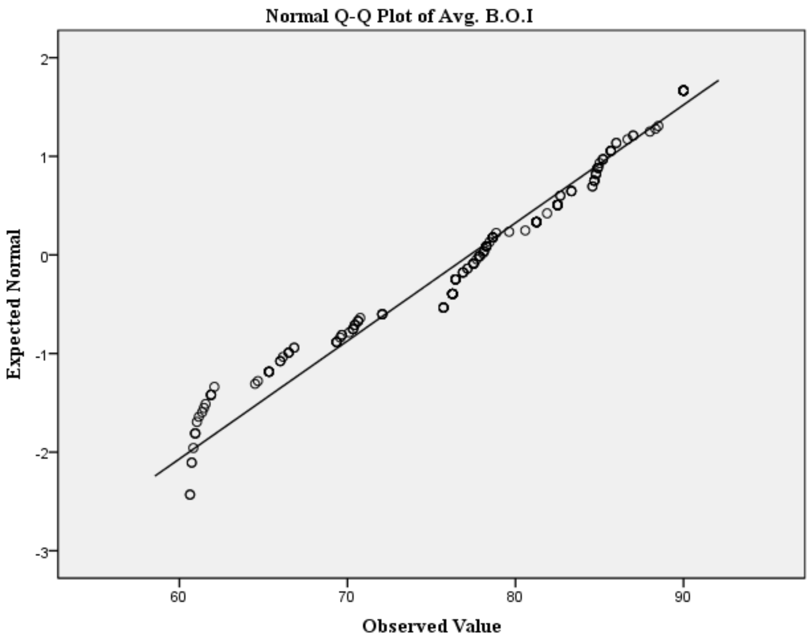
Q-Q plot for the data set of orientation from the first session of the field measurements



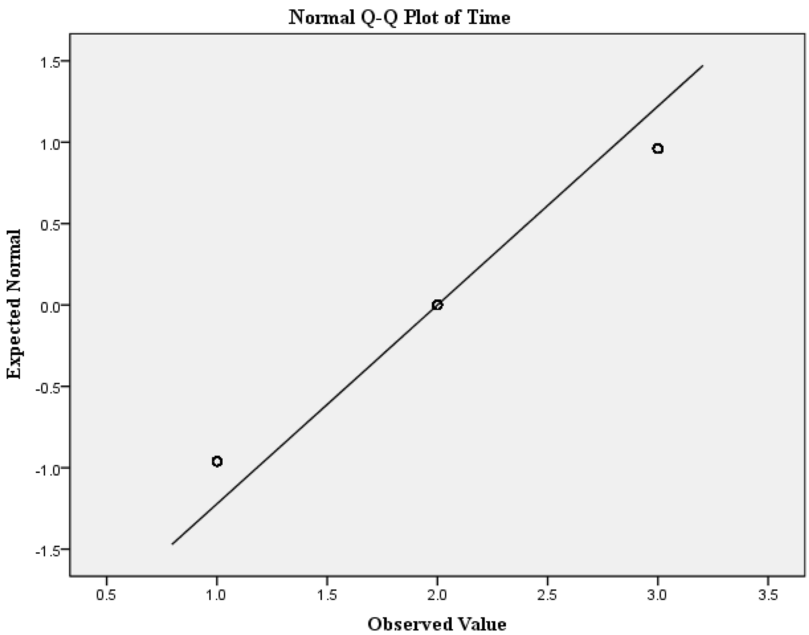
Q-Q plot for the data set of floor levels from the first session of the field measurements



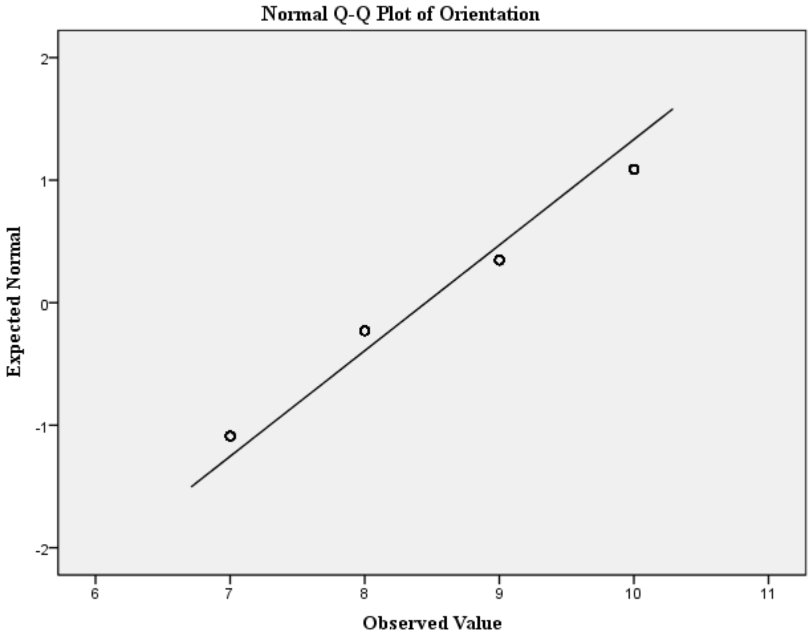
Q-Q plot for the data set of sky conditions from the first session of the field measurements



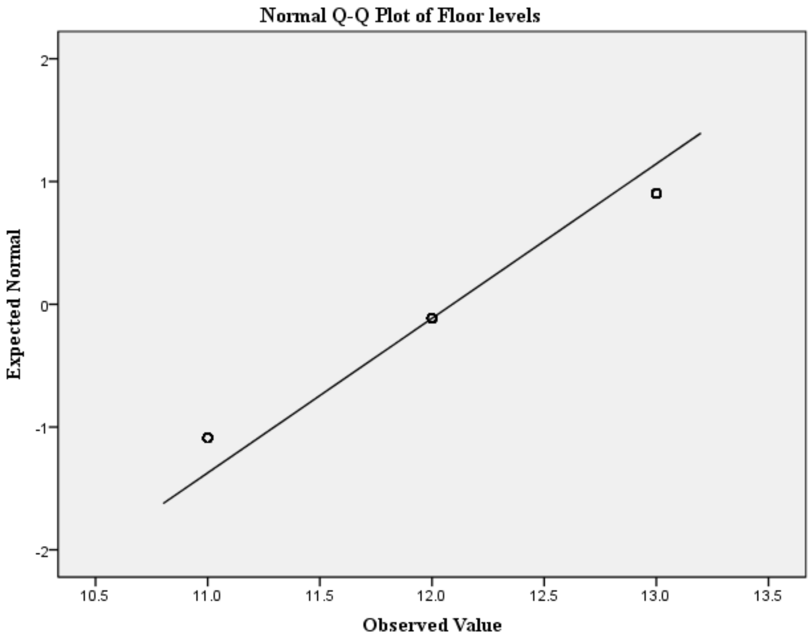
Q-Q plot for the data set of avg. B.O.I from the second session of the field measurements



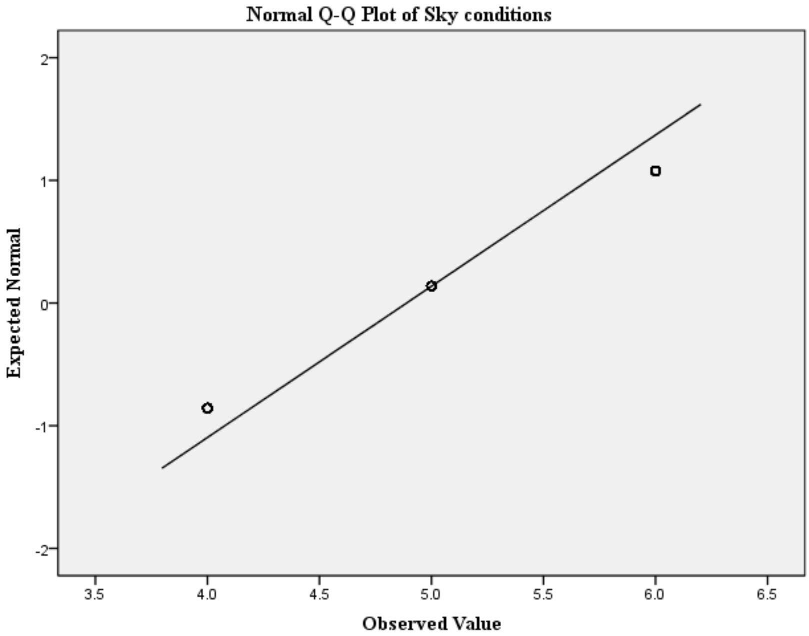
Q-Q plot for the data set of time from the second session of the field measurements



Q-Q plot for the data set of orientation from the second session of the field measurements



Q-Q plot for the data set of floor levels from the second session of the field measurements



Q-Q plot for the data set of sky conditions from the second session of the field measurements

Appendix B
Calculation of avg. B.O.I

Calculation of avg. B.O.I for morning time of the East orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. index (%)	Occlusion	Sky condition	Avg. B.O.I (%)
15.03.2017	9:30 AM	East	Level 1	76.43		Overcast	75.62
			Level 4	66.15			
			Level 11	84.27			
16.03.2017	9:30 AM	East	Level 1	76.43		Overcast	76.51
			Level 4	67.69			
			Level 11	85.42			
17.03.2017	9:30 AM	East	Level 1	76.43		Overcast	76.55
			Level 4	70.00			
			Level 11	83.23			
20.03.2017	9:30 AM	East	Level 1	80.71		Overcast	79.54
			Level 4	70.00			
			Level 11	87.92			
21.03.2017	9:30 AM	East	Level 1	80.00		Sunny	79.19
			Level 4	71.54			
			Level 11	86.04			
22.03.2017	9:30 AM	East	Level 1	80.71		Sunny	79.49
			Level 4	71.92			
			Level 11	85.83			
23.03.2017	9:30 AM	East	Level 1	80.71		Sunny	79.57
			Level 4	71.54			
			Level 11	86.46			
24.03.2017	9:30 AM	East	Level 1	80.71		Overcast	79.73
			Level 4	72.12			
			Level 11	86.35			
27.03.2017	9:30 AM	East	Level 1	93.57		Overcast	83.29
			Level 4	70.77			
			Level 11	85.52			
28.03.2017	9:30 AM	East	Level 1	94.29		Sunny	83.73
			Level 4	70.96			
			Level 11	85.94			
29.03.2017	9:30 AM	East	Level 1	80.71		Overcast	78.86
			Level 4	70.77			
			Level 11	85.10			
30.03.2017	9:30 AM	East	Level 1	80.71		Overcast	78.71
			Level 4	71.15			
			Level 11	84.27			
31.03.2017	9:30 AM	East	Level 1	80.71		Overcast	78.64
			Level 4	71.15			
			Level 11	84.06			
Avg. B.O.I (by orientation)							**79.19**

Calculation of avg. B.O.I for noon time of the East orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. index (%)	Occlusion	Sky condition	Avg. B.O.I (%)
15.03.2017	12:00 PM	East	Level 1	75.71		Partly cloudy	75.82
			Level 4	66.54			
			Level 11	85.21			
16.03.2017	12:00 PM	East	Level 1	80.71		Overcast	78.68
			Level 4	69.81			
			Level 11	85.52			
17.03.2017	12:00 PM	East	Level 1	80.71		Sunny	79.67
			Level 4	70.38			
			Level 11	87.92			
20.03.2017	12:00 PM	East	Level 1	76.43		Overcast	77.18
			Level 4	70.00			
			Level 11	85.10			
21.03.2017	12:00 PM	East	Level 1	80.71		Sunny	79.29
			Level 4	71.73			
			Level 11	85.42			
22.03.2017	12:00 PM	East	Level 1	80.71		Sunny	79.40
			Level 4	71.54			
			Level 11	85.94			
23.03.2017	12:00 PM	East	Level 1	80.71		Sunny	79.57
			Level 4	71.54			
			Level 11	86.46			
24.03.2017	12:00 PM	East	Level 1	80.71		Overcast	79.55
			Level 4	72.12			
			Level 11	85.83			
27.03.2017	12:00 PM	East	Level 1	94.29		Overcast	83.66
			Level 4	70.96			
			Level 11	85.73			
28.03.2017	12:00 PM	East	Level 1	80.71		Sunny	79.17
			Level 4	70.96			
			Level 11	85.83			
29.03.2017	12:00 PM	East	Level 1	80.71		Overcast	78.73
			Level 4	70.58			
			Level 11	84.90			
30.03.2017	12:00 PM	East	Level 1	80.71		Partly cloudy	78.77
			Level 4	71.54			
			Level 11	84.06			
31.03.2017	12:00 PM	East	Level 1	81.43		Sunny	78.78
			Level 4	71.15			
			Level 11	83.75			
Avg. B.O.I (by orientation)							**79.10**

Calculation of avg. B.O.I for afternoon time of the East orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. index (%)	Occlusion	Sky condition	Avg. B.O.I (%)
15.03.2017	4:30 PM	East	Level 1	77.14		Partly cloudy	76.23
			Level 4	66.54			
			Level 11	85.00			
16.03.2017	4:30 PM	East	Level 1	80.71		Overcast	78.11
			Level 4	70.38			
			Level 11	83.23			
17.03.2017	4:30 PM	East	Level 1	80.71		Overcast	79.67
			Level 4	70.38			
			Level 11	87.92			
20.03.2017	4:30 PM	East	Level 1	80.00		Overcast	79.16
			Level 4	71.54			
			Level 11	85.94			
21.03.2017	4:30 PM	East	Level 1	80.00		Sunny	78.96
			Level 4	71.35			
			Level 11	85.52			
22.03.2017	4:30 PM	East	Level 1	80.71		Sunny	79.64
			Level 4	71.54			
			Level 11	86.67			
23.03.2017	4:30 PM	East	Level 1	80.71		Sunny	80.02
			Level 4	71.73			
			Level 11	87.60			
24.03.2017	4:30 PM	East	Level 1	80.71		Overcast	79.00
			Level 4	70.77			
			Level 11	85.52			
27.03.2017	4:30 PM	East	Level 1	94.29		Overcast	83.76
			Level 4	70.96			
			Level 11	86.04			
28.03.2017	4:30 PM	East	Level 1	82.14		Overcast	79.92
			Level 4	70.96			
			Level 11	86.67			
29.03.2017	4:30 PM	East	Level 1	80.71		Partly cloudy	79.13
			Level 4	72.31			
			Level 11	84.38			
30.03.2017	4:30 PM	East	Level 1	80.71		Partly cloudy	78.61
			Level 4	71.15			
			Level 11	83.96			
31.03.2017	4:30 PM	East	Level 1	81.43		Overcast	78.81
			Level 4	71.15			
			Level 11	83.85			
Avg. B.O.I (by orientation)							**79.31**

Calculation of avg. B.O.I for morning time of the North orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	9:30 AM	North	Level 1	70.00	Overcast	69.58
			Level 4	75.00		
			Level 11	63.75		
16.03.2017	9:30 AM	North	Level 1	72.50	Overcast	68.54
			Level 4	69.38		
			Level 11	63.75		
17.03.2017	9:30 AM	North	Level 1	72.50	Overcast	68.96
			Level 4	69.38		
			Level 11	65.00		
20.03.2017	9:30 AM	North	Level 1	78.13	Overcast	74.58
			Level 4	75.00		
			Level 11	70.63		
21.03.2017	9:30 AM	North	Level 1	78.75	Sunny	74.58
			Level 4	75.00		
			Level 11	70.00		
22.03.2017	9:30 AM	North	Level 1	78.13	Sunny	73.96
			Level 4	75.00		
			Level 11	68.75		
23.03.2017	9:30 AM	North	Level 1	76.88	Sunny	73.54
			Level 4	75.00		
			Level 11	68.75		
24.03.2017	9:30 AM	North	Level 1	76.88	Overcast	74.17
			Level 4	75.00		
			Level 11	70.63		
27.03.2017	9:30 AM	North	Level 1	78.13	Overcast	73.96
			Level 4	75.00		
			Level 11	68.75		
28.03.2017	9:30 AM	North	Level 1	77.50	Sunny	74.17
			Level 4	75.00		
			Level 11	70.00		
29.03.2017	9:30 AM	North	Level 1	78.13	Overcast	72.50
			Level 4	70.00		
			Level 11	69.38		
30.03.2017	9:30 AM	North	Level 1	76.88	Overcast	71.88
			Level 4	70.00		
			Level 11	68.75		
31.03.2017	9:30 AM	North	Level 1	78.13	Overcast	76.67
			Level 4	70.00		
			Level 11	81.88		
Avg. B.O.I (by orientation)						**72.85**

Calculation of avg. B.O.I for noon time of the North orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	12:00 PM	North	Level 1	72.50	Partly cloudy	70.63
			Level 4	75.63		
			Level 11	63.75		
16.03.2017	12:00 PM	North	Level 1	74.38	Overcast	69.17
			Level 4	69.38		
			Level 11	63.75		
17.03.2017	12:00 PM	North	Level 1	74.38	Sunny	69.58
			Level 4	69.38		
			Level 11	65		
20.03.2017	12:00 PM	North	Level 1	77.50	Overcast	74.38
			Level 4	75.00		
			Level 11	70.63		
21.03.2017	12:00 PM	North	Level 1	78.75	Sunny	74.58
			Level 4	75.00		
			Level 11	70		
22.03.2017	12:00 PM	North	Level 1	76.88	Sunny	73.96
			Level 4	75.00		
			Level 11	70		
23.03.2017	12:00 PM	North	Level 1	76.88	Sunny	73.54
			Level 4	75.00		
			Level 11	68.75		
24.03.2017	12:00 PM	North	Level 1	78.13	Overcast	73.96
			Level 4	75.00		
			Level 11	68.75		
27.03.2017	12:00 PM	North	Level 1	78.13	Overcast	73.96
			Level 4	75.00		
			Level 11	68.75		
28.03.2017	12:00 PM	North	Level 1	77.50	Sunny	73.96
			Level 4	75.00		
			Level 11	69.38		
29.03.2017	12:00 PM	North	Level 1	78.13	Overcast	72.50
			Level 4	70.00		
			Level 11	69.38		
30.03.2017	12:00 PM	North	Level 1	77.50	Partly cloudy	72.08
			Level 4	70.00		
			Level 11	68.75		
31.03.2017	12:00 PM	North	Level 1	75.00	Sunny	75.63
			Level 4	70.00		
			Level 11	81.88		
Avg. B.O.I (by orientation)						**72.92**

Calculation of avg. B.O.I for afternoon time of the North orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	4:30 PM	North	Level 1	74.38	Partly cloudy	69.38
			Level 4	70.00		
			Level 11	63.75		
16.03.2017	4:30 PM	North	Level 1	75.00	Overcast	69.79
			Level 4	69.38		
			Level 11	65		
17.03.2017	4:30 PM	North	Level 1	75.00	Overcast	69.79
			Level 4	69.38		
			Level 11	65		
20.03.2017	4:30 PM	North	Level 1	78.75	Overcast	74.58
			Level 4	75.00		
			Level 11	70.00		
21.03.2017	4:30 PM	North	Level 1	76.88	Sunny	73.96
			Level 4	75.00		
			Level 11	70		
22.03.2017	4:30 PM	North	Level 1	76.88	Sunny	73.54
			Level 4	75.00		
			Level 11	68.75		
23.03.2017	4:30 PM	North	Level 1	79.38	Sunny	75.21
			Level 4	75.00		
			Level 11	71.25		
24.03.2017	4:30 PM	North	Level 1	78.13	Overcast	73.96
			Level 4	75.00		
			Level 11	68.75		
27.03.2017	4:30 PM	North	Level 1	78.13	Overcast	74.17
			Level 4	75.00		
			Level 11	69.38		
28.03.2017	4:30 PM	North	Level 1	78.13	Overcast	74.17
			Level 4	75.00		
			Level 11	69.38		
29.03.2017	4:30 PM	North	Level 1	78.13	Partly cloudy	72.50
			Level 4	70.00		
			Level 11	69.38		
30.03.2017	4:30 PM	North	Level 1	77.50	Partly cloudy	77.92
			Level 4	70.00		
			Level 11	86.25		
31.03.2017	4:30 PM	North	Level 1	74.38	Overcast	75.42
			Level 4	70.00		
			Level 11	81.88		
Avg. B.O.I (by orientation)						**73.41**

Calculation of avg. B.O.I for morning time of the South orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	9:30 AM	South	Level 1	-	Overcast	76.42
			Level 4	67.83		
			Level 11	85		
16.03.2017	9:30 AM	South	Level 1	-	Overcast	78.33
			Level 4	66.67		
			Level 11	90		
17.03.2017	9:30 AM	South	Level 1	-	Overcast	80.08
			Level 4	70.17		
			Level 11	90		
20.03.2017	9:30 AM	South	Level 1	-	Overcast	79.33
			Level 4	68.67		
			Level 11	90		
21.03.2017	9:30 AM	South	Level 1	-	Sunny	79.00
			Level 4	68.00		
			Level 11	90		
22.03.2017	9:30 AM	South	Level 1	-	Sunny	79.00
			Level 4	68.00		
			Level 11	90		
23.03.2017	9:30 AM	South	Level 1	-	Sunny	79.50
			Level 4	69.00		
			Level 11	90		
24.03.2017	9:30 AM	South	Level 1	-	Overcast	79.50
			Level 4	69.00		
			Level 11	90		
27.03.2017	9:30 AM	South	Level 1	-	Overcast	79.50
			Level 4	69.00		
			Level 11	90		
28.03.2017	9:30 AM	South	Level 1	-	Sunny	78.92
			Level 4	67.83		
			Level 11	90		
29.03.2017	9:30 AM	South	Level 1	-	Overcast	78.83
			Level 4	67.67		
			Level 11	90		
30.03.2017	9:30 AM	South	Level 1	-	Overcast	78.83
			Level 4	67.67		
			Level 11	90		
31.03.2017	9:30 AM	South	Level 1	-	Overcast	78.92
			Level 4	67.83		
			Level 11	90		
Avg. B.O.I (by orientation)						**78.94**

Calculation of avg. B.O.I for noon time of the South orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	12:00 PM	South	Level 1	-	Partly cloudy	75.17
			Level 4	65.33		
			Level 11	85		
16.03.2017	12:00 PM	South	Level 1	-	Overcast	79.83
			Level 4	69.67		
			Level 11	90		
17.03.2017	12:00 PM	South	Level 1	-	Sunny	80.08
			Level 4	70.17		
			Level 11	90		
20.03.2017	12:00 PM	South	Level 1	-	Overcast	79.00
			Level 4	68.00		
			Level 11	90		
21.03.2017	12:00 PM	South	Level 1	-	Sunny	79.00
			Level 4	68.00		
			Level 11	90		
22.03.2017	12:00 PM	South	Level 1	-	Sunny	78.92
			Level 4	67.83		
			Level 11	90		
23.03.2017	12:00 PM	South	Level 1	-	Sunny	79.50
			Level 4	69.00		
			Level 11	90		
24.03.2017	12:00 PM	South	Level 1	-	Overcast	79.50
			Level 4	69.00		
			Level 11	90		
27.03.2017	12:00 PM	South	Level 1	-	Overcast	78.75
			Level 4	67.50		
			Level 11	90		
28.03.2017	12:00 PM	South	Level 1	-	Sunny	76.08
			Level 4	62.17		
			Level 11	90		
29.03.2017	12:00 PM	South	Level 1	-	Overcast	78.58
			Level 4	67.17		
			Level 11	90		
30.03.2017	12:00 PM	South	Level 1	-	Partly cloudy	78.83
			Level 4	67.67		
			Level 11	90		
31.03.2017	12:00 PM	South	Level 1	-	Sunny	78.42
			Level 4	66.83		
			Level 11	90		
Avg. B.O.I (by orientation)						**78.59**

Calculation of avg. B.O.I for afternoon time of the South orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	4:30 PM	South	Level 1	-	Partly cloudy	75.67
			Level 4	66.33		
			Level 11	85		
16.03.2017	4:30 PM	South	Level 1	-	Overcast	80.08
			Level 4	70.17		
			Level 11	90		
17.03.2017	4:30 PM	South	Level 1	-	Overcast	80.08
			Level 4	70.17		
			Level 11	90		
20.03.2017	4:30 PM	South	Level 1	-	Overcast	79.00
			Level 4	68.00		
			Level 11	90		
21.03.2017	4:30 PM	South	Level 1	-	Sunny	79.00
			Level 4	68.00		
			Level 11	90		
22.03.2017	4:30 PM	South	Level 1	-	Sunny	79.50
			Level 4	69.00		
			Level 11	90		
23.03.2017	4:30 PM	South	Level 1	-	Sunny	79.75
			Level 4	69.50		
			Level 11	90		
24.03.2017	4:30 PM	South	Level 1	-	Overcast	79.33
			Level 4	68.67		
			Level 11	90		
27.03.2017	4:30 PM	South	Level 1	-	Overcast	78.75
			Level 4	67.50		
			Level 11	90		
28.03.2017	4:30 PM	South	Level 1	-	Overcast	78.75
			Level 4	67.50		
			Level 11	90		
29.03.2017	4:30 PM	South	Level 1	-	Partly cloudy	78.58
			Level 4	67.17		
			Level 11	90		
30.03.2017	4:30 PM	South	Level 1	-	Partly cloudy	78.83
			Level 4	67.67		
			Level 11	90		
31.03.2017	4:30 PM	South	Level 1	-	Overcast	78.42
			Level 4	66.83		
			Level 11	90		
Avg. B.O.I (by orientation)						**78.90**

Calculation of avg. B.O.I for morning time of the West orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	9:30 AM	West	Level 1	81.67	Overcast	70.86
			Level 4	67.07		
			Level 11	63.85		
16.03.2017	9:30 AM	West	Level 1	81.67	Overcast	72.13
			Level 4	68.59		
			Level 11	66.15		
17.03.2017	9:30 AM	West	Level 1	81.67	Overcast	73.44
			Level 4	72.50		
			Level 11	66.15		
20.03.2017	9:30 AM	West	Level 1	87.00	Overcast	75.77
			Level 4	72.39		
			Level 11	67.92		
21.03.2017	9:30 AM	West	Level 1	86.00	Sunny	73.12
			Level 4	70.33		
			Level 11	63.02		
22.03.2017	9:30 AM	West	Level 1	85.67	Sunny	74.08
			Level 4	73.04		
			Level 11	63.54		
23.03.2017	9:30 AM	West	Level 1	85.33	Sunny	74.23
			Level 4	74.35		
			Level 11	63.02		
24.03.2017	9:30 AM	West	Level 1	88.00	Overcast	74.86
			Level 4	72.72		
			Level 11	63.85		
27.03.2017	9:30 AM	West	Level 1	87.67	Overcast	74.61
			Level 4	72.61		
			Level 11	63.54		
28.03.2017	9:30 AM	West	Level 1	86.00	Sunny	73.04
			Level 4	70.00		
			Level 11	63.13		
29.03.2017	9:30 AM	West	Level 1	81.67	Overcast	68.88
			Level 4	64.67		
			Level 11	60.31		
30.03.2017	9:30 AM	West	Level 1	81.33	Overcast	69.38
			Level 4	65.98		
			Level 11	60.83		
31.03.2017	9:30 AM	West	Level 1	82.00	Overcast	70.62
			Level 4	66.74		
			Level 11	63.13		
Avg. B.O.I (by orientation)						**72.69**

Calculation of avg. B.O.I for noon time of the West orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	12:00 PM	West	Level 1	79.33	Partly cloudy	70.94
			Level 4	68.70		
			Level 11	64.79		
16.03.2017	12:00 PM	West	Level 1	85.33	Overcast	74.58
			Level 4	71.41		
			Level 11	66.98		
17.03.2017	12:00 PM	West	Level 1	85.33	Sunny	74.94
			Level 4	72.50		
			Level 11	66.98		
20.03.2017	12:00 PM	West	Level 1	86.33	Overcast	72.94
			Level 4	69.35		
			Level 11	63.13		
21.03.2017	12:00 PM	West	Level 1	85.33	Sunny	72.38
			Level 4	68.59		
			Level 11	63.23		
22.03.2017	12:00 PM	West	Level 1	84.67	Sunny	73.93
			Level 4	73.70		
			Level 11	63.44		
23.03.2017	12:00 PM	West	Level 1	85.33	Sunny	74.23
			Level 4	74.35		
			Level 11	63.02		
24.03.2017	12:00 PM	West	Level 1	88.00	Overcast	74.96
			Level 4	72.72		
			Level 11	64.17		
27.03.2017	12:00 PM	West	Level 1	85.67	Overcast	73.19
			Level 4	71.09		
			Level 11	62.81		
28.03.2017	12:00 PM	West	Level 1	86.33	Sunny	73.12
			Level 4	69.89		
			Level 11	63.13		
29.03.2017	12:00 PM	West	Level 1	81.33	Overcast	68.63
			Level 4	64.67		
			Level 11	59.90		
30.03.2017	12:00 PM	West	Level 1	82.33	Partly cloudy	69.82
			Level 4	66.30		
			Level 11	60.83		
31.03.2017	12:00 PM	West	Level 1	81.67	Sunny	70.51
			Level 4	66.74		
			Level 11	63.13		
Avg. B.O.I (by orientation)						**72.63**

Calculation of avg. B.O.I for afternoon time of the West orientation for the first session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
15.03.2017	4:30 PM	West	Level 1	80.00	Partly cloudy	71.46
			Level 4	69.89		
			Level 11	64.48		
16.03.2017	4:30 PM	West	Level 1	85.00	Overcast	74.83
			Level 4	72.50		
			Level 11	66.98		
17.03.2017	4:30 PM	West	Level 1	85.00	Overcast	74.83
			Level 4	72.50		
			Level 11	66.98		
20.03.2017	4:30 PM	West	Level 1	86.00	Overcast	73.12
			Level 4	70.33		
			Level 11	63.02		
21.03.2017	4:30 PM	West	Level 1	87.67	Sunny	75.01
			Level 4	74.13		
			Level 11	63.23		
22.03.2017	4:30 PM	West	Level 1	85.33	Sunny	74.27
			Level 4	74.35		
			Level 11	63.13		
23.03.2017	4:30 PM	West	Level 1	88.33	Sunny	74.69
			Level 4	72.83		
			Level 11	62.92		
24.03.2017	4:30 PM	West	Level 1	87.67	Overcast	74.57
			Level 4	72.61		
			Level 11	63.44		
27.03.2017	4:30 PM	West	Level 1	88.00	Overcast	74.00
			Level 4	71.09		
			Level 11	62.92		
28.03.2017	4:30 PM	West	Level 1	85.67	Overcast	72.31
			Level 4	70.00		
			Level 11	61.25		
29.03.2017	4:30 PM	West	Level 1	81.33	Partly cloudy	70.25
			Level 4	68.70		
			Level 11	60.73		
30.03.2017	4:30 PM	West	Level 1	84.33	Partly cloudy	73.93
			Level 4	74.24		
			Level 11	63.23		
31.03.2017	4:30 PM	West	Level 1	84.33	Overcast	71.95
			Level 4	68.59		
			Level 11	62.92		
Avg. B.O.I (by orientation)						**73.48**

Calculation of avg. B.O.I for morning time of the East orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	9:30 AM	East	Level 1	77.86	Partly cloudy	80.47
			Level 4	78.65		
			Level 11	84.9		
24.07.2017	9:30 AM	East	Level 1	77.86	Sunny	80.47
			Level 4	78.65		
			Level 11	84.9		
25.07.2017	9:30 AM	East	Level 1	76.43	Overcast	79.73
			Level 4	78.08		
			Level 11	84.69		
26.07.2017	9:30 AM	East	Level 1	75.71	Partly cloudy	79.52
			Level 4	78.27		
			Level 11	84.58		
27.07.2017	9:30 AM	East	Level 1	76.43	Partly cloudy	80.03
			Level 4	78.46		
			Level 11	85.21		
28.07.2017	9:30 AM	East	Level 1	76.43	Overcast	80.28
			Level 4	79.62		
			Level 11	84.79		
Avg. B.O.I (by orientation)						**80.08**

Calculation of avg. B.O.I for noon time of the East orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	12:00 PM	East	Level 1	77.86	Sunny	80.47
			Level 4	78.65		
			Level 11	84.9		
24.07.2017	12:00 PM	East	Level 1	77.14	Overcast	80.27
			Level 4	78.65		
			Level 11	85		
25.07.2017	12:00 PM	East	Level 1	76.43	Sunny	79.64
			Level 4	77.69		
			Level 11	84.79		
26.07.2017	12:00 PM	East	Level 1	75.71	Sunny	79.73
			Level 4	78.27		
			Level 11	85.21		
27.07.2017	12:00 PM	East	Level 1	76.43	Sunny	79.80
			Level 4	78.27		
			Level 11	84.69		
28.07.2017	12:00 PM	East	Level 1	76.43	Overcast	80.02
			Level 4	78.85		
			Level 11	84.79		
Avg. B.O.I (by orientation)						**79.99**

Calculation of avg. B.O.I for afternoon time of the East orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	4:30 PM	East	Level 1	77.86	Sunny	80.47
			Level 4	78.65		
			Level 11	84.90		
24.07.2017	4:30 PM	East	Level 1	77.14	Overcast	80.16
			Level 4	78.65		
			Level 11	84.69		
25.07.2017	4:30 PM	East	Level 1	75.71	Partly cloudy	79.52
			Level 4	78.27		
			Level 11	84.58		
26.07.2017	4:30 PM	East	Level 1	75.71	Sunny	79.73
			Level 4	78.27		
			Level 11	85.21		
27.07.2017	4:30 PM	East	Level 1	76.43	Partly cloudy	79.80
			Level 4	78.27		
			Level 11	84.69		
28.07.2017	4:30 PM	East	Level 1	75.71	Partly cloudy	80.33
			Level 4	80.58		
			Level 11	84.69		
Avg. B.O.I (by orientation)						**80.00**

Calculation of avg. B.O.I for morning time of the North orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	9:30 AM	North	Level 1	82.50	Partly cloudy	80.42
			Level 4	76.25		
			Level 11	82.50		
24.07.2017	9:30 AM	North	Level 1	82.50	Sunny	80.42
			Level 4	76.25		
			Level 11	82.50		
25.07.2017	9:30 AM	North	Level 1	76.88	Overcast	78.13
			Level 4	76.25		
			Level 11	81.25		
26.07.2017	9:30 AM	North	Level 1	77.50	Partly cloudy	78.33
			Level 4	76.25		
			Level 11	81.25		
27.07.2017	9:30 AM	North	Level 1	76.88	Partly cloudy	78.54
			Level 4	76.25		
			Level 11	82.50		
28.07.2017	9:30 AM	North	Level 1	77.50	Overcast	76.46
			Level 4	70.63		
			Level 11	81.25		
Avg. B.O.I (by orientation)						**78.72**

Calculation of avg. B.O.I for noon time of the North orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	12:00 PM	North	Level 1	82.50	Sunny	80.42
			Level 4	76.25		
			Level 11	82.50		
24.07.2017	12:00 PM	North	Level 1	82.50	Overcast	80.00
			Level 4	76.25		
			Level 11	81.25		
25.07.2017	12:00 PM	North	Level 1	77.50	Sunny	78.33
			Level 4	76.25		
			Level 11	81.25		
26.07.2017	12:00 PM	North	Level 1	77.50	Sunny	78.33
			Level 4	76.25		
			Level 11	81.25		
27.07.2017	12:00 PM	North	Level 1	78.13	Sunny	78.54
			Level 4	76.25		
			Level 11	81.25		
28.07.2017	12:00 PM	North	Level 1	76.88	Overcast	76.25
			Level 4	70.63		
			Level 11	81.25		
Avg. B.O.I (by orientation)						**78.65**

Calculation of avg. B.O.I for afternoon time of the North orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky conditio n	Avg. B.O.I (%)
21.07.2017	4:30 PM	North	Level 1	82.50	Sunny	80.42
			Level 4	76.25		
			Level 11	82.50		
24.07.2017	4:30 PM	North	Level 1	82.50	Overcas t	80.00
			Level 4	76.25		
			Level 11	81.25		
25.07.2017	4:30 PM	North	Level 1	77.50	Partly cloudy	78.33
			Level 4	76.25		
			Level 11	81.25		
26.07.2017	4:30 PM	North	Level 1	77.50	Sunny	78.33
			Level 4	76.25		
			Level 11	81.25		
27.07.2017	4:30 PM	North	Level 1	78.13	Partly cloudy	78.54
			Level 4	76.25		
			Level 11	81.25		
28.07.2017	4:30 PM	North	Level 1	76.88	Partly cloudy	76.46
			Level 4	70.63		
			Level 11	81.88		
Avg. B.O.I (by orientation)						**78.68**

Calculation of avg. B.O.I for morning time of the South orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	9:30 AM	South	Level 1	-	Partly cloudy	77.67
			Level 4	65.33		
			Level 11	90		
24.07.2017	9:30 AM	South	Level 1	-	Sunny	77.67
			Level 4	65.33		
			Level 11	90		
25.07.2017	9:30 AM	South	Level 1	-	Overcast	77.25
			Level 4	64.50		
			Level 11	90		
26.07.2017	9:30 AM	South	Level 1	-	Partly cloudy	78.00
			Level 4	66.00		
			Level 11	90		
27.07.2017	9:30 AM	South	Level 1	-	Partly cloudy	78.25
			Level 4	66.50		
			Level 11	90		
28.07.2017	9:30 AM	South	Level 1	-	Overcast	78.42
			Level 4	66.83		
			Level 11	90		
Avg. B.O.I (by orientation)						**77.88**

Calculation of avg. B.O.I for noon time of the South orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	12:00 PM	South	Level 1	-	Sunny	77.67
			Level 4	65.33		
			Level 11	90		
24.07.2017	12:00 PM	South	Level 1	-	Overcast	77.67
			Level 4	65.33		
			Level 11	90		
25.07.2017	12:00 PM	South	Level 1	-	Sunny	77.33
			Level 4	64.67		
			Level 11	90		
26.07.2017	12:00 PM	South	Level 1	-	Sunny	78.25
			Level 4	66.50		
			Level 11	90		
27.07.2017	12:00 PM	South	Level 1	-	Sunny	78.00
			Level 4	66.00		
			Level 11	90		
28.07.2017	12:00 PM	South	Level 1	-	Overcast	78.08
			Level 4	66.17		
			Level 11	90		
Avg. B.O.I (by orientation)						**77.83**

Calculation of avg. B.O.I for afternoon time of the South orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	4:30 PM	South	Level 1	-	Sunny	77.67
			Level 4	65.33		
			Level 11	90		
24.07.2017	4:30 PM	South	Level 1	-	Overcast	77.67
			Level 4	65.33		
			Level 11	90		
25.07.2017	4:30 PM	South	Level 1	-	Partly cloudy	78.00
			Level 4	66.00		
			Level 11	90		
26.07.2017	4:30 PM	South	Level 1	-	Sunny	78.25
			Level 4	66.50		
			Level 11	90		
27.07.2017	4:30 PM	South	Level 1	-	Partly cloudy	78.42
			Level 4	66.83		
			Level 11	90		
28.07.2017	4:30 PM	South	Level 1	-	Partly cloudy	89.25
			Level 4	88.50		
			Level 11	90		
Avg. B.O.I (by orientation)						**79.88**

Calculation of avg. B.O.I for morning time of the West orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky conditio n	Avg. B.O.I (%)
21.07.2017	9:30 AM	West	Level 1	83.33	Partly cloudy	71.52
			Level 4	69.35		
			Level 11	61.88		
24.07.2017	9:30 AM	West	Level 1	83.33	Sunny	71.52
			Level 4	69.35		
			Level 11	61.88		
25.07.2017	9:30 AM	West	Level 1	86.00	Overcas t	72.42
			Level 4	70.11		
			Level 11	61.15		
26.07.2017	9:30 AM	West	Level 1	85.67	Partly cloudy	72.82
			Level 4	72.07		
			Level 11	60.73		
27.07.2017	9:30 AM	West	Level 1	86.67	Partly cloudy	72.64
			Level 4	70.33		
			Level 11	60.94		
28.07.2017	9:30 AM	West	Level 1	88.33	Overcas t	73.55
			Level 4	70.76		
			Level 11	61.56		
Avg. B.O.I (by orientation)						**72.41**

Calculation of avg. B.O.I for noon time of the West orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	12:00 PM	West	Level 1	83.33	Sunny	71.52
			Level 4	69.35		
			Level 11	61.88		
24.07.2017	12:00 PM	West	Level 1	82.67	Overcast	71.31
			Level 4	70.43		
			Level 11	60.83		
25.07.2017	12:00 PM	West	Level 1	85.67	Sunny	72.44
			Level 4	69.57		
			Level 11	62.08		
26.07.2017	12:00 PM	West	Level 1	85.67	Sunny	72.89
			Level 4	72.07		
			Level 11	60.94		
27.07.2017	12:00 PM	West	Level 1	87.00	Sunny	72.43
			Level 4	69.67		
			Level 11	60.63		
28.07.2017	12:00 PM	West	Level 1	88.00	Overcast	73.23
			Level 4	70.33		
			Level 11	61.35		
Avg. B.O.I (by orientation)						**72.30**

Calculation of avg. B.O.I for afternoon time of the West orientation for the second session of field measurements

Date	Time	Orientation	Floor Level	Avg. Occlusion index (%)	Sky condition	Avg. B.O.I (%)
21.07.2017	4:30 PM	West	Level 1	83.33	Sunny	71.52
			Level 4	69.35		
			Level 11	61.88		
24.07.2017	4:30 PM	West	Level 1	82.67	Overcast	71.38
			Level 4	70.43		
			Level 11	61.04		
25.07.2017	4:30 PM	West	Level 1	85.67	Partly cloudy	72.82
			Level 4	72.07		
			Level 11	60.73		
26.07.2017	4:30 PM	West	Level 1	85.67	Sunny	72.89
			Level 4	72.07		
			Level 11	60.94		
27.07.2017	4:30 PM	West	Level 1	87.00	Partly cloudy	72.43
			Level 4	69.67		
			Level 11	60.63		
28.07.2017	4:30 PM	West	Level 1	86.00	Partly cloudy	72.59
			Level 4	70.33		
			Level 11	61.46		
Avg. B.O.I (by orientation)						**72.27**

Appendix C
Questionnaire survey form

DEPARTMENT OF ARCHITECTURE, FACULTY OF DESIGN AND ARCHITECTURE

A SURVEY ON OCCUPANTS' PREFERENCE OF DAYLIGHT AND WINDOW BLIND OPERATION IN GREEN OFFICE BUILDINGS IN MALAYSIA

Dear Participant,
The topic of this research is "Daylight Performance and Occupants' Behaviour of Window Blind Operation: A Case Study of a Green Office Building in Malaysia". This questionnaire survey aims to explore the occupants' behaviour regarding their control of window blinds and how window blinds are affecting the daylight performance in office buildings in Malaysia. Findings from this survey will be helpful to understand the actual scenario of daylight performance in green office buildings and the problems regarding daylight, artificial lightings and window blinds. This study could be used for future design to improve the visual environment inside office buildings and the productivity of the office employees.
Therefore, I would like to invite you to participate in this survey. Completing this questionnaire should take no longer than 10 minutes. Please complete your survey questionnaire before **31st of July 2017** and keep it on your front desk for collection.
Please be advised that this survey is being conducted privately and it is agreed that individual survey documents will not be forwarded for any other purposes other than for this research and the information in them will not be available to other people apart from presentation in a summary form.
Should you have any question or concern regarding this research, please do not hesitate to contact me at the address below. Thank you very much in advance for your support and cooperation in this survey.

Warm Regards,

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PART A: PERSONAL INFORMATION

Please tick [√] the appropriate answers from the questions below.

A1. Your gender? ☐ Male ☐ Female

A2. Your age? ☐ Under 20 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60 and over

A3. What is your main task at your office?

☐ Performing computer-related task
☐ Reading and writing
☐ Interviewing and/or using a telephone
☐ Other. Please specify

____

A4. Do you have any windows next to your work space?

☐ Yes
☐ No

A5. What is the relationship of your seating position with windows?

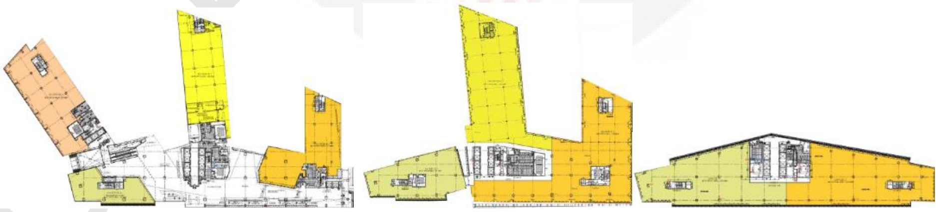
☐ I face the window directly
☐ I face partial window and wall (window corner)
☐ I face sidewall (window is to my right)
☐ I face sidewall (window is to my left)
☐ I face back wall corner (no window)
☐ I face back wall (window is at my back)

A6. On which floor level is your workstation located?

____

A7. What is the orientation of your windows? If you have a corner office, please specify both orientations in the box given below. (Or you can also tick [√] your seating position in the floor plan given below)

☐ North ☐ Northeast ☐ East ☐ Southeast
☐ South ☐ Southwest ☐ West ☐ Northwest



Level 1 Level 4 Level 11

PART B: WINDOW BLIND OPERATION

This section is about controlling the window blinds. Please provide the answers that seem best to you.

B1. Can you control your window blinds at your workspace?

☐ Yes ☐ No (If your answer is No, please go to question C1)

B2. How many times do you adjust the position of the blinds?
☐ I rarely adjust the position of the blinds ☐ Once per day
☐ Occasionally (2-3 times per day) ☐ Often (more than 3 times per day)

B3. Is there any specific time of the day when you open your window blind? Please check all that apply.
☐ Beginning of the day ☐ During morning ☐ Before lunch
☐ During lunchtime ☐ After lunch ☐ During afternoon
☐ End of the day ☐ I rarely open my window blinds
☐ Other. Please specify ______________________

B4. Is there any specific time of the day when you close your window blind? Please check all that apply.
☐ Beginning of the day ☐ During morning ☐ Before lunch
☐ During lunchtime ☐ After lunch ☐ During afternoon
☐ End of the day ☐ I rarely close my window blinds
☐ Other. Please specify ______________________

B5. When you adjust your window blind, what is the approximate position of your window blind? Please tick [√] at the diagram below.
1= Fully opened, 2= 75% opened, 3= 50% opened, 4= 25% opened, 5= fully closed

1
2
3
4
5

B6. Why do you adjust your window blind? Please check all that apply.
☐ To increase the level of daylight in the workspace
☐ To reduce glare/ brightness from daylight
☐ To feel the warmth of the sun
☐ To reduce the heat from the sun
☐ To have a view of the outside
☐ To increase visual privacy
☐ To increase room spaciousness
☐ To reduce the level of visual stimulus from outside
☐ Other. Please specify ______________________

B7. What are the main two reasons for you to open/rise your window blind?
☐ To increase the level of daylight in workspace
☐ To feel the warmth of the sun
☐ To have a view of the outside
☐ To increase room spaciousness
☐ Other. Please specify ______________________

B8. What are the main two reasons for you to close/lower your window blind?
☐ To reduce the overall brightness of workspace
☐ To reduce reflected glare on the computer screen
☐ To reduce the heat from the sun
☐ To increase visual privacy
☐ To reduce the level of visual stimulus from outside
☐ Other. Please specify ______________________

B9. Do you think window blinds can reduce glare from daylight? Please tick [√] the best answer according to you.
1= Strongly disagree, 2= Slightly disagree, 3= Agree, 4= Slightly agree, 5= Strongly agree

Strongly disagree	Slightly disagree	Agree	Slightly agree	Strongly agree
1	2	3	4	5

B10. Do you think window blinds can reduce glare from the computer screen? Please tick [√] the best answer according to you.
1= Strongly disagree, 2= Slightly disagree, 3= Agree, 4= Slightly agree, 5= Strongly agree

Strongly disagree	Slightly disagree	Agree	Slightly agree	Strongly agree
1	2	3	4	5

B11. Do you think window blinds can increase the privacy of your workspace? Please tick [√] the best answer according to you.
1= Strongly disagree, 2= Slightly disagree, 3= Agree, 4= Slightly agree, 5= Strongly agree

Strongly disagree	Slightly disagree	Agree	Slightly agree	Strongly agree
1	2	3	4	5

PART C: SATISFACTION WITH VISUAL ENVIRONMENT

This section is about your satisfaction level with the visual environment in your workspace. Please provide the answers that seem best to you.
C1. Please rate your satisfaction level with your window shading system. Please tick [√] the best answer according to you.
1= Very dissatisfied, 2= Dissatisfied, 3= Slightly dissatisfied, 4= Moderate, 5= Slightly satisfied, 6= Satisfied, 7= Very satisfied

Very dissatisfied	Dissatisfied	Slightly dissatisfied	Moderate	Slightly satisfied	Satisfied	Very satisfied
1	2	3	4	5	6	7

C2. Please rate your satisfaction level with the amount of daylight in your workspace? Please tick [√] the best answer according to you.
1= Very dissatisfied, 2= Dissatisfied, 3= Slightly dissatisfied, 4= Moderate, 5= Slightly satisfied, 6= Satisfied, 7= Very satisfied

Very dissatisfied	Dissatisfied	Slightly dissatisfied	Moderate	Slightly satisfied	Satisfied	Very satisfied
1	2	3	4	5	6	7

C3. Please rate your satisfaction level with the visual comfort of the daylighting (e.g., glare, reflections, contrast). Please tick [√] the best answer according to you.
1= Very dissatisfied, 2= Dissatisfied, 3= Slightly dissatisfied, 4= Moderate, 5= Slightly satisfied, 6= Satisfied, 7= Very satisfied

Very dissatisfied	Dissatisfied	Slightly dissatisfied	Moderate	Slightly satisfied	Satisfied	Very satisfied
1	2	3	4	5	6	7

C4. Which type of light level do you prefer at your workspace? Please tick [√] the best answer according to you.
1= Very low, 2= Low, 3= Moderate, 4= Bright, 5= Very bright

Very low	Low	Moderate	Bright	Very bright
1	2	3	4	5

C5. Please rate the level of glare/excessive daylight from the windows. Please tick [√] the best answer according to you.
1= Intolerable, 2= Uncomfortable, 3= Acceptable, 4= Perceptible, 5= Not perceptible

Intolerable (too much glare)	Uncomfortable (glary)	Acceptable	Perceptible (slightly glary)	Not perceptible (no glare)
1	2	3	4	5

C6. Please rate the level of glare from the wall surface behind your computer screen. Please tick [√] the best answer according to you.
1= Intolerable, 2= Uncomfortable, 3= Acceptable, 4= Perceptible, 5= Not perceptible

Intolerable (too much glare)	Uncomfortable (glary)	Acceptable	Perceptible (slightly glary)	Not perceptible (no glare)
1	2	3	4	5

C7. The options below are potentially negative aspects of your provisions of indoor visual environment. What is the aspect that applies best to your visual environment in your current workspace? (please check all that apply).

☐ Too dark
☐ Too bright
☐ Computer screen glare
☐ Too much daylight
☐ Too much electric light
☐ Not enough daylight
☐ Not enough electric light
☐ Other. Please specify ______________________

C8. Is this overall light level (both daylight and artificial lighting) acceptable to you?

☐ Yes ☐ No

C9. Do you like to have automated blinds installed at your workspace instead of manually controlled blinds?

☐ Yes ☐ No

BIODATA OF STUDENT

S M Jubaer Alam was born on 30th January 1992 in Rajshahi, Bangladesh. He completed his bachelor's degree in architecture from Ahsanullah University of Science and Technology, Dhaka from the year 2009 till 2015. He worked in an architectural firm while he was pursuing his bachelor degree, which he continued after graduation for almost three years before coming to Malaysia for pursuing the master's degree in the Department of Architecture, Faculty of Design and Architecture from the year 2015 till 2019. Right now he is working as an architect in the BRAC Institute of Educational Development in Bangladesh as a part of the humanitarian crisis project based on the Rohingya refugee camps at Cox's Bazar.

LIST OF PUBLICATIONS

Alam, S. M. J., & Shari, Z. (2019). Occupants Interaction with Window Blinds in A Green-Certified Office Building in Putrajaya, Malaysia. *Journal of Design and Built Environment*, *19*(1), 60–73.

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WINDOW BLIND OPERATIONS AND THEIR RELATIONSHIP WITH ENVIRONMENT FACTORS AND OCCUPANT'S BEHAVIOUR IN A GREEN-CERTIFIED OFFICE BUILDING IN MALAYSIA

NAME OF STUDENT:

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