

The Architecture of Public Park: Fading the Line between Architecture and Landscape

Mohd Hamdan Ahmad, PhD

Associate Professor, Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

ABSTRACT: *This paper reviews 3 consultancy projects of public parks in nature. The projects were completed within the last 5 years by group of academic staffs in the faculty. Public Park design can be considered as design in the in-between territory. It hinges on the interdisciplinary relationship between two major fields, architecture and landscape architecture. Landscape architect from department of landscape architecture deals with the park and architect from the department of architecture normally deals with the related buildings. Other consultant from the faculty staff is quantity surveyor from department of quantity surveying, making Public Park as truly the most interdisciplinary project reflecting the multidisciplinary nature of the faculty of built environment. The projects being reviewed here illustrate how academic staffs can contribute to the community through consultancy, and by so doing reflects the good relationship between the university, the city and the public.*

Keywords: Public Parks, Interdisciplinary

Introduction

Public Parks is basically associated with an open space and recreational activities. Public Parks normally consists of two major components: the park and its amenities, the landscape and the architecture. Park design can be considered as the in-between territory that in most cases also involved urban design and ecology or environmental consideration. It hinges on the interdisciplinary relationship between the two fields of architecture and landscape architecture.

Public Park Design in General

Public park design is not just an open space with green area providing place for leisure but it can also become an important node within the city. It acts as a green lung that provide place for people to meet, relax and enjoy while easing of the urban stress and promote healthy activities. Public parks can be turned into educational

place when designers incorporate an element of learning into the design. Similarly public parks can be used as marketing tools promoting healthy community within new housing estate, as many developers have opted to advertise. However, public parks if not planned properly could become a negative place raising social and safety concerns, not to forget the associated cost of maintenance and operation.

Park design involves many professional but the two most prominent design consultants are landscape architect and architect. Landscape architect deals with the park and architect normally deals with the related buildings. Other consultants include from civil, mechanical and electrical engineers, quantity surveyor, theme park designers and lighting specialists, making Public Parks as truly the most interdisciplinary project.

The close collaboration during the design stage produces the final outcome of the project that maintains the physical form but sensibly fades the line between architecture and landscape. It demonstrates the enduring and balance relationship where they both depend on each other to make an impact of careful man-made idea harnessing existing terrain and resources. In most cases the projects draw attention to the design that fit into the tropical environment and natural liaison within existing setting, against the imposing idea of building as object within the park.

The public park projects being reviewed here by the author as architect (as one of the consultant involved) illustrate this close collaboration between the different professionals in public parks design in Johor Bahru under the umbrella of Bureau of Innovation and Consultancy, Universiti Teknologi Malaysia or better known as BIP-UTM. The projects were funded by National Landscape Department (Jabatan Landskap Negara).

**Taman Tropika and Rumah Tropika, Universiti Teknologi Malaysia (UTM),
Skudai, Johor.**

*(Tropical Park and Tropical House, Universiti Teknologi Malaysia (UTM), Skudai,
Johor)*

Taman Tropika is a public park serving both the university and the surrounding community. It is at the edge of the lakes fronting UTM thus enhances the main gateway to UTM. Taman Tropika is the first phase of the public park development around the lake and it was completed in 2000. Other park proposed around the lakes includes laman riadah and laman bistari that will offer active recreational activities and house specific educational events.

Taman Tropika is famous for its collection of heliconias and gingers species. It is mainly designed for passive recreational activities, especially for students to refresh and relax after their busy routine schedules. They can also do light evening strolls and exercises apart from watching others take part in the water activities.

There are two major buildings in the park; The Tropical House and The Gallerium (a gallery cum museum for UTM). Both buildings are treated as pavilion buildings to fit easily the site and reduce the footprints. The location of these building later adjusted on site to avoid existing trees being cut. The gallerium, which was added later, formed the west wing and redefined the courtyard from which the majestic view of the UTM's mosque is framed. Rumah Tropika (Tropical House) is a single space timber building functions as information gallery for Taman Tropika (Tropical Park). Both buildings are designed to be responsive to the natural context. They are designed to take advantage of natural environment and compliment to the park/garden setting. The buildings face to the lake with open timber decking and viewing pavilion.

The character and image of the buildings reflect tropical architectural solution, fully shaded, avoiding direct sunlight and maintaining good daylight. The Tropical House is naturally ventilated. The use of timber in the Tropical House compliment the garden setting by incorporating landscape as part of the life of the building. It is recreational as well as educational facility towards understanding tropical building and plants. It is open to university and neighbouring communities. The overall result is a signature for tropical architecture and park design as illustrated in the photographs below.



Taman Orkid, Hutan Bandar, Majlis Bandaraya Johor Bahru, Johor Bahru.
(The Orchid Garden, Urban Forest, Johor Bahru City Council, Johor Bahru)

The Orchid Garden is the latest addition to the Urban Forest Public Park development under Johor Bahru City Council. The Urban Forest is a regular and popular spot to the city dwellers for early morning and evening jog. It is also a scenic picnic location especially during weekends. The Urban Forest offers public comprehensive parks suitable for all ages, from varieties of children play areas to urban camping and water activities.

The Orchid Garden is responding to the growing number of orchid enthusiasts in Johor Bahru and also supports the annual international orchid fair organised by Johor Bahru City Council. The Orchid Garden here houses many type or species of orchids. The overall master plan takes advantage of the site and its existing natural features. The architecture components include management offices, AV rooms, orchid gallery, jewel house, orchid nursery and maintenance building. The watching tower cum water tank offers majestic view of the orchid garden and to the overall park as well as provides glimpses of the city skyline.

The orchids here are displayed as natural as possible inside and outside the open gallery, as part of the buildings, along the paths and in the wild environment according to their special unique requirement and needs. The architectural solutions must understand and adhere to these special requirements by careful environmental consideration as demonstrated in the design of various buildings. The buildings provide comfort for public or visitors and permit suitable daylight/sunlight for orchid to perform photosynthesis. For the sensitive hybrid orchid species, they are housed under the special transparent structure called jewel house. Even though the Jewel House is a simple structure but the resultant environmental condition must provide the compulsory daylight level, shelter from rain, and the indoor temperature equivalent to those experienced outdoor. The following photographs give us an idea about the overall development of the Orchid Garden.





5.0 Taman Merdeka, Majlis Bandaraya Johor Bahru, Johor Bahru.

(Freedom Park, Johor Bahru City Council, Johor Bahru)

Taman Merdeka is the latest public park initiated by the Johor Bahru City Council. It is situated along Jalan Kolam Ayer and Tasek Utara about 1 km from the Urban Forest. The first phase has just been completed and the next phase will begin soon. Total development Taman Merdeka is about 22 hectares. The Merdeka Park is a themed public park designed to reflect the struggle for independent and promote patriotism among the current generation.

The central idea in this public park is to commemorate the important events leading to the independent of the nation and the state of Johor. The important history of the struggle and challenges towards becoming an independent nation is reflected through historical images, reliefs, notes and symbolic expressions. The overall architecture and landscape design reflects the different era or significant events in Johor, thus creating different themes and experience to the public. The careful consideration on the important of site and natural environment make this park design seem fitting within its context even though the architectural styles changes accordingly.

The different eras or timelines towards independent are put into a sequential zone creating a timeline of architectural illustrations of meaningful and easily appreciated chronological historical information. It is historical gathering expressed physically by the consultant group through architecture and landscape in order to share the moments leading to the independence and indirectly educate the public pictorially with facts and associated ambience.

Taman Merdeka is currently undergoing its second phase of development. When the project is completed it will become a new attraction for the community in Johor Bahru. The project will be important for the young generation to appreciate the struggle of their elders and forefathers in ensuring their country and state now as truly peaceful developing nation. The following photos taken from the first phase illustrate the mixture of architectural style of malay and colonial architecture.

6.0 Conclusion

The public park projects reviewed above focused only on 3 projects. There are other public projects that the staffs in the faculty have contributed meaningfully to the community inside Johor Bahru or in other districts in Johor. This paper has highlighted the intricacies of public park designs as truly reflecting multidisciplinary fields fading the line between architecture, landscape and nature.

Acknowledgement

(3)

I_{dn} is the intensity of the direct normal radiation. Assuming for a given incident angle of (θ) , the relationship between I_{bv} and I_{dn} is a constant ($K\theta$). Thus, it can be expressed as;

$$\text{Cos } (\theta) = I_{bv} / I_{dn} = K\theta \quad (4)$$

The window g-value

The solar heat transmission through a glazing is higher when the solar radiation incident perpendicular on the glazing surface. The energy received by the surface decreases when the solar beam moves away from the window normal. The window *g-value* indicates which portion of the incident solar radiation is transmitted and absorbed by the window and become heat in building.

The solar heat gain is expressed by the transmission and absorption coefficients as polynomials in the cosine of the solar incidence angle (figure 1). Transmittance and absorptance properties for glazing are developed by Roos and Karlsson (1998).

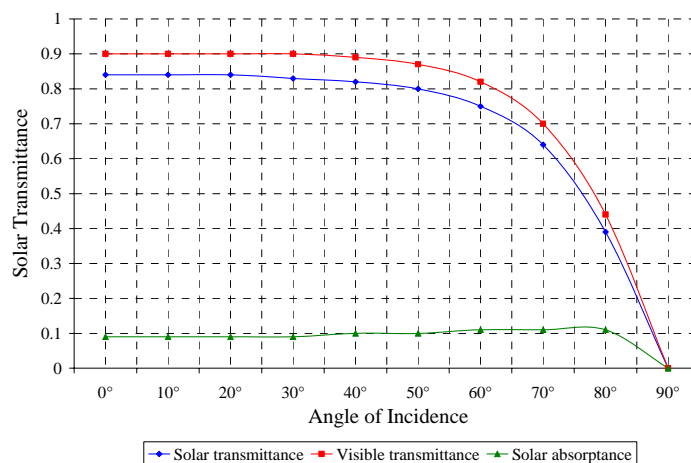


Figure1: The solar transmittance (g-value), visible transmittance and solar absorptance for single clear glass window as a function of the angle of incidence

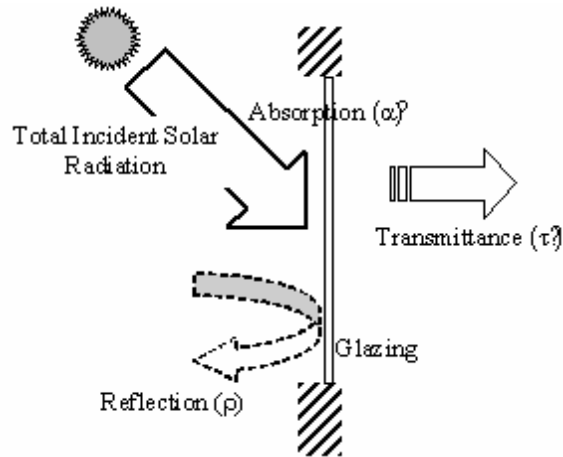


Figure 2: Instantaneous heat balances through sunlit glazing material

Transmission (τ) and absorptance (α) coefficients were determined for direct and diffuse solar radiation as follows:

Hourly solar heat gain on a vertical window surface, $Q_{sol,v}$ (W/m^2) is given by:

$$Q_{sol,v} = I_{b,v} (\tau_b + Ni\alpha_b) + I_{d,v} (\tau_d + Ni\alpha_d) \quad (5)$$

Since only direct solar radiation is considered,

Direct Radiation:

$$Q_{sol,b} = I_{b,v} (\tau_b Ni\alpha_b) \quad (6)$$

Where,

$$g_b = (\tau_b Ni\alpha_b) \quad (7)$$

$$\tau = C1 + C2\cos(\theta) + C3\cos^2(\theta) + C4\cos^3(\theta) + C5\cos^4(\theta) + C6\cos^5(\theta) \quad (8)$$

And

$$\alpha = A1 + A2\cos(\theta) + A3\cos^2(\theta) + A4\cos^3(\theta) + A5\cos^4(\theta) + A6\cos^5(\theta) \quad (9)$$

For diffuse radiation, Stephenson calculated τ_{dif} and α_{dif} to be 0.799 and 0.0544 respectively. Values of the constants $C1, C2, C3, C4, C5$ & $C6$ and $A1, A2, A3, A4, A5$ & $A6$ depends on the glass type and the number of panes. Referred values were obtained from the DOE 2.2 Engineering manual.

The inward flowing fraction N_i of the absorbed radiation can be expressed as:

$$N_i = h_i / (h_i + h_o) \quad (10)$$

Where h_i and h_o are the heat transfer coefficients of the inside and out side glazing surfaces respectively, given in $W/m^2 K$. Inward flowing fraction for single glazing is 0.268, reference to ASHRAE fundamentals, (1993). This value is used for present calculations.

Hence, the secondary heat transmission from the absorbed solar radiation can be given as:

$$\tau_{\bar{a}} = N_i \alpha = 0.268 * \alpha \quad (11)$$

Based on the above theoretical assumptions hourly values were derived from the simulation. Then correspondent g -values were determined for each set of solar altitude (β) and azimuth (ϕ) angles using the fundamental solar geometrical relationship. However g -values for direct solar radiation is taken into consideration as the diffuse component of radiations are independent of the sun position.

$$\cos(\theta) = \cos(\beta) * \cos(\phi - \psi) \quad (12)$$

Where (ψ), is the orientation of the façade from the same reference direction as the solar azimuth. If the sun is behind the façade ($\phi - \psi$) >90 or negative (-) value is indicated.

The g_{θ} - values obtain from the above method is the g -value for the reference window. By normalizing the g_{θ} values with g_0 base value, (which is the maximum

transmittance for any given angle, means when the angle of incidence is zero) and the new *g value* can be plotted according to the solar projection and super impose on a solar path diagram.

$$G = g_{\theta} / g_0 \quad (13)$$

The nomenclature for *G* is represented by 'g-value', which implies the fraction of incidence direct solar radiation (I_{bv}) transmitted into the interior through the corresponding glass window. The plotted normalized *g value* is represented by a concentric circle. The inner most circle encompasses the solar position for the $g > 0.9$ value, the second innermost circle for $g > 0.8$ and the third $g > 0.7$ so on. Hence, $g > 0.7$ value implies that 70% of solar radiation from g_0 value is transmitted into the interior through the window pane.

GCos-value

Values obtain for K_{θ} (Eq. 4) and $g(\theta)$ (Eq.12) from step one and two can be combined into one single value and define it as *GCos-value*. This also can be called as cosine weighted solar angle dependent g-value, Duboi (2000). Hence, for a given incident angle (x), it can be stated as:

$$G_{(x)} \text{Cos}_{(x)} = \{g(x)\} \times \{K(x)\} \quad (14)$$

The *GCos-value* thus specifies the fraction of direct normal solar radiation (I_{dn}) that is transmitted in to the building through the window opening. The calculated *GCos values* using Subang Jaya Meteorological data for east, west, north and south orientations were shown in the following tables (Appendix 1: a, b, c & d). For East and West orientations values were obtain on all twelve months. North orientation data were tabulated for April, May, June, July and August as the direct solar radiation falls on this façade only during these months. South orientation data were collected during the months of January, February, March, September, October, November and December. One day is selected for each month to understand the correlation between each parameter described in above steps. These dates were assumed to be the maximum solar radiation received for respective months. However, for further

analysis, months with highest GCos values, maximum incident and transmitted values were selected.

The obtained $G_{(x)}\text{Cos}_{(x)}$ values were normalized with $G_{(0)}\text{Cos}_{(0)}$ base value, (which is the maximum value for any given angle, when the angle of incidence is zero) and the new GCos- value can be plotted according to the solar projection and super impose on a solar path diagram as for *g-value* in step two. Similar to *g-value*, each GCos value encompasses solar position at given altitude and azimuth angle. E.g. Maximum values of $\text{GCos}>0.9$ delimits the inner most circle, $\text{GCos}>0.8$ next inner most circle and $\text{GCos}>0.7$ third inner circle so forth.

Direct Solar Gain

The intensity of the solar radiation varies throughout the day and the year depending on the location and the atmospheric conditions. The intensity direct solar radiation (I_{bv}) can be calculated on any surface for given atmospheric conditions using equation, (Eq. 3). Hence, total solar gain due to direct solar radiation can be obtained by;

$$Q_{sol} = I_{dn} \cdot \text{GCos} \cdot A \quad (15)$$

Where A is the window area.

The values of Q_{sol} is calculated using solar radiation data obtained from Subang Meteorological Station, in Kuala Lumpur and compared with window GCos-values for the main cardinal orientations, (Appendix 1: Table a, b, c, d).

Discussion of Results

The shading depth depends on the required period of the day, where the solar transmission is high. Assuming the building is occupied from 09:00 AM-17:00PM and this period can be accepted as the maximum shading is required. Since the working period is asymmetrical with respect to solar path, critical hours of solar radiation transmission for each orientation differed. The lowest horizontal shadow angle (HSA - 2.3°) is selected from all cardinal orientations to determine the shading length. Depth of the device is given as a proportion to the window height, (1.82 meter or 6 feet).

This dimensionless ratio; external horizontal shading depth to window glazing height, is defined as 'overhang ratio' (OHR).

The following procedure was used to determine the overhang ratio or the projection factor:

1. Determine the critical overheating period of the day, depending on the orientation of the fenestration. E.g. east 9:00- 12:00 hours, west 13:00- 17:00 hours, north and south between 9:00 AM and 17.00 PM hours.
2. From the tables (Appendix 1: a, b, c & d) maximum G-Cos values were identified for respective orientations.
3. Compare the solar radiation intensities obtain for the respective G-Cos values at (2).
4. Select the highest solar intensity and the correspondence G-Cos value and the correspondence overhang ratio.

1. East and West Orientation

Impact of solar radiation incidence on the east façade is critical from 09:00-12:00 hours and 13:00-17:00 hours for the west oriented facades. Beyond this limit the building itself give shade as the sun position is behind the respective facades.

Window angle dependent *g-values* and *GCos-values* are high (>0.9) for east orientation in the morning hours with lowest solar altitude angles and gradually decreased when sun reaches toward noon position. This implies that between 8:00 and 9:00 hours in the morning, most of the incident radiation transmits through the fenestration system (more than 90%). However, solar gain due to direct solar radiation incidence on the vertical surface is low between 8:00 and 9:00 hours compared to higher solar altitude. Vice-versa, although there is high intensity of global solar radiation (> 600 W/m²) around noon the fraction of radiation transmitted is lower (less than 40%) than at low solar altitude solar positions. Among all the months, January, February and March (table 1) indicated a high *g-value* (>0.9) and *GCos* (>0.8) values for east orientation. This implies that over 90% of *g_o-value* was transmitted into the building. Also, it could be stated as 10% of solar radiation

transmittance was reduced from g_0 -value for that respective solar altitude and azimuth angles. Correspondence overhang ratios for all three days were indicated as 1.74, 1.72 & 1.59 for January, February and March respectively. But the direct solar gain is high on March 21st, compared to January and February. This indicates that only overhang ratio of 1.59 is required to terminate maximum amount of direct solar radiation impinging on the east façade compared to overhang ratios at other low solar altitude angles. This is about 8% reduction compared to the overhang ratio at lowest solar altitude (1.74). Therefore, it can be assumed that an external horizontal shading device with an overhang ratio 1.6 (~1.59) as optimum depth for east facing fenestration. The lowest overhang ratio of less than 0.2 were reported on April, May, June, August, September, October, November and December at 12.00 noon, for east facing fenestration. The overhang ratios for fenestration on east façade range from 0.13 to 1.74 during critical hours (9:00-12:00).

Similarly, for west orientation a high g -value (>0.9) and $GCos$ -values (>0.9) are indicated for the month of September and October at 17:00 hours (table 1). Also the correspondence overhang ratios were 2.26 and 2.53 which suggested a very deep horizontal overhang. But on these two days and at the particular hour (17:00), the direct solar gain is very low. From all the months March and May indicated high direct solar gain on the west façade. Hence, the results indicated an overhang ratio of between 2.04 and 1.90 is sufficient to eliminate maximum amount of direct solar radiation incident on the west façade during the critical hour (17:00) of the overheated period. The overhang ratio range varies from >0.1 to >2.53 for west orientation.

Table 1: Summary of maximum g -value and $GCos$ -value obtain for East and West orientations.

Orientation/ Day/Month	Hour	Sol. Alt	Sol. Azi	VSA	OHR	Incid. Anagl	g -value	G-Cos value	Qsol (W/m ²)
E-2801	9	28	112.7	30.0	1.74	35.5	0.99	0.81	367
E-2302	9	29.5	103.4	30.2	1.72	32.1	1.00	0.84	274
E-2103	9	32.2	92	32.2	1.59	32.3	1.00	0.84	444

W-2103	17	27.7	268.4	27.7	1.90	27.7	1.00	0.88	213
W-2105	17	24.6	290.6	26.1	2.04	31.7	1.00	0.85	332
W-2409	17	23.9	267.9	23.9	2.26	24.0	1.00	0.91	79
W-2010	17	21.1	257.6	21.6	2.53	24.3	1.00	0.91	121

This implies that considering the glass solar radiation transmittance or the g -value, G_{Cos} -value and the solar gain due to direct solar radiation incident on the glazing are important factor in determining the solar shading depth.

2. North and South Orientation

The g -value and G_{Cos} value for North and South indicated lower values than east and west orientations. During the month of May, June and July high g -value (>0.7) and G_{Cos} -values (>0.2 , >0.3 & >0.2 respectively) were obtained for north orientation. Month of June indicated high values than other months, (table 2). Hence the G_{Cos} value is never higher than 0.4, meaning that the window orientation itself reduces the incident radiation by 60% during the month of June. Evaluating g -values for the date 22 June, at 09.00 hrs and 17.00 hours (>0.8) indicated higher than other values. But a constant value (>0.7) is indicated during the shading period, 09:00-17:00. This implies that the solar radiation transmittance is symmetrical during the maximum shading period.

Direct solar gain through south window were obtained on January, February, March, September, October, November and December. Among these months November, December and January obtained a high g -value (>0.8) and G_{Cos} -values (>0.3) than other months. As in north orientation, G_{Cos} -value is never exceeding 0.4. Thus orientation of the window itself reduces the intensity of the incident radiation by 60% during the months where the impact of solar radiation is maximum. Month of December indicated a highest g and G_{Cos} values for south orientation and values remain constant ($g > 0.8$, $G_{Cos} > 0.34$) throughout the required shading period. Note that during the month of June and December the sun position is in the north solstice and south solstice respectively.

Projection factor differs from a minimum >0.1 to a maximum >0.8 for north orientation, while range for south orientation is >0.2 to >1.2 . But as for the north and south orientation maximum g -value and G_{cos} values and their corresponding overhang ratios were shown in table 2. According to table 2, best options of overhang ratios for north and south are respectively $0.8 > OHR > 0.7$ and $0.6 > OHR > 0.5$.

Table 2: Summary of maximum g -value and G -Cos value obtain for North and South orientations.

Orientation/ Day/month	Hour	Sol Alt	Sol. Azi	VSA	OHR	Incid. Ang	g -value	G -Cos value	Q_{sol} (W/m^2)
N-2206	9	32	64.1	55.0	0.70	68.3	0.80	0.35	122
N-2206	17	25.3	294.6	48.6	0.88	67.9	0.81	0.35	58
S-2112	11	53.7	138.2	61.29	0.55	63.81	0.82	0.36	267
S-2112	13	63.1	189.4	63.41	0.50	63.49	0.82	0.37	302

Conclusion

The results showed that window's solar angle dependent properties and its geometrical relationship to the direct solar radiation provide information to make meaningful hypothesis about the external overhang depths. Comparison between the window properties and the amount of solar energy transmitted, enable to predict more realistic shading hypothesis than shading device calculations based on incident angle only. It can be argued that, the obtained values can be defined as optimum geometry of a shading device, compared to the direct solar radiation transmittance.

The above results suggested optimum overhang ratio of 1.6 (~1.59) for east orientation, overhang ratio between 1.90 and 2.04 for west orientation, overhang ratio between 0.8 and 0.7 for north orientation and between 0.6-0.5 for south orientation. These optimum values were obtained for the building occupied period that is from 9:00 am in the morning to 17:00 pm in the evening.

A design method to define the optimum solar shading geometry was presented. Compared to shading mask method to define shading geometry, this method provide additional information on intensity of solar radiation, window solar angle dependent property and the geometrical relationship to the direct solar radiation. These additional information assists to determine the critical overheated periods affecting on a building façade at a given location and orientation. However, energy simulations need to be carried out to justify the shading hypothesis obtained from this experiment.

Another benefit of this method is that it gives a series of options of different shading strategies internal or external, to decide based on shading device gcos-value (or solar heat gain coefficient-SHGC) for different orientations. For example, a shading device (internal or external) with gcos-value with $0.4 > \text{gcos} > 0.3$ on south window can be used to get maximum protection from solar heat gains.

The present study was conducted only considering the effect of direct solar radiation. This may give more reasonable results under clear sky conditions. However, considering the diffuse component might give more precise information on the total heat transmittance. Further, in this study uses solar radiation data obtained on a single year. A more precise approach would consist of having more solar radiation data, at least of five years. Also the solar radiation calculations were based on data obtained for horizontal surface. Data obtained on vertical surface will provide more accurate results on overheating period and on shading geometry.

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Appendix 1:

Table a: East Orientation

Day/ Month	Hour	Sol. Alt	Incid. Ang	VSA	OHR	g- value	G-Cos value	SMS sol.rad (W/m ²)	Qsol (W/m ²)
28/01	7	3.5	19.0	3.7	15.49	1.00	0.95	na	na
	8	14	24.1	14.8	3.77	1.00	0.91	269	246
	9	28	35.5	30.0	1.74	0.99	0.81	453	367
	10	41.5	48.6	45.1	1.00	0.97	0.64	553	354
	11	54.2	62.5	60.4	0.57	0.88	0.41	580	236

	12	64.4	76.6	75.6	0.26	0.61	0.14	647	91
	13	68.5	90.8	-89.1	-0.02	0	0	492	0
	14	63.4	105.1	-73.8	-0.29	0	0	586	0
23/02	7	3.7	10.9	3.8	15.21	1.00	0.98	na	na
	8	14.8	18.5	15.1	3.71	1.00	0.95	25	24
	9	29.5	32.1	30.2	1.72	1.00	0.84	325	274
	10	43.9	46.5	45.2	0.99	0.98	0.67	628	422
	11	58	61.2	60.4	0.57	0.89	0.43	678	292
	12	70.6	75.9	75.5	0.26	0.63	0.15	714	109
	13	76.8	90.7	-89.3	-0.01	0	0	828	0
	14	69.6	105.4	-74.2	-0.28	0	0	425	0
21/03	7	4.9	4.9	4.9	11.66	1.00	1.00	na	na
	8	17.2	17.2	17.2	3.23	1.00	0.96	278	265
	9	32.2	32.3	32.2	1.59	1.00	0.84	528	444
	10	47.2	47.3	47.3	0.92	0.97	0.66	625	413
	11	62.1	62.3	62.2	0.53	0.88	0.41	891	366
	12	76.9	77.3	77.2	0.23	0.59	0.13	928	120
	13	86.2	92.2	-87.8	-0.04	0	0	344	0
	14	72.5	107.2	-72.7	-0.31	0	0	372	0

Table b: West Orientation

Day/ Month	Hour	Sol.Alt	VSA	OHR	Incid. Ang	g- value	Gcos- value	SMS sol.rad (W/m ²)	Qsol (W/m ²)
	11	62.1	-62.2	-0.53	117.7	0	0	891	0
	12	76.9	-77.2	-0.23	102.7	0	0	928	0
	13	86.2	87.8	0.04	87.8	0.14	0.01	344	2
	14	72.5	72.7	0.31	72.8	0.71	0.21	372	78
	15	57.6	57.7	0.63	57.7	0.92	0.49	505	249
	16	42.7	42.7	1.08	42.8	0.98	0.72	567	409

2103	17	27.7	27.7	1.90	27.7	1.00	0.88	242	213
	18	12.7	12.7	4.44	12.7	1.00	0.98	72	70
2105	11	60.3	-65.4	-0.46	113.5	0	0	703	0
	12	70.5	-80.1	-0.17	99.4	0	0	533	0
	13	72.5	85.2	0.08	85.4	0.26	0.02	505	11
	14	64.3	70.4	0.36	71.3	0.74	0.24	708	168
	15	52	55.7	0.68	57.5	0.93	0.50	572	285
	16	38.5	40.9	1.16	44.0	0.98	0.71	508	359
	17	24.6	26.1	2.04	31.7	1.00	0.85	392	332
	18	10.5	11.1	5.08	22.2	1.00	0.93	128	118
2409	11	65.8	-66.0	-0.44	113.9	0	0	855	0
	12	80.3	-81.1	-0.16	98.9	0	0	803	0
	13	82.8	83.9	0.11	83.9	0.33	0.03	722	25
	14	68.6	68.9	0.39	68.9	0.79	0.28	442	125
	15	53.8	53.9	0.73	54.0	0.95	0.56	211	118
	16	38.8	38.8	1.24	38.9	0.99	0.77	489	377
	17	23.9	23.9	2.26	24.0	1.00	0.91	86	79
	18	8.9	8.9	6.38	9.0	1.00	0.99	31	30
2010	12	74.8	-82.8	-0.13	97.0	0	0	919	0
	13	74.4	82.0	0.14	82.2	0.41	0.05	808	44
	14	63.5	66.8	0.43	67.5	0.81	0.31	625	194
	15	49.9	51.7	0.79	52.8	0.95	0.58	189	109
	16	35.6	36.6	1.35	38.3	0.99	0.78	305	238
	17	21.1	21.6	2.53	24.3	1.00	0.91	133	121
	18	6.9	7.0	8.11	12.9	1.00	0.98	44	43

Table c: North orientation

Day/ Month	Hour	Sol.Alt	VSA	OHR	Incid.Ang	g- value	Gcos- value	SMS sol.rad (W/m ²)	Q _{sol} (W/m ²)
2206	8	18.4	39.5	1.21	67.5	0.81	0.36	244	88
	9	32	55.0	0.70	68.3	0.80	0.35	353	122
	10	45.2	63.0	0.51	68.9	0.79	0.33	442	147
	11	57.4	67.2	0.42	69.3	0.78	0.32	405	131
	12	66.8	69.1	0.38	69.5	0.78	0.32	714	226

13	69.3	69.6	0.37	69.6	0.78	0.31	650	205
14	62.7	68.4	0.40	69.4	0.78	0.32	450	143
15	51.6	65.5	0.46	69.1	0.79	0.33	394	129
16	38.8	59.7	0.58	68.5	0.80	0.34	336	114
17	25.3	48.6	0.88	67.9	0.81	0.35	164	58
18	11.6	27.3	1.93	67.1	0.82	0.37	78	29

Table d: South orientation

Day/ Month	Hour	Sol.Alt	VSA	OHR	Incid.Ang	g- value	Gcos- value	SMS sol.rad (W/m ²)	Q _{sol} (W/m ²)
2112	9	29.9	49.60	0.85	64.90	0.80	0.34	242	82
	10	42.6	57.35	0.64	64.30	0.81	0.35	414	146
	11	53.7	61.29	0.55	63.81	0.82	0.36	739	267
	12	61.6	63.12	0.51	63.53	0.82	0.37	605	222
	13	63.1	63.41	0.50	63.49	0.82	0.37	822	302
	14	57.4	62.29	0.53	63.74	0.82	0.36	608	220
	15	47.1	59.15	0.60	64.05	0.81	0.36	380	135
	16	34.9	53.17	0.75	64.63	0.80	0.34	342	118
	17	21.8	41.67	1.12	65.34	0.79	0.33	247	81

Sol.Alt: Solar Altitude Sol.Azi: Solar Azimuth VSA: Vertical shadow angle

OHR: Overhang ratio Incid. Ang: Incident angle

SMS sol.rad: Global solar radiation at Subang Meteorological Station (Kuala Lumpur)

Q_{sol}: Solar gain due to direct solar radiation through window (W/m²)