PARAMETRIC STUDIES ON BUILDING SEPARATION OF DAYLIGHT PERFORMANCE IN OBSTRUCTED LOW COST HIGH-RISE RESIDENTIAL BUILDING THROUGH COMPUTER SIMULATION TECHNIQUES IN KUALA LUMPUR, MALAYSIA

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ABSTRACT: *The use of daylight in residential buildings has become an important strategy to improve environmental quality and energy efficiency by minimizing artificial lighting requirements thus maximizing daylight intensity into building. These can be achieved by a good design planning of building configuration and proper size of fenestration in building façade. This paper investigates to adequate the daylighting performance in terms of illuminance level (lux) and daylight factor (DF) in low cost high-rise residential building in tropical area. The objective of the study is to find out the optimum distance of building separation for high-rise residential building in consideration to sufficient daylight in the building during the daytime. The computer simulation software were performed using IES<VE> (Integrated Environmental Solution <Virtual Environment>) to model daylighting analysis for illuminance (lux) and daylight factor (DF) in obstructed high-rise residential building. The results have indicated the minimum, average and maximum illuminance and daylight factor in the high-rise residential building affected by building shading effect, whereas, 30m of building separation is the best distance between buildings in terms of planning to obtain the acceptable daylight and to enhance the daylight performance in the building.*
Keywords: Building separation, daylighting, sky obstruction, high-rise

1.   INTRODUCTION

Daylighting is one of the most significant issues in passive design strategies that architects and other building designers need to consider about. As a main source of light, daylighting offers greater benefits over artificial lighting. Sufficient daylight in the house will give stimulate effect and contributes greatly to the well-being in human life every day. It can play a major role in resource conservation, occupants' level of productivity, health and comfort. Daylighting dynamism and constant change can characterize buildings and spaces with a living quality that cannot be achieved with any other design element. However, daylighting can create unwanted lighting conditions in the visual field causing discomfort and glare, in addition, causing overheating (heat gain) during sunny and bright day. As human nature, people desire a pleasant natural lighting in their living environments. Being one of the most heavily populated cities in the world, Malaysia has confronted many challenges in solving the housing needs. High-rise buildings are the most common types of housing next to low-rise in Malaysia. In Malaysia, government provides a lot of initiatives to support the living the cost of low-income groups. In the current situation of land properties in Malaysia, Malaysia is having the shortage of land due to rapid development and building construction, especially in the busy and hectic city. Therefore, the land price in the urban area is triplet higher than rural area. In this circumstance, the building developers have to design and cramped the building modules as much as possible into the limited land area by going vertically. Malaysia's pertinent land scarcity problem resulted in the rapid an effective increase in the number of high-rise building construction that develops during the last ten years. Malaysia had moved into a techno-era, in which almost all the buildings in big cities, such as Kuala Lumpur became air conditioned.

In order to maximize the space from the limited resources of lands, most residential buildings are high-rise flat blocks which built very close to each other, resulting in severe sky obstructions [3]. Consequently, the flats on the lower floors receive low quality and quantity of daylight inside building interior. As a result, the residents at lower floors need to rely on additional artificial lighting even at the daytime with high daylight intensity [4]. Meanwhile, flats on the upper level receive more daylight quantity and superimposed to high quality of daylight, tend to overheating.

The key building variables affecting daylighting are building area and orientations, glass type, window areas, shading and external obstruction [5]. These five variables are conferring great impact for the utilization on daylighting to the building. On the other hand, the illuminance distribution is much affected by the reflectance value of the surface [6]. The light reflected from the ground (streets) and opposite facades can be important sources of interior lighting [1-2].

One of core variables is external obstruction that can cause shading effect to adjacent buildings. It could possibly be slight or severe on sky obstruction in a dense area for high-rise residential buildings. The external obstruction influences the daylighting performance in two aspects; (1) the amount sky being obstructed or unobstructed, (2) the colour of the external surface finish which can be regarded as the reflected luminance from the obstructing buildings [5]. The external obstruction depends on the height (h) of neighboring buildings and the separations (w) [5]. The separation is important aspect compared to the height because it will determines the adequate daylight in residential room space. The rooms in residential building can be classified according to their occupancy and use, and then many different activities requiring different lighting levels can be developed inside the same space. This paper deal with lighting coming into the rooms through the window providing daylight in obstructed low cost high-rise residential building where it is considered as a system providing and controlling illuminance and daylight factor distribution in the rooms. The purpose is to find out the optimum building separation for daylighting optimization in residential building.

2.   METHODOLOGY

Computer simulation techniques suggest more advantages with respect to complexity of the experiments compare to physical scale model. Computer simulation is applied in order to investigate the shading effects between two buildings. The simulations are conducted in Radiance software of Integrated Environmental Solution-Virtual Environment (IES-VE) on a model that presents low cost high-rise residential building. IES-VE software is a system of integrated building analysis simulation tools, which can simulate large number of result include lighting, thermal, energy costs and heating-cooling load calculations within a building. IES-VE has sufficient capability simulate daylight performance in the building [8]. In addition, radiance is a computer software package developed by the Lighting Systems Research Group at Lawrence Berkley Laboratory in California, USA. It was developed as a research tool to accurately calculate and predict the visible radiation within a space. Simulation runs are carried out for Kuala Lumpur location (3.12^0N, 101.55^0E). Sun path position for Malaysia is change every half a year in the north and south side periodically which is the daylighting conditions under Malaysia sky can change rapidly within a short time. The sky condition was assumed to be overcast sky condition. The intensity of daylight changes from 1000 to 30,000lux, depending on the measure of overcast and solar altitude [7].

2.1 Building description

Malaysia people live in high-rise residential units due to dense population and land shortage. Most developments are packed with high-rise buildings constructed close to each other, whereas there is little room to maneuver. Kuala Lumpur has reached the status of 100 percent urban population follow by Selangor state with 87.6 percent urban population. All public low-cost housing units developed in the urban areas to be high-rise flats. The building used for the simulation is a low cost high-rise residential (PPR) block with 20 units per floor. All low cost high-rise flats were built under PPR scheme in cities and major towns such as in Kuala Lumpur are using the standard 18-storey high-rise flat design with 20 units per floor. Since unit and storey layout of PPR high-rise flats are similar in design, one site are selected as a case study (PPR Lembah Pantai Kerinchi). The typical unit domestic unit is containing three bedrooms, a living/dining room and miscellaneous area (kitchen and toilets). The total area for one unit house is 650 sq.ft ($60.385m^2$) which divided into living/dining area ($24.194m^2$), bedroom 1 ($10.821m^2$), bedroom 2 ($6.671m^2$), bedroom 3 ($6.505m^2$), kitchen ($4.515m^2$), toilet ($4.777m^2$) and small yard ($2.90m^2$). The ceiling height of the house is 2.5m. The window is a standard design with single glaze material and one layer standard brick for wall construction.

Table 1: List of 24 PPR Projects in Kuala Lumpur (total of 34,106 units) (Source: JPN, 2005)

No	Name of PPR
1	PPR Lembah Subang
2	PPR Sg. Besi
3	PPR Pekan Batu 5, Jalan Ipoh
4	PPR Taman Wahyu II
5*	PPR Kg Batu Muda
6*	**PPR Lembah Pantai Kerinchi**
7	PPR Pudu Ulu
8	PPR Bukit Jalil I
9	PPR Bukit Jalil II
10	PPR Taman Intan Baiduri
11	PPR Taman Wahyu I
12	PPR Ampang Hilir
13	PPR Linear City
14	PPR Kg Malaysia Permai
15	PPR Air Jerneh, Sg. Bonus
16	PPR Kg. Baru Air Panas, Tambahan
17	PPR Salak Selatan
18	PPR Jalan Lapangan Terbang Lama
19	PPR Linear City II
20	PPR Kg. Muhibbah, Puchong
21	PPR Kg. Limau Pantai Dalam
22	PPR Pekan Keping
23	PPR Kg. Seri Malaysia
24	PPR Jalan Chocrane

Note:

*Projects under SPNB

Density for flats=40 units/acre, however for Kuala Lumpur (KL) allow for 70 units/acre
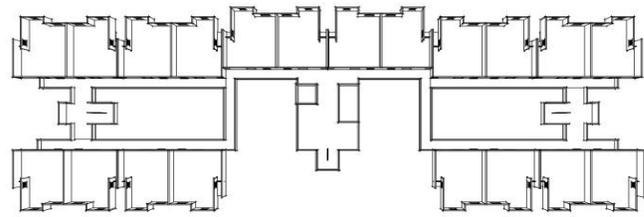
Household size=5/unit

Fig.1: Standard typical storey plan for 18-storey low cost flat.

Fig. 2: Standard unit layout plan (typical domestic unit) for 18-storey low cost flats.

2.2 Model description

The model of house is simply drawn referring to layout plan in order to study daylight performance in residential building concerning to building separation. Two building blocks with same height are drawn using computer simulation.
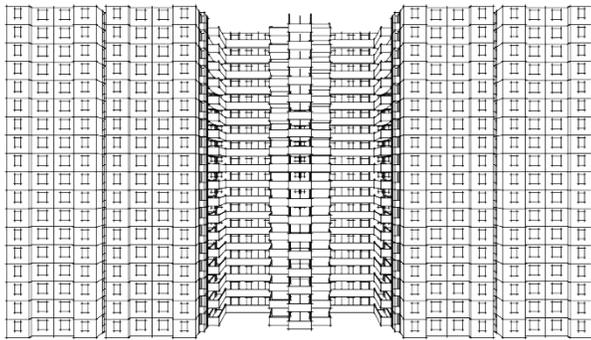
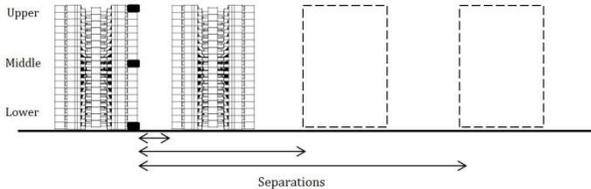**Fig. 3: 18 storey of low cost high-rise residential block**

Fig. 4: Model to analyze the daylight performance in three different levels of houses with multiple distances.

2.3 Evaluation method
The evaluation will be on the assessment of daylight performance into the building which is only focusing on the living area by using Radiance IESVE. A comparison between simulation results helped with findings of how the changes of building distance influence the performance of daylight in the living area. The distance between buildings will be set as main variable. The height of building and building orientation will be set as constant or fixed variables. The building separation starts at 3m, 6m, 9m, 12m, 15m, 18m, and 21m to 30m. Each orientation has three (3) tested areas from dissimilar houses which are selected from different floor level (lower, middle and upper). The illuminance working plane in Radiance is set to simulate the daylighting. This building has simulated for five orientations (north, south, east, west and northwest) which is according to the actual building orientation on site. However, only the houses facing the east (obstructed area/ received shading effect) will be analyzed throughout this study, as the main point is to find out the ideal building separation (front-to front) for obstructed high-rise dwelling building.

2.4 Planning guidelines
As per Selangor planning guideline, the building separation for building with same height: Front-to-front = 24.4m (80'), side-to-front = 12.2m (40'), side-to-back = 12.2m (40'), back-to-back = 12.2m (40'), and side-to-side = 9.14m (30'). However, based on the interviews with some building experts, the idea of planning guidelines revision of building distance is based on the designer's preferences. The front-to front building distance is very important in planning because it refers to the main space area in housing layout such as living and master bedroom. People tend to spend their time most of the time in the living area; watching television, reading, and some leisure activities. These two spaces need sufficient daylight during high density daytime.

Distance	3m	6m	9m	12m	15m	18m	21m	30m
Guidelines								
Simulations								

Front-to-front 24.4m

Fig.5: A benchmark to be simulated front-to-front building separation measurement based on the planning guideline.

Referring to figure 6, the daylight distribution in a room size (5m x 5m) for building separation 24.4m at 18 storey building scattered until 2m depth. This is to show that the distance provided by building planner is only 25% of daylight can be penetrated through window under overcast sky condition. The daylight factor (DF) for this room appears around 1% to 2%. However, the illuminance and daylight factor might show different result if the building is higher. In opinion, the distance provided is not really appropriate to be applied if the height of two buildings is higher than 18 storey due to population density and land shortage in planning.
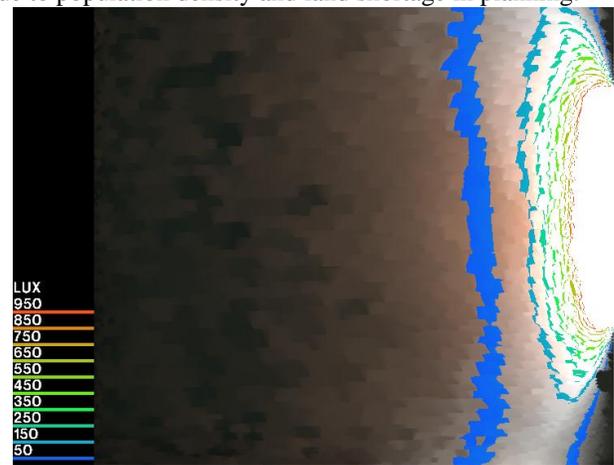

Fig.6: Illuminance reading from window distance at lower unit with 24.4m building separation referring to planning guideline.

3.   RESULTS AND DISCUSSIONS

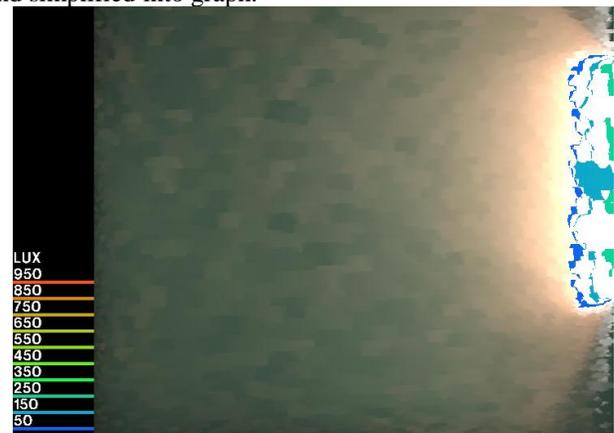The results obtained from 240 simulations run were analyzed and simplified into graph.

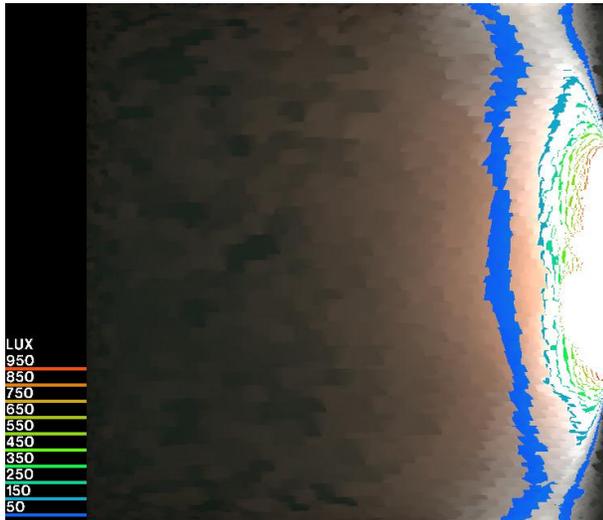**Fig.7: Illuminance reading from window distance at lower unit with 3m building separation.**

Fig.8: Illuminance reading from window distance at lower unit with 15m building separation.
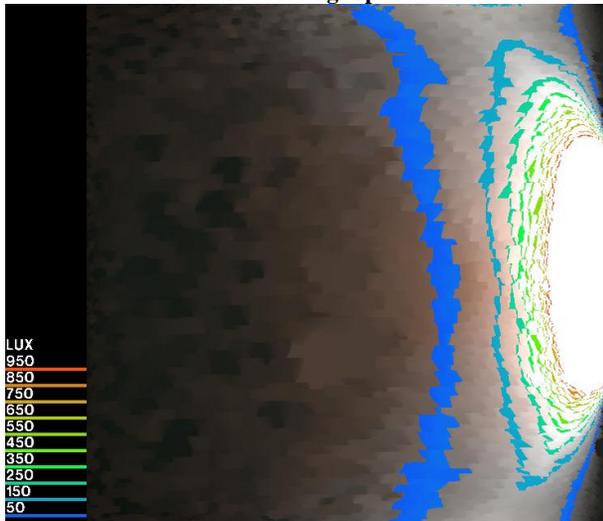

Fig.9: Illuminance reading from window distance at lower unit with 30m building separation.

The results showed the illuminance reading at lowest housing unit in high-rise residential building for distance 3m, 15m and 30m. The maximum reading will be identifying the amount of sufficient light in the specific area. Therefore, the lower unit was selected to be compared due to its lower floor level which always receiving less daylight during the daytime. Unlike middle and upper floors, it receives adequate daylight and sometimes tends to overheating during sunny day. The illuminance reading for 3m building separation showed that the daylight spotted until 1.5 m depth with maximum 350 lux in living area. This indicates that the room is less bright for activities. The building separation of 15m distance showed that the illuminance dispersed around 1.8m to 2.0m depth. The maximum lux can be seen up until 950lux to 1500 lux. It shows that the room is a little dim in a fine day. Meanwhile, the lux reading in a room with 30m building separation is at maximum 4000lux to 4500lux. The daylight disseminate up to 3m depth from the window distance. At this level, 50% to 60% of daylight has covered the room space, which denotes that the daylight distribution in this room is sufficient for daily tasks. From the result, it can be conclude that the 30m

distance of building separation give an acceptable daylight under an overcast sky condition. In other circumstances, under non-overcast skies, nearby buildings may hinder the direct sunlight and partly obstruct the view of diffuse sky. Hence, the reflected components can be the main sources of interior lighting. Most available daylight for windows of lower and middle floors of a building surrounded by high-rise buildings is primarily reflected light from the opposite buildings with various reflectance values. The ground reflected component would be small. Daylight illuminances inside a room are, however, not only comparative to the peripheral illuminance but also depend on the exact sky luminance dissemination at any given time. This is because a point in a room will obtain direct light only from particular areas of the sky.
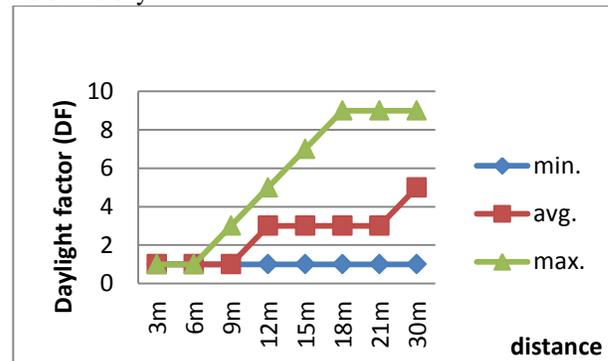

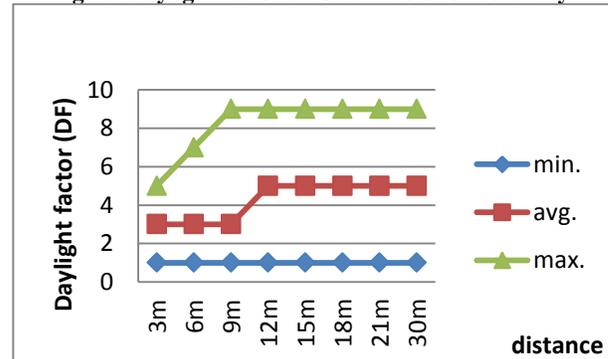**Fig.10: Daylight factor at lower floors for 18 storey.**

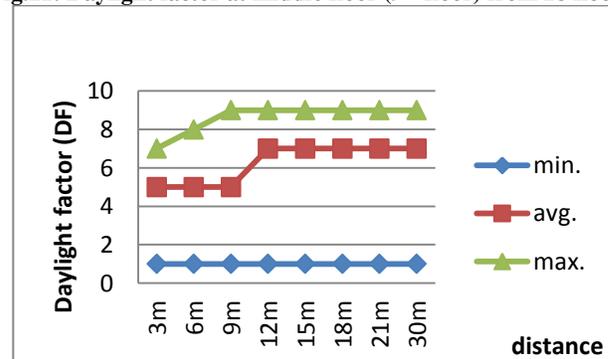**Fig.11: Daylight factor at middle floor (9th floor) from 18 floors.**

Fig.12: Daylight factor at upper floor for 18 storey.

The daylight factor (DF) is the most common measurement used in daylighting studies. It is useful because even though the absolute level of light available outside might change drastically, the daylight factor for a given time of day and sky condition remains fairly constant. The daylight factor (DF) is usually measured in an overcast sky condition, thus direct

sunlight is excluded. Daylight factor is define as the ratio of daylight illuminance at a point on a given plane due to the light received directly or indirectly from a sky of known or assumed luminance distributions on a horizontal plane due to unobstructed sky. The brightness inside a building and the supplementary distribution can be classified by the daylight factors (DF) as follows:

Table 2: Daylight factors and impact

DF (%)	Lighting	Glare	Thermal comfort
>6.0	Intolerable	Intolerable	Uncomfortable
3.5-6.0	Tolerable	Uncomfortable	Tolerable
1.0-3.5	Acceptable	Acceptable	Acceptable
<1.0	Perceptible	Imperceptible	Acceptable

In Malaysia, the Malaysian Standard (MS 1525:2014) has outlined illuminance levels recommendations for various tasks and applications. The recommended range for daylight factors is 1.0% to 3.5%. However, the determination of daylighting for tasks and applications in Malaysian Standard is only based on the principles of the study in efficient lighting practice. The prescription of the illuminance level for a particular task application is in conjunction with colour rendering index (CRI). This standard should be employed as a benchmark in lighting study in Malaysia. Referring to figure 10, daylight factor is acceptable within a distance of 12m to 21m of building separation based on the average value. As it getting further in distance, the daylight factor is become intolerable. This is due to the massive exposure to the direct sun, ground and diffuse light. The daylight factor at the middle and upper floor is much higher than lower floors. The value is in tolerable (3.5%-6.0%) and intolerable (<6.0%) range. The middle floor is receiving more daylight especially on the upper floor. The upper floor receives a lot of direct sunlight and reflected light that caused overheating to the room space and glare. The easiest way to get plenty of daylight into a space is to use very large openings; but direct solar radiation in the vicinity of critical task areas and a direct view of the sky from these areas will expose occupants to excessive brightness differences that will result in poor visibility and visual comfort. Overall, the best daylighting systems should provide natural light without glare, overheating, and with limited impact to the building envelope.

4.   CONCLUSION
The amount of available daylight in Malaysia is high, intense and long. Even though the type of sky in Malaysia is considered overcast, the amount of cloud cover is constantly changing and exposes bright patches of daylight, thus typical sky can be seen to be more like the cloudy sky. In order to determine the optimum building separation for daylighting optimization as well as daylighting performance in residential building, this paper has been studied the distance between two high-rise residential buildings in a several distances. The result can be seen as illuminance and daylight factor distribution from window area in contour band graph and line graph. It can be concluded that the building has achieved the optimum daylight penetration into the room starting from 30m of building separation. This can be seen from the result

shown, whereas, the lighting interior has covered up until 50% to 60% from the entire room. In comparison to the planning guideline suggesting 24.4m, the daylight can only penetrate maximum 25% from the entire room. Therefore, the purpose of this study has been achieved.

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