Building Information Modelling (BIM) For Estimation of Heat Flux from Streetscape Material

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Abstract: Streetscape elements are the major contributors to the urban heat island (UHI) phenomenon in the built urban environment. The hot surface air in this phenomenon is concentrated in urban regions and will gradually decrease in surrounding temperatures in suburban or rural regions. The effect of UHI can be seen through the increasing of land surface temperature and influencing the urban ecological systems, climates, and environments. A study has been conducted to identify the impact of urban heat island surrounding the PMU's streetscape furniture. In this study, the UHI variation has been investigated using BEM and city scale model. The UHI obtained were analyzed and modeled using satellite imagery and GIS. The 3D models of the PMU's façade were also been developed by using a laser scanner and thermal camera. Based on the analyses, the existing condition of seven selected PMUs are very high for Bangsar, High for Abu Bakar Baginda, Jalan Meru and Batu 4 Kuantan, Medium-high for Kuantan North and Taman Jaya and medium for Setia Alam. Land Surface Temperature (LST) in PMU facade is ranging between 23 ºC to55ºC. Building information modeling (BIM) analysis shows that the existing material used in most PMU facades with solar reflectance was uniformly low to medium-low. Building information modelling (BIM) result shows the building will give greater heat flux (+42% to +53% at 3 pm) because of the solar reflectance (%) from the facades of surrounding streetscape material used. By obtaining the information regarding the elements and factors that contribute to the UHI phenomenon within the study area, the reduction of heat absorption can be performed.

Keywords: Streetscape, Urban Heat Island, Building Energy Models, City Scale Model, Satellite Imagery, Geographical Information System, Laser Scanner, Thermal Camera

I. INTRODUCTION

Streetscapes are classified as a component of the built urban environment. It can be defined as the pattern of motion and the city's geometrical shape [1]. In other words; streetscape is the street's visual components which include furniture, street, adjacent buildings, trees, open areas, etc. these components arecombined to create a street character [2], [3].

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Sustainable streetscape, on the other hand, is described as multimodal rights of way designed and operated to create benefits linked to movement, ecology, and community that together encourage a broad sustainability agenda that encompasses the three E's: equity, environment, and economy, and sustainable urban streets can create more livable communities [4].

Sustainable streetscapes is crucial for shaping the sustainable cities' visual appearance and environmental health index [5]. It guarantees that spaces are durable and function as a part of the eco-system that helps create better places. As a result, sustainable streetscape intends to enhance the quality of the environment by decreasing heat island impacts, maintaining regionally restricted natural resources by decreasing energy use, water use and storm water runoff by enhancing permeable ground area and landscaping, and maintaining urban fabric by enhancing the visual picture of any city [4].

Urban Heat Island (UHI) occurred due to the concentration of hot surface air in the urban region and gradually decrease in surrounding temperatures in the suburban or rural region[6],[7], and [8].From the studies performed by [9] and [10], it is found that the air temperature can increased by the UHI effect in an urban city by 2°Cto 8°C. In extensive studies conducted in Athens which involved 30 urban stations, shows that the urban station's record temperatures that are between 5°C and 15°C higher than temperatures recorded at reference suburban stations [11].

There are many streetscape elements have negatively affected the visual image of these cities as well as urban heat island (UHI).The complex-built environment with lots of impervious surfaces, lack of cooling vegetation and with a dark color of street furnishing and construction materials such as pavement and rooftops have a high specific heat capacity and, hence, have a strong tendency to absorb and store heat energy. The objective of this research is to identify the impact of urban heat island surrounding the streetscape furniture on the PMU building.

Scope and Limitations

Base on the sustainable streetscape elements described previously, PMU is chosen as a facade of the total built environment that links to the streetscape of PMU furniture. In physical urban planning concepts, PMU's can be the hub in transforming the elements of the sustainable streetscape in smart urban design. Fig. 1 shows the components and principles of sustainability in streetscape related to PMU's facades and its surrounding.

Fig. 1 The components and principles of sustainability in streetscape related to PMU's building setback facades and it surrounding

Physical characteristics of PMU facade streetscape styles are single building with individual streetscapes semi-modern architecture style. This style indicated by square form the dominance of horizontal and vertical lines, and the use of modern fabricated materials (such as glasses, concrete, steel, aluminum, rock gravel), with various type of facade colors. Most of those buildings' setback represents a complex attractive image that is functioning as commerce and service facilities. PMU facade individual streetscape can be classified as curb, storm drain, conventional pavement, wall, street lighting, and gravel ballast or known as surface aggregates used in grounding systems as a rain garden and storm water.

II. METHODOLOGY

The research methodology involved in this study is divided into three (3) phases as shown as Fig. 2.

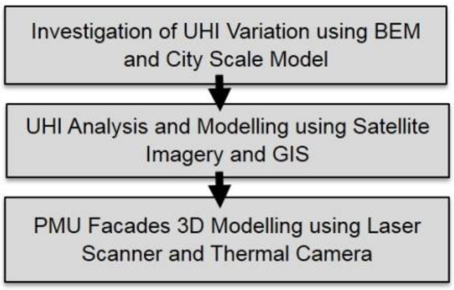


Fig. 2 Sustainable streetscape workflow

Investigation of UHI Variation using BEM and City Scale Model

A combination of building energy models (BEM) and the city model is used to study large-scale UHI variation related to the PMU façades. Outdoor parameters such as material, temperature, solar radiation, long-wave radiation, and moisture are external inputs into such models. These models are simplistic in representing the mutual impact of a building with its surrounding area and thus their integration with larger-scale models is inevitable when the effect of UHI on building energy performance is investigated.

UHI Analysis and Modeling using Satellite Imagery and GIS

Satellite images (e.g. Terra and Aqua) are analysed to correlate temperature of the ground with land-use and land-use coverage of the proposed region. In geographical information system (GIS), regression models were developed to describe the spatial-temporal land surface temperature (LST) variation associated with parameters such as topographic position, land-cover diversity, building volume per area, orientation, and anthropogenic heat release. Retrieved images such as moderate resolution image spectroradiometer (MODIS) are used by regression models.). MODIS is adjusted against surface emissivity and atmospheric effects (absorption and emission) before being used to model UHI in PMU's facades.

Develop 3D Model of the PMU's Facades using Laser Scanner and Thermal Camera

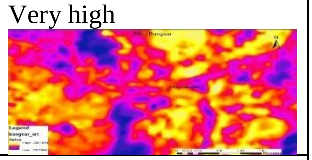
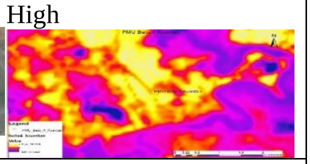
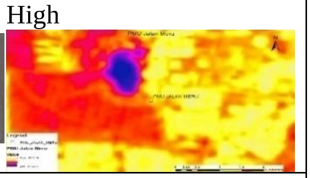
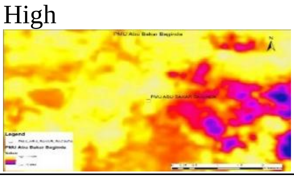
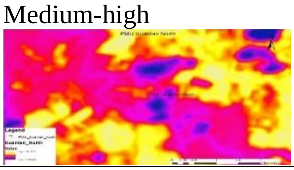
In this study, planar satellite imagery, geographic information systems (GIS), as-built drawing, laser scanner, and thermal camera technique were exploited to develop 3D model of the PMU's facades for further representation of the complex geometric structure of their streetscape. It's aimed to improve the earlier UHI analysis using building energy models (BEM).

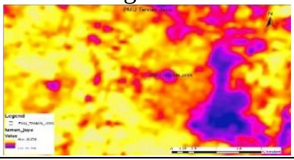
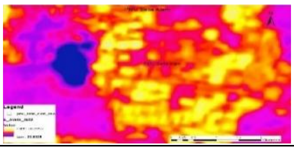
III. RESULTS AND ANALYSIS

UHI Analysis using Satellite Imagery

Based on the analysis and modeling conducted, the hotspot areas (urban heat analysis (UHI)) related to PMU facades and it surrounding were determined as shown in Table 1.

Table. 1 Pmu's Facades And Surrounding Streetscape Urban Heat Island (Uhi) Index Analysis

PMU	PMU Facades & Surrounding Streetscape	UHI and Land Surface Temperature (LST)
Bangsar		Very high 
Batu 4 Kuantan		High 
Jalan Meru		High 
Abu Bakar Baginda		High 
Kuantan North		Medium-high 

Taman Jaya		Medium-high 
Setia Alam		Medium 

From Table 1, it can be seen that the PMU Bangsar facades show very high urban heat island (UHI) index. Whilst PMU Setia Alam shows medium-high urban heat island (UHI) index. From the UHI and Land Surface Temperature column,it shows that the high temperature are represented by yellow color the dark blue represents the lower temperature.The impact of streetscape facades between the building design facades related to the material, orientation, environments, and landscape are analysed based on urban heat island (UHI) result using Autodesk Revit software.

The Impact of Orientation towards Heat Absorption

Fig. 3 shows the orientation influencing the heat absorption on streetscape surrounding PMU Bangsar, PMU Taman Jaya, and PMU Setia Alam.

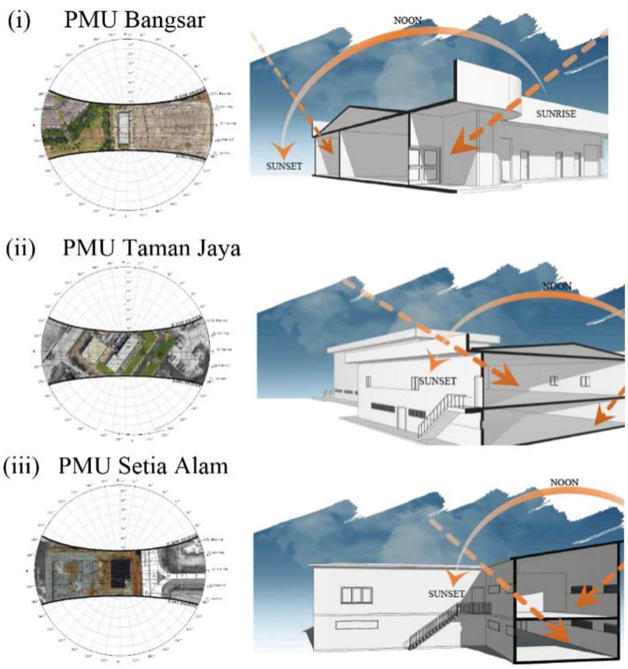


Fig. 3 The orientation of PMU Bangsar, PMU Taman Jaya and PMU Setia Alam facade

Fig. 4 shows the analysis of building energy models (BEM), using Autodesk Revit software for four (4) different months.

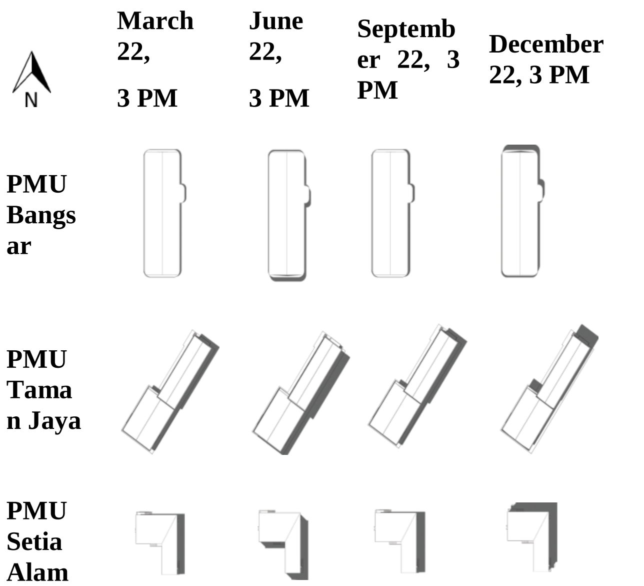
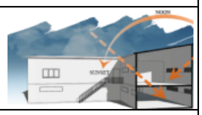


Fig. 4 The analysis of Building energy models (BEM), using Autodesk Revit software for four (4) different month.

UHI has been detected around the PMU's in a variety of geographies and is distinguished by a significant variation in temperature in an urban area and neighbouring rural regions. This difference is called the UHI intensity, $\Delta Tu{-}r$ and can be observed at three levels and thus, there are three types of UHIs i.e. Surface UHI (SUHI) that is studied at the surface of an urban area; Canopy Layer UHI (CLUHI) that is studied at a height of 2 m above the surface (often called the Canopy Layer); and Boundary Layer UHI (BLUHI) is studied at a height of about 2 km at the atmospheric boundary layer, where large-scale effects come to fore. In this research, the urban heat index (UHI) is focused on surface and canopy layer which being the most significant as most human activity takes place. Surface and canopy layer for UHI index also influenced by the environmental factor as listed in Table 2.

Table. 2 Pmu's Environmental Data Input That Used For Building Energy Modelling Analysis In Bim

PMU Bangsar	PMU Taman Jaya	PMU Setia Alam
Site Position/Orientation		
		
Solar Radiation (Yearly Average)		
G horizontal: 1696 kWh/m^2 Diffuse horizontal: 957 kWh/m^2 Direct normal: 947 kWh/m^2	G horizontal: 1756 kWh/m^2 Diffuse horizontal: 937 kWh/m^2 Direct normal: 1046 kWh/m^2	G horizontal: 1740 kWh/m^2 Diffuse horizontal: 952 kWh/m^2 Direct normal: 1012 kWh/m^2
Air Temperature (Yearly Average)		

25.8 °C	26.8 °C	26.3 °C
Terrain		
Altitude: 35 m Slope inclination: 0.9° Slope azimuth: 264° (W)	Altitude: 3 m Slope inclination: 0 ° Slope azimuth: 333° (NW)	Altitude: 10 m Slope inclination: 0.3 ° Slope azimuth: 309° (NW)
Building Density/Population (GPW)		
Density: 3791 inh./km^2	Density: 1144 inh./km^2	Density: 1205 inh./km^2

The surface and canopy layer are chosen, because it shows the condition of high heat flux in near night time and smaller during daytime. Based on environmental data input (see Table II) such as temperature, sun rise direction, humidity, rainfall the modelling analysis show that, PMU's building will give greater heat flux (+42% to +53% at 3 pm). The heat caused by the solar reflectance (%) from the facades of building and the material from the streetscape. The simulation result above are based on the comparison of the condition of heat that reflected from the orientation of PMU building and streetscape material based on four (4) different month as in Fig. 4. Referring to the three (3) PMU buildings, the building facades facing east and west receive enormous heat radiance due to the direct sunlight from the symmetry sun path in Malaysia. The analysis of the materials used in the streetscape at PMU's facades showed that it gave high heat absorption at the PMU building especially at PMU Bangsar whose position is facing the Sun. While the terrain height also will affect the heat absorption and the cooling process of the PMU. The relationship between air temperature surrounding the streetscape with the terrain, building density and solar radiation toward the heat absorption of the building were also been assessed. The simulation results show that, the streetscape in PMU's are absorb more heat in area which high in building density. The analysis shows that the absorption is reduced in high terrain, the area which more shadow and lower to medium solar radiation. The effect of heat absorption on this streetscape also affects the surrounding PMU, where the heat supplied on streetscape increases the heat effects of PMU.Relationship between vegetation in streetscape landscape and material were simulated and it shows that heat absorption by the streetscape material is decreasing due to the vegetation (see Fig. 5).

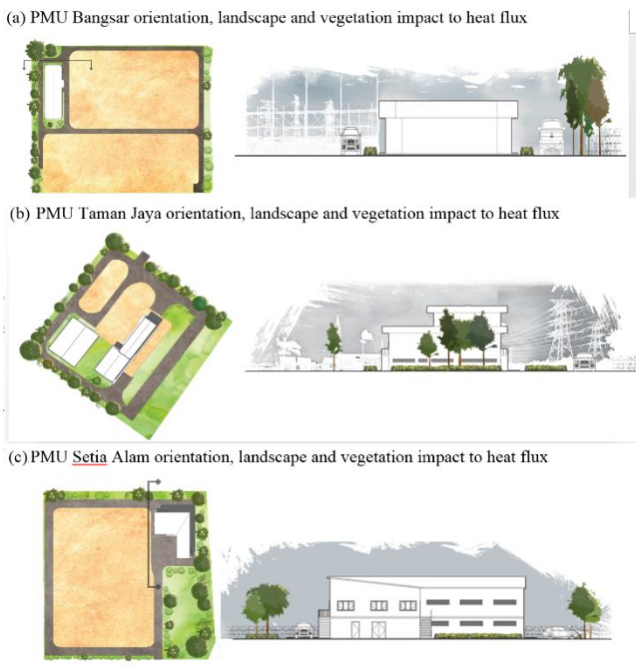


Fig. 5 The analysis related to vegetation, landscape and PMU building facades toward heat absorption

PMU Facades 3D Modelling using Laser Scanner and Thermal Camera

Thermal camera image shows the range of temperature variance of streetscape surface and building setback as Table III. Land Surface Temperature (LST) in PMU's facade ranging between 23 ºC - 55ºC. Building information modelling (BIM) analysis shows that the existing material use in most PMU's facades with solar reflectance was uniformly low to medium as shown in Table IV. Building information modelling (BIM) results shows the building will give greater heat flux (+42% to +53% at 3pm) because of the solar reflectance (%) from the facades of surrounding streetscape material used.

Table. 3 The Range of Temperature Variation of Streetscape Surface and Building Setback

	Min Temp (ºC)	Max Temp (ºC)	Average Temp (ºC)	Temp variance (ºC)
Pavement	28.30	45.00	36.65	16.70
Wall (clay brick)	23.20	35.50	29.35	12.30
Gravel Ballast (granite)	27.45	53.70	40.58	26.25
Curb	25.20	37.30	31.25	12.10
Storm Drain	27.70	37.30	32.50	9.60
Building (sand cement)	29.50	49.00	39.25	19.50

Table. 4 Pmu's Facades Streetscape Reflectance Characteristic

	Ultra violet reflectance (%)	Visible reflectance (%)	Near infra-red reflectance (%)	Solar reflectance (%)
Pavement	4.30	11.30	13.50	12.00
Wall (clay brick)	11.50	29.60	24.20	31.10
Gravel Ballast (granite)	7.50	20.50	20.50	20.00
Curb	7.20	12.30	11.50	11.70
Storm Drain	8.90	19.50	17.20	17.80
Building (sand cement)	10.10	23.10	26.75	21.70

IV. CONCLUSION

Based on the satellite image analyses conducted in this study, the existing condition of seven selected PMUs are very high for Bangsar, High for Abu Bakar Baginda, Jalan Meru and Batu 4 Kuantan, Medium high for Kuantan North and Taman Jaya and medium for Setia Alam. Land Surface Temperature (LST) in PMU facade is ranging between 23ºC - 55ºC. Building information modelling (BIM) analysis shows that the existing material use in most PMU facades with solar reflectance was uniformly low to medium low as Table 3. Building information modelling (BIM) result shows the building will give greater heat flux (+42% to +53% at 3 pm) because of the solar reflectance (%) from the facades of surrounding streetscape material used. It is suggested that analysis on the PMU building facades and their streetscape using mechanical and electrical characteristic should be performed in future research for better results.

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