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The Impact of Building Layout on the Thermal Environment at the University: A Case Study in UiTMPulau Pinang Campus

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ABSTRACT – The university's thermal environment affects the life of occupants in terms of their physical and mental health. Thermal environments are important factors in designing buildings in the university. The study was conducted in Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang, Permatang Pauh Campus buildings in a tropical region with a hot and humid climate. The purpose of this study is to analyze the influence of building layout on the surrounding thermal environment. The thermal environment parameters for every layout were investigated through field measurement. The results showed that the best building layout from the three selected building layout samples is the building layout at location C. Our findings reveal that building orientation at location C can lead to a 10% reduction in temperature fluctuations and increase air velocity by 70% and 5% increase in relative humidity. The building layout at location C has the best wind dispersion layout compared to the other building layout because it has a lot of open areas around the building. Building layout C also has the best heat dissipation because the layout of the building was not stacked with other buildings. Building layout C was in a location with good humidity that matches the human thermal comfort even in the climate of monsoon season in Malaysia during the end of the year December to January.

KEYWORDS: Building Layout, Thermal Environment, Humidity.

1.0 INTRODUCTION

Malaysia experiences high average temperatures which can affect daily activities and thermal comfort. High temperatures can significantly reduce productivity and lead to health issues such as heat stroke [1]. The layout of buildings plays a crucial role in influencing the thermal environment, including factors such as temperature, humidity, and air velocity. The workof Nasir et al. mentioned air temperature is an important index for identifying thermal comfort[2]. Indoor temperatures can be effectively reduced through building orientation, window placement, and the use of shading devices [3]. In this context, well-designed building layoutsare important to improve these challenges, especially in developing urban areas. In university environments where students and staff spend long hours; productivity and well-being areenhanced if thermal comfort is ensured [4].

Pulau Pinang is among Malaysia's places experiencing higher temperatures [5]. This can result in discomfort and health implications like heat stroke. According to Hampo et al. [6], studies show that prolonged exposure to high temperatures significantly decreases productivity and raises health risks for occupants of such buildings. The designs of current Malaysian cities' structures are less efficient than those in other countries; hence, they have higher temperatures and low thermal comfort [7]. Additionally, numerous buildings built in Malaysia do not have proper considerations for designing thermal comfort which leads to excessive reliance on mechanical cooling systems [8]. The present study investigates how building layout influences the thermal environment at UiTM Cawangan Pulau Pinang, Permatang Pauh Campus to address this gap. This way, it will help to understand the building design which can be improved in thermal comfort.

Building layouts can be improved to raise thermal comfort, decrease health hazards, and improve productivity in universities and beyond. The thermal environment of buildings is a critical factor that affects occupants' comfort and health. The study found that the design of a building can also influence indoor temperature, humidity, and ventilation. The findings of Fohimi et al., demonstrate a hybrid ventilation between forced mechanical ventilation and forced natural ventilation can improve air distribution while maintaining thermal comfort inside the atrium [9]. Other strategies such as different types of oblique windows, shade devices, and directions are also extracted in [3] that may reduce the internal temperatures. Also, Gupta and Chandiwala noted that natural ventilation was key in maintaining thermal comfort, especially in hot climates [10]. This work has shown by Al-Tamimi and Fadzil that the layout of buildings with open spaces and opening placement would allow more fresh air into the buildings hence reducing dependence on mechanical cooling systems [11]. It is important therefore to carefully consider the organization of space while designing office buildings, particularly in countries with extreme climatic conditions such as Malaysia.

While previous research has extensively studied the connection between building design and thermal comfort, focused investigations regarding the influence of distinct building layouts in Malaysian universities are not available. The majority of the existing literature concentrates on residential and commercial buildings or touches on urban planning at a macro scale. Malaysia has unique environmental conditions that require detailed studies on how particular building designs can counteract difficulties caused by high temperatures and high humidity levels. What this study does is bring in experimental data as well as an analysis of how various buildings perform thermally in UiTM Cawangan Pulau Pinang, Permatang Pauh Campus.

2.0 METHODOLOGY

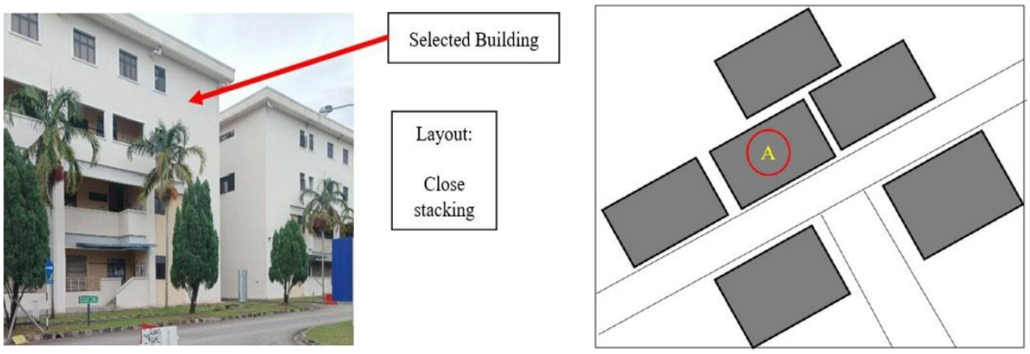
This study employs an experimental method approach to examine the impact of building layout on the thermal environment at UiTM Cawangan Pulau Pinang. The data were collected through direct measurements of air temperature, air velocity, and relative humidity at three different building layouts which are close stacking (Layout A), stacking with open area (Layout B), and non-stacking with open area (Layout C). These measurements were taken using calibrated instruments.

2.1 Building Layout Selection

Three different building layouts were selected which are close-stacking, stacking with open area, and non-stacking layouts. From a simple perspective, the difference between all these three building designs is whether the building was arranged or stacked closely, stacked but with an open area, or others.

2.1.1 Building Layout A

Building Layout A is characterized by a closely stacked configuration. As illustrated in Figure 1, the selected building for Layout A is positioned in close nearness to adjacent structures. The buildings in Layout A are tightly grouped, with only small walking paths available between them. The area surrounding Building Layout A is tightly built up, with minimal open spaces or clear areas around the buildings.

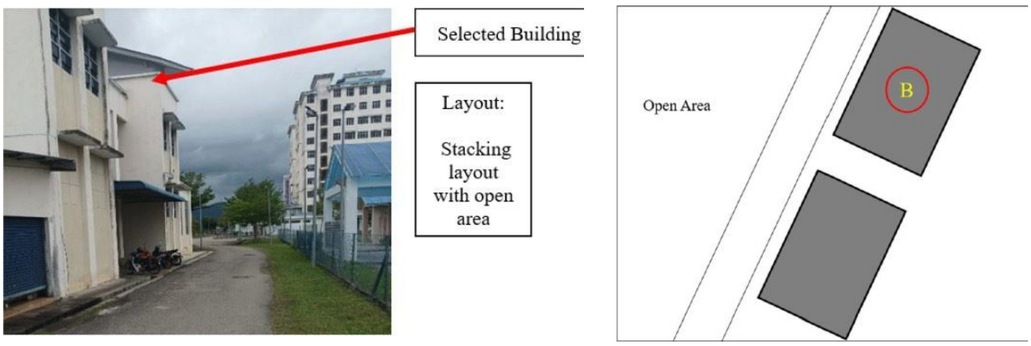


(a) (b)

Figure 1: (a) Selected building for Building Layout A (b) The arrangement of Building Layout A from the top view

2.1.2 Building Layout B

Building Layout B features a stacking configuration but includes an open area to enhance airflow. As shown in Figure 2, the selected building for Layout B is situated near other buildings.However, unlike Layout A, the area surrounding Building Layout B incorporates open spaces that facilitate better air circulation. The buildings in Layout B are closely arranged, but not overlycongested. There are walking paths and an open area designated for solar panels, contributing to the overall openness around the buildings.



(a) (b)

Figure 2: (a) Selected building for Building Layout B (b) The arrangement of Building Layout B from the top view

2.1.3 Building Layout C

Building Layout C represents a non-stacking configuration with open space around it. As illustrated in Figure 3, the selected building for Layout C is positioned at a considerable distance from other buildings. This layout ensures that Building Layout C is not clustered with adjacent structures, allowing for significant open areas around it. The surroundings include open parking spaces and fields, which contribute to the spacious environment and enhance air circulation.

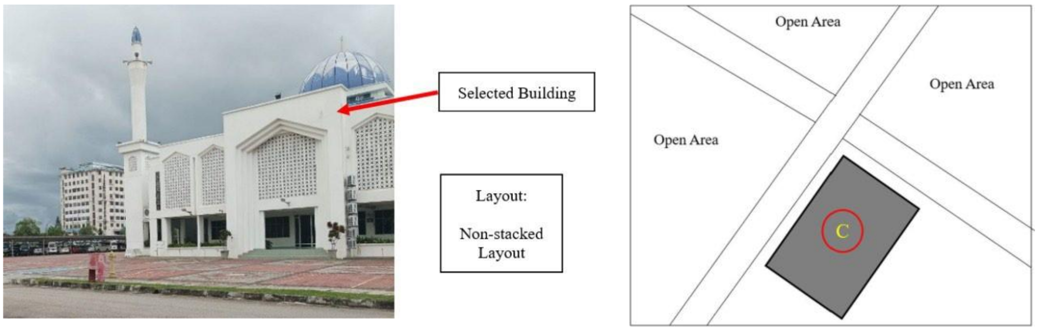


Figure 3: (a) Selected building for Building Layout C (b) The arrangement of Building Layout C from the top view

2.2 Measuring Instrument

Several accurate measuring instruments were used to evaluate the thermal environment in different building layouts. These instruments were chosen because of the confidence levels that they possess in accurately measuring major environmental variables. The temperature, relative humidity, and air velocity were all recorded with VT120 Integral Thermo-Anemometer and Benetech Data Logger GM1365.

2.2.1 VT120 Integral Thermo-Anemometer

The VT120 Integral Thermo-Anemometer is used to measure indoor air temperature and air velocity. This instrument was chosen for its reliability and accuracy. The most accurate readings are obtained by holding the anemometer in a vertical position, gathering consistent and reliable data. Figure 4 shows the Integral Thermo-Anemometer VT120 used in this study.

Figure 4: VT120 Integral Thermo-Anemometer

The specifications for this instrument are detailed in Table 1, highlighting its measurement range and accuracy.

Table 1: VT120 Integral Thermo-Anemometer Specification

Specification	Air Velocity	Air Temperature
Unit Measurement	m/s	°C
Range	0.4 until 30	-10 until 50
Accuracy	± 3%	± 0.6 °C

2.2.2 Benetech Data Logger GM1365

The Benetech Data Logger GM1365 was utilized to measure air temperature and relative humidity. Figure 2 shows the Benetech Data Logger GM1365. This device is crucial for capturing detailed data on the thermal conditions within the selected building layouts, providing insights into the relative humidity levels alongside temperature measurements.

Figure 5: Benetech Data Logger GM1365

The important specifications for this instrument are detailed in Table 2.

Table 2: Data Logger GM1365 Specifications

Specification	Value
Temperature Measuring Range	-30 until 80 °C
Humidity Measuring Range	0 until 100% RH
Accuracy Tolerance	± 0.3

2.3 Experimental Procedures

To standardize the data collection, the experiment was carried out at noon because of the highest temperature period of the day. Fohimi et al. observed that air temperature also can be affected by the weather such as a rainy day or hot day [12]. Measurements were made at the entrances of A, B, and C building layouts. The VT120 Integral Thermo-Anemometer andBenetech Data Logger GM1365 were used at each location. Instruments were powered up and tested. Data collection started one minute after activation for proper functionality. The data will be taken from 12:15 until 13:10 noon on selected hot days during the end of the year Decemberto January. This procedure was repeated the next day at Building Layout B and the following day at Building Layout C. The experiment was repeated several times at each location to ensure reliable and robust data.

3.0 RESULT AND DISCUSSION

3.1 Air Temperature Comparison with Three Building Layouts

Based on the data collected, it can be known from Figure 6 that the average temperature for the building at Layout A is 33.52oC higher than other buildings which is the building at Layout B is 33.21oC and the building at Layout C is 31.64oC. This result isconsistent with other studies that showed internal building temperatures are higher in building layouts favoring compact forms and less overshadowing due to increased solar heat gain [13]. This suggests that Layout A had the hottest building of all. In contrast, the building with Layout C experienced the lowest temperature on average based on collected data which indicates that the building in Layout C is also among the cooler kinds of buildings and this aligns with studies suggesting an open layout for buildings tends to have lower indoor internal temperatures [14]. The building orientation at location C can lead to a 10% reduction in temperature fluctuations. These observations emphasize the significant impact of building layout on microclimate and thermal comfort within architectural environments.

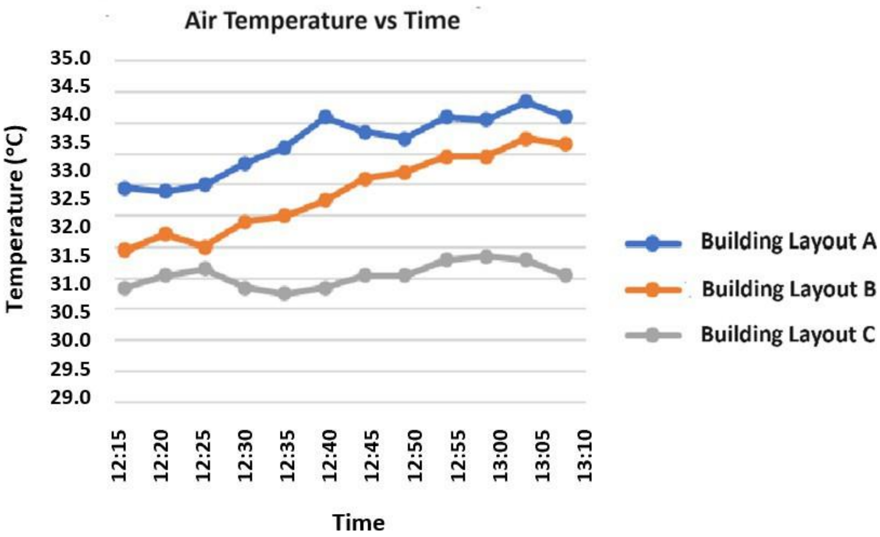


Figure 6: Graph of Air Temperature versus Time for three building layouts

3.2 Air Velocity Comparison with Three Building Layouts

From Figure 7 the building in Layout C, with an average air velocity of 0.4 m/s, showed the highest average air velocity compared to the building in Layout A is 0.18 m/s and 0.39 m/s for the building in Layout B. The findings indicate that building orientation at location C can increase air velocity by 70%. This is consistent with studies suggesting that situating buildings in open spaces or on high ground contributes to the average strengthening effect of air velocities [15,16]. In contrast, the building at Layout A had the lowest average air velocity according to the data - consistent with evidence suggesting that buildings located in sheltered or obstructed positions have lower wind speeds and poor airflow [17]. These observations highlight the significant influence of building location on air movement and ventilation effectiveness within architectural contexts.

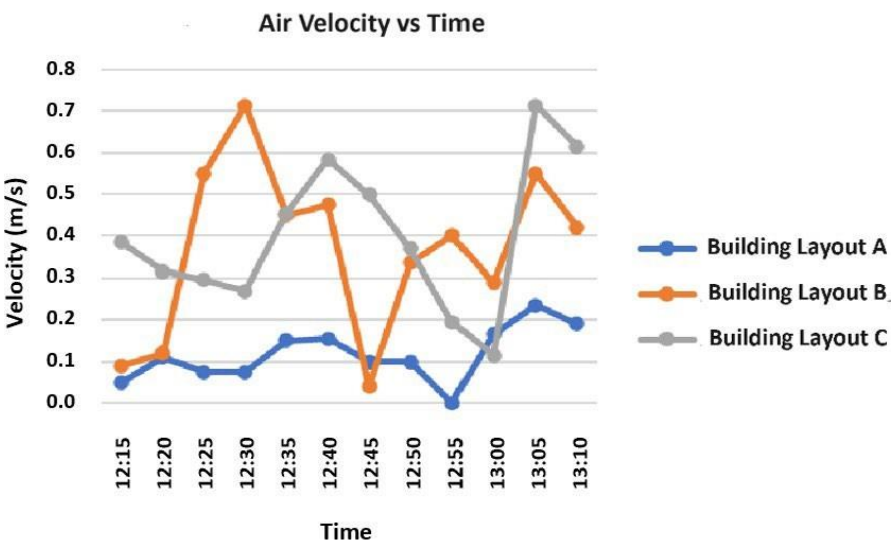


Figure 7: Graph of Air Velocity versus Time for three building layouts

3.3 Relative Humidity Comparison with Three Building Layouts

From Figure 8, it can be seen that the building at Layout C has the highest average value of relative humidity of 66.17 % compared with other selective buildings from the collected data.

The findings indicate that building orientation at location C can 5% increase in relative humidity. This is in line with other works pointing to how constructions located in either sheltered or low-ventilation spots can support evaporation conditions leading to higher dampness, as well as compounded air stagnation that retains even more moisture [18,19]. The most experienced average relative humidity at Layout B's building is 65.02%, but the lowest one found in all data was representant of the building settled down with Layout A of 64.25% and, according to a study that related humidity to exposed or well-ventilated locations where air exchange rate is more constant and better connection between internal space and moisture dissipation [20]. Such observations highlight the important influence of building positioning and ventilation on indoor humidity within architectural spaces.

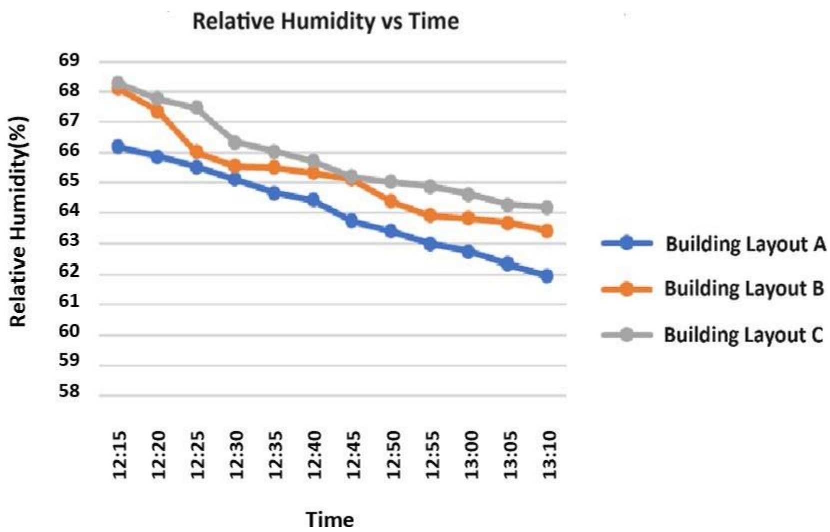


Figure 8: Graph of Relative Humidity versus Time for three building layouts

4.0 CONCLUSION

The study demonstrates that building layout has a substantial impact on the thermal environment. The best building layout from the three selected building layout samples are building layout at Layout C. The building layout at Layout C as shown in the methodology section has the best wind dispersion layout compared to the other sample of building layout because it has a lot of open area around the building and the other nearly buildings were not too close to each other. Building Layout C also has the best heat dissipation because the layoutof the building was not stacked with other buildings. Building Layout C was in a location with good humidity that matches the human thermal comfort even in the climate of monsoon season in Malaysia during the end of the year December to January. Universities and city planners should consider these findings to design more thermally comfortable and efficient buildings. Further studies could explore additional parameters and different climates to generalize the findings.

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