Developing building comfort index from building climate factors in a tropical urban environment

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Abstract. This study investigates on the internal climate condition of buildings in an urban area situated at the Infrastructure University Kuala Lumpur (IUKL). The factors that contribute to the effect of building climate are being identified and the building climate information portrays by using the Geographical Information System (GIS). The main contributing factors of building climate are building design, building material, orientation of the building towards the sun and surrounding climate around the building. The main objectives of this study are to develop a building comfort index using geospatial technologies and to investigate the building climate factors based on the building climate data collected from building samples. The devices used are temperature and humidity meter and noise level meter. The building comfort data collected from each room are room temperature, humidity and noise. The study area is in Kajang, Selangor area, which is being identified as an urban area. Buildings chosen are composed of ten (10) buildings in IUKL. The results of the study revealed that the building climate index (BCI) for all buildings in IUKL comprise of six (6) buildings are having BCI of Comfortable and four (4) buildings with BCI of Less Comfortable. A mathematical equation was obtained from the data collected by using the statistical power formula and tolerances of the data were being obtained from predicted data which has 72% tolerance and onto tested data which has 93% tolerance. The results of the study implicate building manager, architect, building surveyor, town planner and building user. It is hoped that further studies focus on obtaining the BCI of the buildings once in every three months of the year.

1. Introduction

Being one of the tropical countries in the world, the weather in Malaysia is having warm or hot and rain throughout the year. In general, the amount of rain that majority of the states in Malaysia receive is less than 200mm. In fact, Peninsular Malaysia, especially in south Perak, Selangor, Negeri Sembilan, Melaka, Johor and East Pahang receive less than 100mm of rain and being categorized under 60% of mean value. However, in certain area such as north-west of Perlis, Kedah and north Perak receive more than the normal mean value of rain, within the range of 300mm to 400mm. Hence, Peninsular Malaysia has a record number of rainy days ranged from 5 to 18 days [1].

In Malaysia, there are many types of buildings of which the shape and design are inspired through years by history, aesthetical values as well as influences from other countries. There are many types of buildings available such as residential, office and business purpose, learning centre, public and other. Residential buildings are from single, double, strata type (high-rise) and multi-storey type, as well as bungalow and others. Office and business purpose building are factories, shop lots building
of single storey to multi-storey, historical building and tourist attraction building. Learning centre buildings are school ranging from nursery, day care centre, primary school, secondary school and higher education like colleges and universities. Public building are general building that are used by people like court, ministry administration building, transportation centre and others.

The design of these buildings is differently presented in different states. For example, shop lots in Kuala Lumpur are generally multiple rows of double storey or more, as compared to shop lots in Terengganu which are generally single storey single row. Same goes to the design of residential building in Kuala Lumpur and Selangor whereby, there are a lot of high-rise residential building as compared to Perak and Kedah which are having less of high-rise residential building. However, there are some building types that have general and specific design such as school design and structure in Selangor are the same as the one in Kelantan. This is because the design and structure of every school in Malaysia are being controlled by the ministry since year 2000 [2].

The materials that were used for a building also changes throughout the years. Long ago, Malaysia used to have buildings made of timber and in 1930's, Malaysia is one of the leading countries that used timber construction in most of construction work. These can be seen in most of the historical building left or being preserved until now for the reference of architecture design and traditional Malay values within a construction of a building. As time goes by and technology booming, the invention and innovation of building construction materials have taken over the timber construction work as the main method of building construction. Nowadays, many things need to be taken into consideration when deciding which method to use for building construction. Other than the need to meet the end user or customer requirement, the architects and civil engineers also need to design and built buildings referring to the budget provided by the land developer.

There are many people involved in the building construction process. A real estate agent is needed to estimate the value of the land that construction work will be carried out. Land surveyor is needed to do the preliminary survey of the area, to carry our setting out survey while construction is the ongoing process to ensure the buildings are being built on the correct point and deformation or monitoring survey once the construction work is finished. This is to ensure the safety of the building and to confirm with the project manager that the building is on the correct position and according to the site plan that was provided by the civil engineer earlier. A quantity surveyor is needed to estimate the costing of the whole construction project, varying from the cost of the materials, workers and others. In the end, the land developer together with the project manager and civil engineer will bring the final plan to get the approval letter from the local authority for the tenant to occupy the building. Just before the approval, the building needs to be tested on whether or not the building is following the act set by the respective Occupational Safety and Health (OSHA).

2. Background of the study

According to [3], building envelopes fulfil many functions such as structure, climate control, energy savings and generation, aesthetics, psychological well-being, and occupant comfort. Building climate can be in terms of building temperature, pressure, humidity and wind speed. By analyzing the climate of the building, this will help in the future building planning and development. Materials used when constructing a building depends on the purpose of a building. Building materials are materials that are used for construction purposes. Some of the materials that are occurring naturally, which have been used to construct building are clay, rocks, sand, wood, twigs and leaves. Man-made or synthetically made materials for building construction are also being used and the use of these materials are segmented into specific specialty trades, such as carpentry, insulation, plumbing and roofing work. These materials are actually making the building looks nicer or in another word, the make-up of habitats and structures including homes. There are many factors that contribute to climate of a building including building materials, orientation of the building towards the sun, building design and the surrounding climate of the building.

Building climate is being defined as the inner condition of the building such as temperature, air pressure, wind speed and humidity within the building. In general term, room temperature being described as common indoor temperature, which usually in the range of 20 °C (68 °F or 293 K) to 25 °C (77 °F or 298 K) [4]. Room air pressure is usually the same as the atmospheric pressure outside (outdoor), in which the standard atmosphere is stated as being 101325pascals or 101.325kPa [4]. The
effect of wind blowing onto a building will generate difference of pressure up to 20 Pascals between outside and inside of the building structure and creates variations in the building pressure [5]. Humidity being defined as water vapor in the air, which is the transformation from water to gas state. By having high humidity, it reduces the sweat affect when cooling down the body by reducing the rate of evaporation of moisture from the skin [5].

2.1 Building Energy Efficiency
A study on agent-based modelling of interaction between commercial building stocks and power grid describes a preliminary study on simulating commercial buildings modelled as consumer agent [6]. The study relates to the interaction with the power grid. The procedure includes a simple hourly bottom-up building energy model which was developed provided the climate condition, building design and operation. In addition to this research, the model used in the study is to stimulate different types of commercial buildings as agents. Hence, the model is to derive hourly load profile of the whole building stock at the city or regional level. The model helps in a way to overcome the problems arise between building stocks and power grid. Another study [7] agrees with the earlier research in terms of using a specific model which involved in economic growth [6]. Although this research [7] focuses on economic Model Predictive Control (MPC) for building climate control, the model used was for the benefits of the environment. The MPC was used to control a system of energy producers and consumers in a Smart Grid. Heat pumps for residential heating system in buildings with a floor heating system were used. Other than that, the thermal capacity of the building was also used to shift the energy consumption to periods with low electricity prices and the heating system of the house becomes a flexible power consumer in the Smart Grid. This search [7] postulates that the model that they used is linear state space model and the controller that showed the results was an economic MPC formulated as a linear program. As such, the model forecast of both weather and electricity price. The result of the study reveals the use of economic MPC was to manipulate the compressor in the heat pump so that the total electricity cost is low and minimized. To add, the cost also involves keeping the indoor temperature in a predefine interval. The result also reveals that the economic MPC is able to shift the power consumption load to periods with the prices of low electricity. Simultaneously, the study shows that the load shifting ability of the economic MPC will exploit the weather forecasts in order to reduce the total cost of operating the heat pump and therefore, the concept of economic MPC was to proof the use of perfect forecasts. [8] agree with the earlier research [6] that the results on building heating and cooling loads help in energy consumption and it is efficient in different climates. Hence, the energy consumption is efficient in different climates [9]; [10]; [11]; [12]. Energy consumption is important in building and environment and will help the community to overcome to the increase of economy status [8].

2.2 Building Climate and Thermal Performance
According to [13], climate change affects the management of thermal performance risks in buildings subjects. They state that quantification of the risks posed by climate change is possible considering many restrictions. The study refers to the principal tool for quantifying climate change related risk to the thermal building performance is transient building simulation. As such, this study focuses on the computational approach in making equivalent comparisons between both the present and future climate conditions based on the climate data that was developed by meteorological and climate change experts. According to the study, a transient simulation is required as the interest lies with two key thermal performance aspects; energy use for heating and cooling and overheating risk. With regards for both aspects, the risk that is to be quantified is related to fluctuations in heat flows and internal or external temperatures over time, making more generic methods like unsuitable monthly averages. The results in the study by [13] reveal that firstly, the current building simulations tool, when combined with automated sampling and output analysis together with the data aggregation technique, allow the making probabilistic predictions of the thermal behaviour of buildings subject to climate change. Secondly, the regular approach of computing risks a product of consequences and probability has been showed to work for climate change impact assessment studies of individual case study buildings. Thirdly, the performance indicators for climate change impact need further development as premature to set thresholds for acceptability of climate change risk. Thus, there
appears to be interest in the industry to take the quantification and indicators of risk to the next level. Fourthly, since climate change is a serious matter the needs to be taken into consideration when designing, constructing and managing building, hence, the current building stock is likely to be much more resilient towards climate change than general assumption. Lastly, to reduce uncertainties, further climate change risk impact assessments of buildings, more work is in the areas of system performance degradation and life expectancy, maintenance and interventions and the creation of a body knowledge allows simulations to likely timing and impact of changes to the building will therefore increase the usefulness of predictions. Overall, a balance approach is needed to produce climate change impact studies on a building level that have sufficient resolution. It implicates the enable design teams, clients and facility managers to act on the information resulting from such studies. Studies related to [13] results were based on sampling-based methods for uncertainty and sensitivity analysis [14]; [15]; [16]; [17].

Urban Planner and architects are desire for techniques to model an urban microclimates and urban block surfaces temperatures for strategic urban designs at the early design stages [18]. The study done by[18] introduces a simplified mathematical model for Urban Simulations (UMsim) that includes urban surfaces temperatures and microclimates. The used of UMsim was to simulate the microclimates that particularly between two (2) sets of data which are surface temperatures of urban [18]. This UMsim simulation can be used to assess the impact of urban surfaces properties of the urban microclimates, which will be able to form robust data and images of urban environments for sustainable urban design [18].

In the study conducted by [18], they have considered several parameters in order to compute the microclimate simulation for the existing building. That includes direct solar radiation, diffuse radiation, reflected radiation, long wave radiation, heat convection in the air, heat transfer in the exterior wall and the ground within the building complex. The mathematical model was solved by using the toolbox in the Matlab software [18]. From this study, there was an argument whereby there was a need to be at least two (2) levels of modeling and analysis for the simulation of the building, as well as modelling and analysis for urban thermal environment simulation. The need was supposed to provide interactive design feedback that quickly test the viability of the idea and multiple options to be compared and the early planning stage of the building development [18].

The objectives of this study are to investigate the building climate factors and to develop the Building Comfort Index (BCI) using geospatial technologies.

3. Methodology
The research flowchart for this study is:
Step 1: Investigating the contributing factors to the building microclimate
Step 2: Collecting building internal climate data (rooms temperature, humidity, noise) and Analyzing the building microclimate data in relation to the contributing factors
Step 3: Building microclimate model development, Building Comfort Index (BCI) development – [19] and Building Comfort mathematical model development – Multiple regression analysis
Step 4: Testing the mathematical model onto the testing building (other educational institution – UPM & Uniten)
Step 5: Verifying the testing data with the developed mathematical model (tolerance percentage to be more than 60%) and Questionnaire survey to the building users (in 3 controlled environment rooms)
Step 6: Finalizing the Building Comfort Index for buildings

Building climate data information is collected by using the Temperature and Humidity Meter and Sound Level meter. These devices enable the user to obtain information related to temperature and humidity of a closed area, for example room, classroom, laboratory and others. The information required are:
1. Room temperature
2. Room pressure
3. Room humidity

The data and information provided by the device will be in terms of numbers and its respective unit. For example, the temperature data will be in degree Celsius and the pressure data will be in kilopascals. These numbers will be analyzed in relation to the contributing building climate factors;
building materials, building orientation towards the sun, building surrounding climate and building design.

The study is conducted at the Infrastructure University Kuala Lumpur (IUKL), Kajang which is located at Unipark Suria, Jalan Ikram – Uniten, 43000, Kajang, Selangor. The local authority that responsible for this study is Majlis Perbandaran Kajang (MPKj). Samples of data collection are taken within the university buildings. IUKL is classified as urban area since land development and the upgrading of building infrastructure happen occasionally.

The development of the Building Comfort Index (BCI) (Table 1) is based on the equations used to develop building thermal modelling discussed in the literature review. Each room that is selected to take their building microclimate condition will be measuring its room temperature, room humidity and room noise. The room temperature will be categorized into three (3) comfort index temperature (CIt) scaling from one (1) to three (3). Scale 1 is categorized as Comfortable with room temperature of 28°C onwards, scale 2 is categorized as More Comfortable with room temperature between 25 – 28°C and scale 3 is categorized as Most Comfortable with room temperature of 24°C and below. As for room humidity, the comfort index humidity (CIh) is also categorize into three (3) being the first scale to be Comfortable with room humidity of 44% or less. Scale 2 of the room humidity with More Comfortable category is between 45 – 65% and scale 3 is for rooms with humidity of 65% or more, which is categorized as Most Comfortable. The last microclimate building condition will categorize the room comfort index noise (CIn). Scale 1 of the room noise index is for room having 65Hz or more, that is categorized as Comfortable. The second category of comfort index of More Comfortable that is on the second scale are rooms that is having noise between 45 – 65Hz. The third scale of the room noise condition is categorized as Most Comfortable with 45Hz or less.

Table 1. Suitable building thermal condition as shown in the related scale was adapted from finding of a research [20].

| No | Item | Comfort index | Condition |
|----|------|---------------|-----------|
| 1. | Internal room temperature (Building 1 to 10) | 1 - Most Comfortable | ≤18°C |
|    | a) Classroom | 2 - More Comfortable | 18-23°C |
|    | b) Computer lab | 3 - Comfortable | 24-27°C |
|    | c) Workshop | 4 - Less Comfortable | 28-29°C |
|    | d) Meeting room | 5 - Least Comfortable | >30°C |
|    | e) Administration Office | | |
|    | f) Library | | |
|    | g) Hostel | | |
| 2. | Internal room humidity (Building 1 to 10) | 1 - Most Comfortable | ≤35% |
|    | a) Classroom | 2 - More Comfortable | 35 – 45% |
|    | b) Computer lab | 3 - Comfortable | 46 – 65% |
|    | c) Workshop | 4 - Less Comfortable | 66 – 75% |
|    | d) Meeting room | 5 - Least Comfortable | ≥75% |
|    | e) Administration Office | | |
|    | f) Library | | |
|    | g) Hostel | | |
| 3. | Internal room noise (Building 1 to 10) | 1 - Most Comfortable | ≤35Hz |
|    | a) Classroom | 2 - More Comfortable | 35 – 45Hz |
|    | b) Computer lab | 3 - Comfortable | 46 – 65Hz |
|    | c) Workshop | 4 - Less Comfortable | 66 – 75Hz |
|    | d) Meeting room | 5 - Least Comfortable | ≥75Hz |
|    | e) Administration Office | | |
|    | f) Library | | |
|    | g) Hostel | | |

Hence, from the equations discussed, the Building Climate Index (BCI) is formed to be; BCI of a building:
BCI = BCI_t + BCI_h + BCI_n  \hspace{1cm} (1)

where:
BCI_t = Average of Room Comfort Index of a Building (temperature)
BCI_h = Average of Room Comfort Index of a Building (humidity)
BCI_n = Average of Room Comfort Index of a Building (noise)

To calculate BCI, one must calculate the Room Comfort Index (RCI). The base of these equations was developed from the building thermal modeling mathematical model that has been discussed in the literature review. Hence,

RCI of a room:
RCI = RCI_t + RCI_h + RCI_n  \hspace{1cm} (2)

where:
RCI_t = Room Comfort Index (temperature)
RCI_h = Room Comfort Index (humidity)
RCI_n = Room Comfort Index (noise)

The BCI then will be used in categorizing the buildings into five (5) types of building comfort. Scaling from 1 to 5, with Least Comfortable, Less Comfortable, Comfortable, More Comfortable and Most Comfortable, as shown in Table 2 below.

| BCI | Comfort condition |
|-----|-------------------|
| 5   | Most Comfortable  |
| 4   | More Comfortable  |
| 3   | Comfortable       |
| 2   | Less Comfortable  |
| 1   | Least Comfortable  |

4. Results and Discussion

4.1 Building climate factors – material, building orientation, building surrounding climate and building design

There are four (4) factors that were being considered as contributing factors towards the building climate data. The first factor is building material. The data showed that material contributed to the climate of the rooms. Normally, the material used to build the building is made of bricks, which was also considered as being a common building material. The results for building material showed that the bricks were able to maintain the temperature of the rooms throughout the day, hence giving the maximum comfort to the room user. The results also showed that there were not much difference in temperature between the same types of room, for example all lecture rooms with the range of 27°C. However, the data for humidity and noise varies in comparison to the building material. This might due to the fact that the hard surface tends to reflect sound and also contributes in making the humidity level of the room higher or lower. Humidity level for labs has a huge difference between the highest and lowest level. This might be because of the type of work that is done in the lab. Technical labs tend to have more machines that produces humid in the air, hence the high in humidity level. Sound level in the library has the lowest level compared to the other types of rooms. This is caused by the material used to build the library is also brick, but with additional of glasses as windows and other type of sound absorbing wall. This is because in general, library is a quiet place, hence the low level of sound.

The other contributing factor towards the building climate data is orientation of the building that contains the rooms towards the sun. The orientation was categorizes into facing sun, 50% facing sun and not facing sun. All lecture rooms were located within the same building, however not all receive the same sun orientation. But, the data collected shows that they have the average temperature for all lecture rooms, which was 27°C. Library has varies room temperature due to the orientation of the sun are different from one point to another. Temperature of labs also shows different from one another and the cause of it was the lab that has the highest temperature to be facing directly to the sun. Temperature of office room also shows an average on 27°C, except for one office, that has less temperature. This might be because the office does not face the sun. All types of rooms are having the
humidity level of 47% to 87%, with library having the less humidity as compared to other rooms and buildings. Library received the less sun light, that means not all part of the library is facing the sun. This also due to the fact that the lab equipments release some energy too, that mixes with the heat from the sun that produces high humidity air in the lab. Sound level of all types of rooms are also within the same range. This shows that the orientation of the rooms towards the sun do not affect the room comfort, since the sound level was maintained at the level between 44Hz to 55Hz (uncomfortable level of sound is 70Hz and above).

Surrounding climate is also being considered as contributing factor towards building climate. During the time that the data was taken, the weather was warm and clear since the data was collected between end of morning time, towards midday and a little bit of time right after midday. The same surrounding climate reflects in the average room temperature for all types of rooms. When there is not a huge difference between the highest room temperature and lowest room temperature, this shows that the same climate can maintain the room temperature. In terms of humidity, most of the lecture rooms and most of the labs has the highest humidity level compared to library that has the lowest humidity level. Even though the surrounding climate was the same, but that was not the factor that affects the building climate data. Same goes to sound level that was not affected by building surrounding climate. This is because sound comes from an energy that is being transmitted or bounced from a surface. Surrounding climate at that time, which was warm and clear do not release any sound energy that can pass through the air. That is why the differences in the highest and lowest sound level, was not far difference in the lecture rooms, library areas, labs and office rooms as well as the other rooms in IUKL.

The last contributing factor for the building climate was building design. All rooms that the building climate data was taken from are being designed with modern and standard concept for an institution of higher learning in Malaysia. The design concept for every room was made to serve the purpose of the room. For example, a lecture room was design to be large and wide area, to occupy at least 60 students at a time. Labs on the other hand was design to enable the installation of equipments required for experiments or test to be carried out. These design concepts are also made to maintain the comfort level of the user, which is reflected in terms of room temperature, room humidity and room sound level. Room temperature for all rooms were maintained at the average comfort temperature level. This means that the design of the rooms gives comfort to the room user, hence will enable the increase in productivity of the user. Humidity and sound level data also reflect the comfort level of the room. Thus, the design of the room enables the room to produce comfortable range of humidity and sound level, hence serving the purpose of the room for lecture room, library area, laboratory and office room.

4.2 Building Climate Index (BCI)

The data and analysis from the tables above were discussed based on the contributing factors such as building material, building design, building orientation towards the sun and building surrounding climate. The details of the analysis are as follows.

| Building | BCI | BCI 12-2 pm | BCI 4-6 pm | Average BCI | BCI Category | Comfort Condition |
|----------|-----|-------------|------------|-------------|---------------|------------------|
| 1        | 9   | 9           | 7          | 8           | 3             | Comfortable       |
| 2        | 9   | 8           | 7          | 8           | 3             | Comfortable       |
| 3        | 9   | 9           | 9          | 9           | 3             | Comfortable       |
| 4        | 8   | 7           | 7          | 7           | 3             | Comfortable       |
| 5        | 10  | 8           | 7          | 8           | 3             | Comfortable       |
| 6        | 8   | 8           | 7          | 8           | 3             | Less Comfortable  |
| 7        | 8   | 8           | 8          | 8           | 3             | Less Comfortable  |
| 8        | 9   | 11          | 10         | 10          | 4             | Comfortable       |
| 9        | 8   | 8           | 8          | 8           | 3             | Less Comfortable  |
| 10       | 8   | 8           | 9          | 8           | 3             | Comfortable       |
Table 3 above shows the individual Building Climate Index (BCI) for every building in IUKL. The table above also shows the individual BCI for three (3) different parts of the day in which the building climate data was collected. The three (3) different parts of the day was from 9 – 11am, 12 – 2pm and 4 – 6pm. The BCI from different parts of the day is being calculated as average to obtain the overall BCI for the building. The table shows that the BCI for building 1 is 3 (Comfortable), building 2 is 3 (Comfortable), building 3 is 3 (Comfortable), building 4 is 3 (Comfortable), building 5 is 2 (Less Comfortable), building 6 is 2 (Less Comfortable), building 7 is 2 (Less Comfortable), building 8 is 3 (Comfortable), building 9 is 2 (Less Comfortable) and building 10 is 3 (Comfortable).

There are six (6) buildings having Comfortable BCI and four (4) buildings having Less Comfortable BCI. These BCI value shows that the majority of the buildings in IUKL is in a Comfortable condition. No building is in Least Comfortable, More comfortable and Most Comfortable comfort conditions.

The building climate data collected were room temperature, room humidity and room sound. The data were collected from ten (10) buildings in an institution of higher learning, namely IUKL.

4.3 Building comfort index correlation formula
In order to prove that the formula of BCI is reliable, the data collected were then being calculated by using the power formula in the software named Statistical Package for the Social Sciences (SPSS) by using the linear regression analysis method, in order to obtain the standard mathematical model for correlation coefficient of each BCI contributing factors, temperature, humidity and noise.

The standard mathematical model for linear regression analysis is being portrayed as

\[ y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \]

where;
- \( y \) = Dependent variable
- \( x \) = Explanatory Variables
- \( \beta \) = Coefficients
- \( \varepsilon \) = Random Error

The coefficient obtained from SPSS stated as in the table below:

According result obtained from multiple regression analysis, the beta values obtained for temperature is 0.279, for humidity is 0.247, for noise is 1.405 and constant value is -2.028. Form the result obtained, the mathematical equation obtained for this set of data is:

\[ y = 0.279 t + 0.247 h + 1.405 n - 2.028 \]  

4.3.1 Power formula for the linear regression
From the coefficient beta that was obtained from the linear regression analysis, the data collected is then being calculated by using the power formula:

\[ y = c \times RT^{\beta_t} \times RH^{\beta_h} \times RN^{\beta_n} \]  

where;
- \( y \) = dependent variable
- \( \beta_t \) = Beta Temperature
- \( c \) = constant
- \( \beta_h \) = Beta Humidity
- \( RT \) = Room Temperature
- \( \beta_n \) = Beta Noise
- \( RH \) = Room Humidity
- \( RN \) = Room Noise

All data collected are calculated by using the power equation above. The result is then summarized and obtained an average of -4432.387.

A set of human perception data was collected from a questionnaire survey that was obtained from the room users. A total of 98 responses obtained from the room users. The users are randomly picked from various age, background and the frequency of them using the rooms. Three (3) rooms were set up to the comfortable level of room comfort index composed of comfortable level of room temperature, room humidity and noise. These rooms are classroom, office and administration room and indoor laboratory.
4.4 Room Comfort Level Data from Room User

In order to ensure that the result obtained was acceptable, a series of experiment was conducted amongst the room user. The experiment conducted involved three (3) rooms with controlled comfort level of temperature, humidity and noise. The rooms are a standard air-conditioned studio, air-conditioned classroom and a moderate-controlled air-conditioned office room. The outcome of the experiment was that the room user finds that they feel comfortable while staying within the room based on temperature, humidity and noise within the room. The result of the experiment was from ninety eight (98) respondents.

The R-squared value of correlation between the measured BCI and the human perception BCI is obtained as 0.2083. The R-squared is to be 21% out of 100%. The BCI result revealed that human perception is considered as comfortable since majority of the values fall under category 3 (comfortable) for both measured and perception.

According to [21], R-squared value is expected to be low especially in any field of attempt that is to predict human behavior. For example, in psychology, typically the R-squared values are lower than 50%. The reason being is that humans are simply harder to predict compared to physical processes. Frost [21] also stated that if the R-squared value is low but the statistical values are significant in relation to the predicted value, then the result obtained can be concluded that the changes in the predictor values are in line with changes in the response value. Regardless of the values of R-squared, the significant coefficients do still represent the mean change in the response for one unit of change within the predictor while holding the other predictors in the model consistent. It is obvious that this type of information is highly valuable [21].

[22] and Penn State University (2017) agreed with [21] that the acceptance of R-squared value is depending on the research area. Social scientist who usually trying to learn something about the big variation on human behavior will have a hard time to get the r-squared value above 25%. On the other hand, engineers who are conducting statistical research on technical systems would likely find that r-squared value of 30% is not acceptable (Penn State University, 2017). R-squared is not only to be used in guiding the user through a statistical analysis towards better and better model since among the models beforehand, the worst R-squared with a value of 97% and the best value with an R-squared of 0% [22].

5. Conclusion

This study implicates the people who want to know and visualize internal building climate data through the produces Building Climate Model (BCM). The people who usually need to know these types of data are building contractors, building maintenance, quantity surveyor, urban and town planner, land surveyors, architects, construction managers and the most important is the building users. Referring to this study, the users of the buildings in IUKL are mainly students, lecturers, administrations officers, general workers and lab executives. It is hope that this study benefits and inspires other researchers to carry out further research to expand the BCI and Building Climate Model (BCM) by adding more information and a user friendly tool for others to use.

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