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Cooling load estimation using cooling load temperature different (CLTD) method for ergonomic lecture room

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ABSTRACT

Accurate cooling load estimation is essential for achieving thermal comfort and energy efficiency in air-conditioned buildings, particularly in educational facilities with varying occupancy levels. This study estimates the cooling load of a lecture room (BK6) at UniCiti Alam, Universiti Malaysia Perlis, using the Cooling Load Temperature Difference (CLTD) method. Both external and internal heat gains—including heat transfer through walls and glazing, solar radiation, occupants, lighting, equipment, and air infiltration—were evaluated based on local climatic conditions and building characteristics. Cooling load calculations were performed for cases with and without corrected CLTD values to assess their impact on total heat gain. Results indicate that the maximum cooling load occurs at 1:00 p.m., with a total cooling load of 23.62 kW (32 HP) when corrected CLTD values are applied and 24.60 kW (33 HP) without correction. The difference between the two cases was found to be relatively small, at approximately 0.9 kW. The findings confirm that the existing air-conditioning capacity is insufficient to meet the actual cooling demand under full occupancy. In addition, an Excel-based calculation template was developed to facilitate practical cooling load estimation using the CLTD method. The proposed approach provides a reliable and user-friendly tool for Heating Ventilation, and Air-conditioning (HVAC) system sizing and can support energy-efficient design and operation of lecture rooms and similar buildings.

Keywords: Cooling load, Heat transfer, Ergonomic, HVAC, CLTD

1. INTRODUCTION

The subject of global climate change has risen to prominence in the scholarly community. It has constructed green buildings to minimize global warming by conserving energy. Some research has investigated occupancy detection to conserve energy, and the effect of natural lighting is also modified by occupancy. The cooling load has an impact on the temperature in the room. The cooling load is the amount of thermal energy used to cool the space. External and internal heat loads impact the supply of thermal energy. The heat generated by conduction, radiation, and convection is known as external heat load. Internal heat load refers to the heat created by humans and appliances in the area. Heat conduction and convection through door and window glass because of temperature differences, and heat produced by airflow due to door opening and through the crack of the window are all examples of external heat loads. The heat produced by other equipment, heat generated by users, and heat generated by lighting and electrical devices It is important to perform research to identify the thermal conditions in buildings for air conditioning, given the importance of temperatures being fixed in green buildings in order to aid in the achievement of green buildings. The population inside a building influences the heating load, as do other factors such as the building's outside and inside environmental conditions [1-5].

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Basic principles and industry experience are often used in the air conditioning business to design air conditioning systems. Human error is a risk with these procedures. Different methodologies for heat load estimations are provided by international organizations such as ASHRAE. However, because some of the methods are quite complicated, hand calculations using this approach may result in errors. In today's competitive market, technical sales engineers in the HVAC business must be well-versed in new technologies to successfully and quickly provide more optimum solutions. Smartphones have the same processing power as PCs but are more mobile [6-10].

Cooling load estimation is a way to control air-conditioning. Many public buildings use this air-conditioning to provide a controlled perimeter environment. Examples of public buildings that use air-conditioning are offices, homes, industries, and public halls and this air- conditioning will provide comfort to humans to get the best performance for some industrial processes. Full air-conditioning means the authenticity, movement, temperature, and humidity of the air controlled and the design specifications will determine it. However, the size of air- conditioning has many designers using the simple square foot method. This means "1 ton for every 500 square feet of floor area". This method is very useful in the initial estimation of equipment size [11-16].

In developed countries, the contribution of the building sector is around 20-40% of the total energy consumption. The building sector also produces around 32% of the total global energy consumption. HVAC systems are an important source of energy consumption in buildings. More than half of the building industry's energy consumption uses HVAC. HVAC offers great energy-saving potential in most cases. To improve the energy efficiency of HVAC systems, researchers know that optimal control and problem detection or diagnostics are required. Build cooling load forecasts in the ultra- short term. With a simulation duration of less than one hour, some optimal control methods and fault detection diagnostic procedures are critical. Kusiak and Li introduced an Artificial Neural Network (ANN) to predict building cooling loads to reduce cooling energy consumption [17-20].

A significant portion of the heating and cooling loads are distributed throughout the building through the roof and walls. A lot of energy will save if the construction is designed with passive approaches in mind. Passive cooling and construction approaches can have a good impact on environmental issues. When energy use goes down, so does power production, and no greenhouse gases are put into the air. People these days want to build with concrete and bricks, which don't stop heat from moving through the external walls very well. Instead, they demand thermal comfort throughout the year. As a result, if people build the building without even using passive methods, it will use more energy to cool and heat, which is a bad thing. So, looked for another way to solve this problem. The passive air - conditioning alternatives, which use less energy to cool and heat buildings [21-22].

There are several factors that can affect the thermal conditions of a building, namely room temperature, climate, and the location of the building being built. So there is this factor that is closely related to the cooling load calculation. The CLTD method is one of the methods for calculating load room cooling through the roof of a building where data is accessible using the temperature differential principle between external and inside surroundings [6]. The cooling load included in the factor may be calculated using the CLTD technique. By using this CLTD method it can be verified manually. When there is a tight match between the materials available for the CLTD, the results achieved by the CLTD procedures can vary by 5%–10%. This focuses the on need of having a broad set of materials for the CLTD approach [23-25].

The research focuses on estimating cooling load using the CLTD method for the lecture room at Uniciti. Currently, the main problem of the lecture room is that the actual cooling load is not known, resulting in uncomfortable environment when the room is fully utilized. It is assumed due to the available air-conditioning unit that is insufficient to accommodate the actual cooling load. Another problem of the lecture room is that there is no facile template to estimate cooling load.

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Therefore, this will remain the lecture room in uncomfortable zone until now. Two objectives have been drawn up based on the problem statement: 1. To estimate the actual cooling load for lecture room (BK6) using CLTD method, and 2. To develop an Excel template to facilitate the estimation of cooling load via CLTD method.

2. MATERIALS AND METHODS

The project will involve estimating cooling load temperature using various CLTD. This experiment will also be carried out in the lecture room at Uniciti Alam Sg. Chuchuh. CLTD is a technique for determining the amount of heat delivered to a lecture hall, as well as a simplified method of computing loads. Interior heat gain, photovoltaic transfer gain, and systems heat increase are three ways that total heat gain may be broken down into its component parts. The reason for this investigation is to analyse the cooling load of Uniciti lecture rooms using the CLTD approach This may also be used to calculate the total heat gain (THG) to decrease energy usage in the lecture room. Moreover, the objectives of this project are to evaluate the usage of horsepower air conditioners suited for Uniciti lecture rooms.

Building construction drawings and weather data under conceptual filtration conditions are required to determine cooling capacity. In general, the following procedure should be performed on Figure 1.

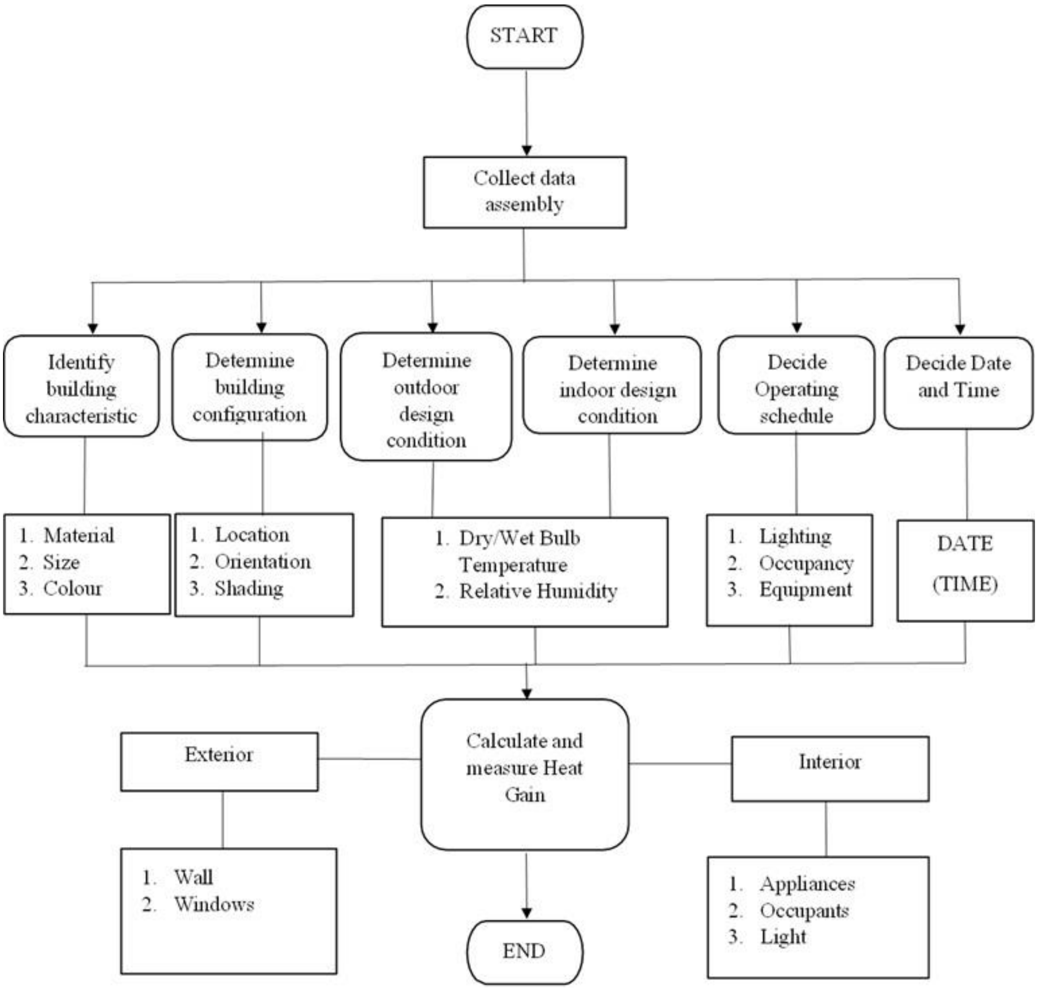

Figure 1. Flowchart for Methodology

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Data collection is the process of obtaining, measuring, and evaluating reliable information for research purposes. For the first time, measure and collect data on cooling load, building characteristics, configuration, exterior design condition, interior design condition, operation schedule and time date and will make calculations in general. Building characteristics will be identified by analysing the building's layout and specifications, which is the initial phase of this project. These building characteristics, such as construction materials, size, external colour, and structure, will be accessed. Exterior walls, ceilings, doors, and windows are examples of construction materials. With the architectural plan, height, and section, it can estimate the area of the room in the structure. Blue, white, and grey are examples of external surface colours. Defining a building location, orientation, and exterior shading from building designs and needs is one of the configuration-based procedures. Will be, visit the site of the proposed location, and see if this orientation allows the space to take advantage of daylight consistently and control glare along the long facade of the building. Natural landscaping or architectural components such as awnings, overhangs, and trellises can be used to give shading. Some shading devices, known as light racks, can also operate as reflectors, reflecting natural light for daylight lighting deep into the building's interior. Outdoor design conditions and analysing weather data selection is one of the procedures for design conditions. However, the results for dry-bulb and wet-bulb temperature might differ significantly from the data that is often utilised. To figure out how hot the dry bulb was, a thermometer was used in and around the space. Wet-bulb temperature is measured with a cotton swab. sample will be put in a beaker, and the air temperature in and around the room will be measured with a thermometer. To make sure that the result lives up to expectations, the right decision must be made. Inspect the interior design by taking measurements of the ventilation rate, interior dry bulb temperature, and interior wet bulb temperature, among other things. Permissible variation and control limitations must also be specified.

The operating schedule used in the lecture room for this project is like, the use of lighting. Which is, how long the lights are turned on each day. It is how many people use the lecture room at one time and when the lecture room is not in use. The last point to mention is the lecture room's equipment. An example (chairs, projectors, and tables). This is also the time frame during which this equipment will be run continually and closed. The start and end times of the experiment must be selected to calculate the cooling load. So, in the month of November the experiment was conducted and from 8 am to 6 pm was conducted.

3. RESULTS AND DISCUSSION

The cooling load of manufacturing lab for outdoor design condition, dry bulb temperature (DBT) is 33°C, for wet bulb temperature (WBT) is 29°C and relative humidity (RH) is 65%. For the indoor design condition, dry bulb temperature (DBT) is 28°C, for wet bulb temperature (WBT) 23°C and relative humidity (RH) is 53%. Lecture room UniCiti Alam UniMAP located at latitude 6° 38° 59.0 North. For the longitude, it located at 100° 15° 23.9 East. Figure 2 shows the layout of the Lecture room UniCiti Alam UniMAP.

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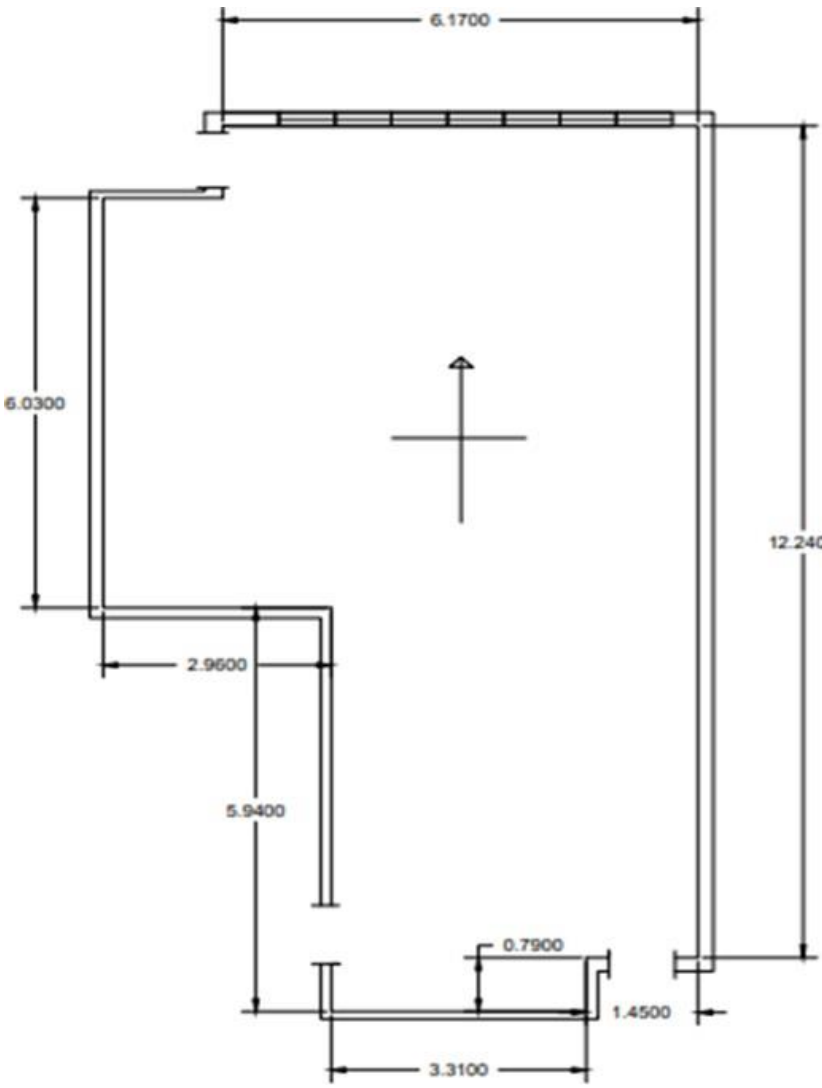

Figure 2. Layout of lecture room (BK6) at UniCiti Alam UniMAP (the dimension is in m unit)

The value of equivalent temperature differential for wall (without correction) is recorded in Table 1. Based on table, the value of temperature is start from 8am until 6pm. For the temperature of wall, its exposure at three locations which is east, south, and west wall from 8am until 8pm.

Table1. Equivalent temperature differential (˚C) for wall without correction.

Time/ Wall	am				pm						
	8	9	10	11	12	1	2	3	4	5	6
East wall	7.38	4.90	4.74	6.06	6.86	9.27	10.57	10.69	10.00	8.90	7.80
West wall	5.12	4.70	4.21	4.21	4.21	4.81	5.31	5.50	5.71	8.62	7.47
South wall	2.92	2.49	2.01	2.11	2.20	3.88	2.98	4.58	6.09	7.77	8.18

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The equivalent temperature differential values for walls (with correction) are recorded in Table 2. Based on the schedule, the temperature values start from 8 am to 6 pm. As for the wall temperature, it is located in three locations which are the west, north and east walls. To obtain the temperature differential value corresponding to the correction, the temperature value obtained every hour needs to be added to the temperature differential value corresponding to the correction. For this building, the corrected temperature value is 3.6°C.

Table 2. Equivalent temperature differential (˚C) for wall with correction.

Time/ Wall	am				pm						
	8	9	10	11	12	1	2	3	4	5	6
East wall	10.98	8.50	8.34	9.66	10.46	12.87	14.17	14.29	13.60	12.50	11.40
West wall	8.72	8.30	7.81	7.81	7.81	8.41	8.91	9.10	9.31	12.22	11.07
South wall	6.52	6.09	5.61	5.71	5.80	7.48	6.58	8.18	9.69	11.37	11.78

In daily life, cooling loads play a crucial role in ensuring that occupants or persons may remain in situ without being uncomfortable. Currently, with the unpredictability of the world climate, inhabitants or individuals will feel uncomfortable. A cooling load estimate procedure is needed to calculate the total heat gain for a building to find out how much cooling load is required for that building. This is necessary to find out how much cooling load is required. Calculating the heat load of a building is extremely essential for selecting the appropriate air conditioning equipment as well as the air handling unit. This will allow for a pleasant operation as well as excellent air distribution inside the air-conditioned zone.

The CLTD approach was used in this study to determine the overall heat gain. An experiment to calculate the amount of heat gain was done in BK6 which is a lecture room located in Uniciti Alam UniMAP. Rooms designated as BK6 can be found on the second floor of the structure. The size of the laboratory is 80.22m^2, and its volume is 320.88 m^3. The circumstances of the laboratory's outside and interior design are both evaluated and assessed. Dry bulb temperature (DBT) and wet bulb temperature (WBT) are the two approaches that are used in the process of determining the temperature of an interior environment (WBT). The outside region has DBT values of 33˚C and WBT values of 29 ˚C. The temperature on the interior of DBT is now 28˚C, whereas that of WBT is 23˚C.

In the lecture room or BK6, there is a type of wall that is the outer wall. For the outer wall area, it has three wall directions which are east, west, and south. Each direction has its own area. For the east wall, the width value is 33.5m^2, for the west is 35.7m^2 and for the south is 21.2m^2. The glass area is also measured. The glass is in one direction which is north. So, the total north area for the glass is 10.07m^2.

Rate of solar through glass in 15 November is measured. The latitude of the building is at 30 north. For equivalent temperature differential for wall, data of equivalent temperature differential is measured in Table 1 and 2. Rate of solar through glass and equivalent temperature differential for wall is measured from 8 am until 6 pm. From these data, the time when the highest heat gain happen is determined which is at 1pm.

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Based on this data, the value of the total amount of heat is calculated. For large total heat values, it is calculated using two cases. The first case is large heat with corrected equivalent temperature differential and for the second case is, without corrected equivalent temperature differential. For the first case, the value of room sense heat (RSH) is 9955.85 W. This includes heat gain through solar transmission and other types of heat gain such as by occupants, light, and appliances need to be determined. For the latent heat of the room (RLH), the calculated value is 13665.75 W. Therefore, for the total amount of heat, the value is 23621.60 W. To achieve the objective of using the appropriate horsepower, it is necessary to convert Watts to horsepower. The value of 1 horsepower (HP) is equivalent to 746 W. Based on the calculation, 23621.60W is equivalent to 32 HP. This means, for this BK6 the appropriate use is 32hp (Table 3).

For the second case without the corrected equivalent temperature difference, the value of RSH is 10.934.37 W. For RLH, the value obtained is 13665.75 W. For the large amount of heat, the value is 24600.12 W. Based on the results, the total horsepower produced without the corrected equivalent temperature difference is 33 HP (Table 4). Based on the total value of each method with and without the corrected equivalent temperature difference, it shows a small gap between the total heat of 902.12 W. It was observed that the cooling load with the corrected equivalent temperature difference is higher than the without the corrected equivalent temperature difference. This is due to the additional value of temperature in Table 2, as compared to Table 1, leading to an insignificant increase in grand total cooling load.

The amount of heat gain in the BK6 lecture room can be minimized and reduced by improving the design conditions of the lecture room. Factors that cause high energy consumption and heat gain are through solar transmission through walls, internal heat gain through light and through infiltration. These three factors are factors that use high energy consumption and heat gain. One of the improvements that can be made in the BK6 lecture room to reduce heat gain is to reduce the number of lamps used in the laboratory. For this lecture room, the lighting power is 540W. So, by reducing the number of lamps or changing the type of lamps used in the lecture room, the lighting power can be reduced. Next, is to improve the infiltration for the laboratory. Infiltration occurs when warm air and moisture penetrates through cracks in the wall. To reduce heat gain, the total perimeter for door and window cracks must be improved.

In classroom cooling load estimation, human factors represent a dominant internal load component and must be treated in accordance with established thermal comfort and heat gain standards such as those outlined by ASHRAE. Occupants contribute both sensible and latent heat as a function of metabolic rate, activity level, and duration of occupancy, with students typically classified under light, seated activities and instructors under light standing or walking activities. Due to the high occupant density and predictable scheduling characteristic of classroom spaces, the internal heat gain from occupants can constitute a substantial portion of the total cooling load. Sensible heat gain from occupants directly affects indoor air temperature, while latent heat gain increases the moisture content of indoor air, thereby influencing dehumidification requirements.

From an ergonomic and thermal comfort standpoint, ASHRAE Standard 55 emphasizes the importance of maintaining acceptable ranges of air temperature, relative humidity, air velocity, clothing insulation, and metabolic rate to achieve occupant comfort and minimize thermal dissatisfaction. In addition, compliance with ASHRAE Standard 62.1 necessitates the provision of adequate outdoor air ventilation to maintain acceptable indoor air quality, which further increases the cooling load due to the conditioning of warm and humid outdoor air. Consequently, accurate representation of human-related parameters, including occupancy density, metabolic heat generation, activity patterns, and ventilation requirements is essential for precise cooling load estimation and for the design of energy-efficient classroom air-conditioning systems that meet both thermal comfort and indoor air quality criteria.

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Table 3. Cooling load estimation for lecture room with corrected equivalent temperature difference.

SPACE USED FOR CLASSROOM SIZE (7.72 x 13.03)-1.64 -17.58 - 1.15 = 80.22m^2 x 4 = 320.88m^3				
ESTIMATE FOR 5 p.m LOCAL TIME				
HOUR OF OPERATION	DAY TIME			
CONDITION	**DB**	**WB**	**%RH**	
OUTDOOR	33	29	65	
ROOM	28	23	53	
DIFERRENCE	5			
	70 PEOPLE x 0.30 cmm/PERSON = 21 cmm VENTILATION cmm = 21			
DOOR CRACK		3 DOORS x 1.806m^2 x 1.98 cmm/m^2 = 11cmm 114m x 2.5/60cmm/m = 4.75cmm INFILTRATION cmm = 11 + 4.75 = 15.75cmm		
SENSILBLE HEAT				
	AREA OR QUANTITY (m^2)	**SOLAR GAIN-GLASS**		**TOTAL**
EAST GLASS	0	0		0
WEST GLASS	0	0		0
NORTH GLASS	10.07	44		443.08
SOUTH GLASS	0	0		0
		SUB TOTAL		443.08
LOAD CALCULATION				
ITEM	**AREA OR QUANTITY (m^2)**	**SUN GAIN OR TEMP. DIFF OR HUMIDITY DIFF**	**FACTOR**	**W**
EAST WALL	33.5	9.27	2.64	819.84
WEST WALL	35.7	4.81	2.64	453.33
NORTH WALL	0	0	0	0
SOUTH WALL	21.2	2.58	2.64	144.40
TRANSMASSION GAIN-OTHERS				
DOORS	5.4	5	0.63	17.01
ALL GLASS	10.07	5	5.9	297.07
FLOOR	100.3	2.5	6.05	1517.04
INTERNAL HEAT GAIN				
PEOPLE	70	-	75	5250
POWER	0	-	0	0
LIGHT	432	-	1.25	540
		SUB TOTAL		9481.76
SAFETY FACTOR		5%		474.09
		ROOM SENSIBLE HEAT		9955.85
PEOPLE	70	-	55	3850
STEAM	0	-	0	0
APPLIANCES (PROJECTOR)	141	-	65	9165.0
		SUB TOTAL		13015.0
SAFETY FACTOR		5%		650.75
		ROOM LATENT HEAT		13665.75
		ROOM TOTAL HEAT		23621.60
GRAND TOTAL				32hp

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Table 4. Cooling load estimation for lecture room without corrected equivalent temperature difference.

SPACE USED FOR CLASSROOM SIZE (7.72 x 13.03)-1.64 - 17.58 - 1.15 = 80.22m² x 4 = 320.88m³				
ESTIMATE FOR 1 p.m LOCAL TIME				
HOUR OF OPERATION	DAY TIME			
CONDITION	**DB**	**WB**	**%RH**	
OUTDOOR	33	29	65	
ROOM	28	23	53	
DIFERRENCE	5			
	70 PEOPLE x 0.30 cmm/PERSON = 21 cmm VENTILATION cmm = 21			
DOOR CRACK		3 DOORS x 1.806m² x 1.98 cmm/m² = 11cmm 114m x 2.5/60cmm/m = 4.75cmm INFILTRATION cmm = 11 + 4.75 = 15.75cmm		
SENSILBLE HEAT				
	AREA OR QUANTITY (m²)	**SOLAR GAIN-GLASS**		**TOTAL**
EAST GLASS	0	0		0
WEST GLASS	0	0		0
NORTH GLASS	10.07	44		443.08
SOUTH GLASS	0	0		0
		SUB TOTAL		443.08
LOAD CALCULATION				
ITEM	**AREA OR QUANTITY (m²)**	**SUN GAIN OR TEMP. DIFF OR HUMIDITY DIFF**	**FACTOR**	**W**
EAST WALL	33.5	12.87	2.64	1138.22
WEST WALL	35.7	8.41	2.64	792.63
NORTH WALL	0	0	0	0
SOUTH WALL	21.2	7.48	2.64	418.64
TRANSMASSION GAIN-OTHERS				
DOORS	5.4	5	0.63	17.01
ALL GLASS	10.07	5	5.9	297.07
FLOOR	100.3	2.5	6.05	1517.04
INTERNAL HEAT GAIN				
PEOPLE	70	-	75	5250
POWER	0	-	0	0
LIGHT	432	-	1.25	540
		SUB TOTAL		10413.68
SAFETY FACTOR		5%		520.68
		ROOM SENSIBLE HEAT		10934.37
PEOPLE	70	-	55	3850
STEAM	0	-	0	0
APPLIANCES (PROJECTOR)	141	-	65	9165.0
		SUB TOTAL		13015.0
SAFETY FACTOR		5%		650.75
		ROOM LATENT HEAT		13665.75
		ROOM TOTAL HEAT		24600.12
GRAND TOTAL				33hp

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4. CONCLUSION

In this study, lecture room BK6 at UniCiti Alam UniMAP was selected for cooling load estimation. The CLTD method is used to calculate the total heat gain. Heat gained by humans, light, infiltration, equipment can also be easily calculated using the MS - Excel program. In this program, the cooling load due to walls and glass can also be calculated.

In this chapter, the heat gain data for the computer lab has been successfully calculated using the CLTD method. By obtaining heat gain data, load reduction management can be optimized and to reduce the current cooling load can be achieved. Heat gain data can also be provided in lecture rooms. Electricity consumption can also be reduced by improving the condition of the lecture room by referring to the amount of heat gain data. In conclusion, the problem that existed before can be improved by providing this heat gain data.

For recommendations, providing heat gain data for all types of buildings such as for laboratories, cafeterias, auditoriums and others is a good way to manage or use electricity to save more. The system used in this lecture room has the potential to be improved as a result of this study. In the future, if you provide data about this cooling, then others will be able to use it as a reference to manage the amount of cooling needed at the time it is needed.

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