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Analysis of the Cooling Load of the Air Conditioning System on the 1st Floor of the Dian Nusantara University Building Using the CLTD Method

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Abstract: In Indonesia's tropical climate, educational buildings such as Dian Nusantara University face thermal comfort challenges due to high temperatures and intense solar radiation, necessitating accurate cooling load analysis for AC system optimization. This study aims to calculate the total cooling load on the first floor using a descriptive quantitative approach with the ASHRAE-based CLTD method, through measurements of building dimensions, occupants, equipment, and the local climate of Cibubur. The results indicate a total load of 53.88 kW (15.3 TR), dominated by wall envelopes (32.0%), glass (21.1%), and occupants (17.1%), while the installed AC capacity of 70 kW is 30% oversized in aggregate but undercapacity in some rooms. The conclusions emphasize the need to adjust AC capacity per room and the combination of split and cassette AC types for energy efficiency; implications include operational cost savings and improved thermal comfort in tropical buildings.

Keyword: Load, CLTD, Split AC, Cassette AC, AC Capacity Evaluation

INTRODUCTION

Thermal comfort conditions are a critical factor affecting the effectiveness of academic and administrative activities in educational buildings. In tropical regions, high ambient temperatures and solar radiation intensity lead to significant cooling requirements. Therefore, air conditioning systems play a crucial role in maintaining proper thermal conditions. However, determining cooling system capacity without adequate load calculations can potentially lead to inefficient energy consumption (Çengel & Ghajar, 2015).

The 1st floor of the Dian Nusantara University building serves as a service area and workspace with a relatively high occupancy rate during operational hours. Based on preliminary observations, the air conditioning units are operated continuously without adjustments for fluctuations in cooling load caused by changes in the number of occupants, electrical equipment utilization, and the influence of daily weather conditions. This indicates a potential discrepancy between the existing cooling system capacity and the actual cooling requirements of the space.

Based on these conditions, the research problems are formulated into several questions: what is the actual cooling requirement of the 1st floor of the Dian Nusantara University building based on the CLTD method; which factors contribute most dominantly to the cooling load; and what is the level of compatibility between the installed AC capacity and the actual cooling requirements. This study aims to calculate the actual cooling load and evaluate the adequacy of the cooling system capacity currently in use.

Academically, this study contributes to the application of cooling load calculation methods for educational buildings in tropical climates under real operational conditions. This study reinforces previous findings regarding the importance of evaluating existing HVAC system capacities and addresses the empirical research gap focusing on operational educational buildings.

METHOD

This research uses a quantitative approach with a descriptive analytical design. The method applied is the calculation of cooling loads using the Cooling Load Temperature Difference (CLTD) approach in accordance with ASHRAE guidelines. The research object covers the entire space on the first floor of the Dian Nusantara University Building, Cibubur Campus, which is used for administrative, office, and public service activities.

Data collection was conducted through a field survey, measuring room dimensions, wall surface areas, and glass openings, as well as identifying building envelope materials. Internal load data was obtained by recording the number of occupants, electrical equipment power, and lighting systems under maximum load conditions. Air infiltration rates were determined based on the intensity of user movement, while climate parameters and CLTD correction factors were based on ASHRAE standard tables tailored to the study location.

The research flowchart is shown in Figure 1. The research was conducted with the following steps: problem identification, data collection (room dimensions, wall materials, glass, number of occupants, electrical equipment, lighting, climate conditions), calculation of cooling load using the CLTD method, evaluation of installed AC capacity, and drawing conclusions.

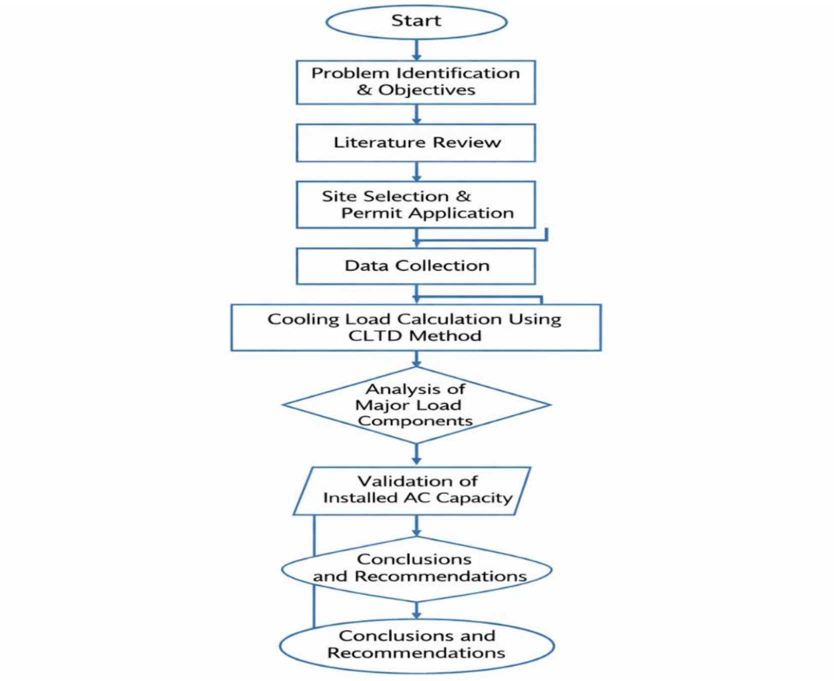

Figure 1. Research Flowchart

The floor plan of the 1st floor of Dian Nusantara University Cibubur can be seen in Figure 2.

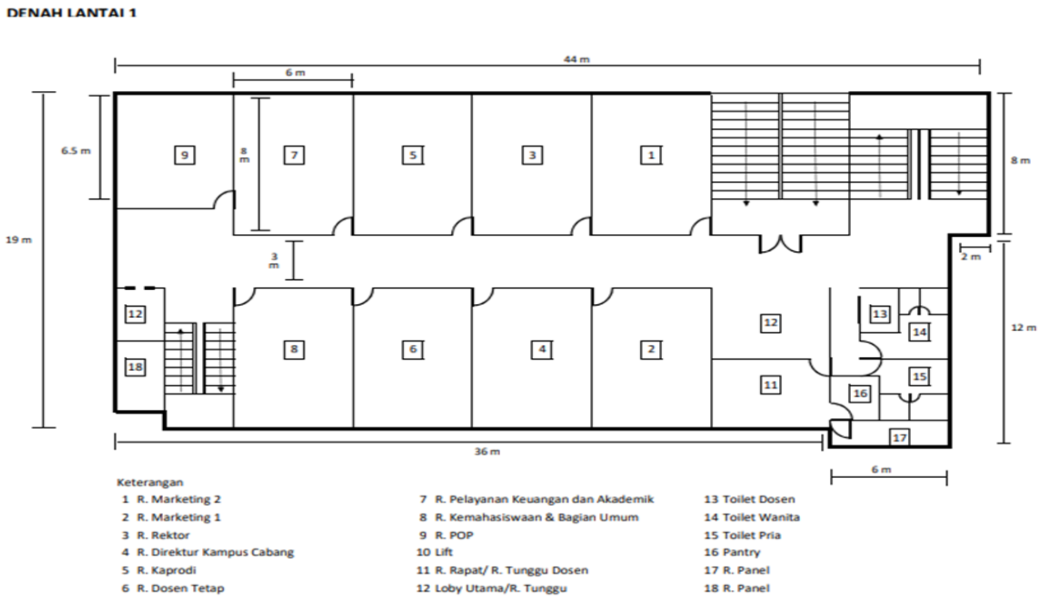

Figure 2. Floor plan of Dian Nusantara University Cibubur

General data of Undira Floor 1 research is shown in Table 1.

Table 1. Research data from Undira's 1st Floor

No	Data	Information
1	Research object	1st Floor of Dian Nusantara University Building, Cibubur
2	Building function	Lectures and academic activities
3	Total room area	489 m²
4	Number of residents	67 people
5	Glass type	Single glass
6	Wall color	Bright
7	Outside temperature	32–35 °C
8	Internal temperature	24–26 °C

RESULT AND DISCUSSION

Cooling Load Calculation

The calculation is done using the CLTD method using the equation:

$$Q = U \times A \times CLTD$$

Where Q is the heat load (W), U is the total heat transfer coefficient (W/m²K), A is the surface area (m²), and CLTDc is the corrected CLTD value according to the ASHRAE table.

Wall heat load calculation:

a) Rooms 1-8 (8 m x 6m)
(Floors: Marketing 1 & 2, Rector, Director, Head of Study Program, Permanent Lecturers, Financial Services, Student Affairs).
Wall area:

$$A = 2\,(8 + 6) \times 3 = 84 \text{ m}^2$$

Room temperature 26 °C
Wall heat load:

$$Q_{wall} = 1{,}7 \times 84 \times 11 = 1.571 \text{ W}$$

For the Head of Study Program Room (29 °C):

$$Q_{wall} = 1{,}7 \times 84 \times 14 = 1.999 \text{ W}$$

b) Room 9 – BOP (6,5 m + 6 m)

Wall area:

$$A = 2\,(6{,}5 + 6) \times 3 = 75 \text{ m}^2$$

Wall heat load:

$$Q_{wall} = 1{,}7 \times 75 \times 11 = 1.403 \text{ W}$$

c) Room 10 – Meeting Room (4 m x 6 m)

Wall area:

$$A = 2\,(4 + 6) \times 3 = 60 \text{ m}^2$$

Wall heat load:

$$Q_{wall} = 1{,}7 \times 60 \times 11 = 1.122 \text{ W}$$

d) Room 11 – Lobby (7 m x 6 m)

Wall area

$$A = 2\,(7 + 6) \times 3 = 78 \text{ m}^2$$

Wall heat load:

$$Q_{dinding} = 1{,}7 \times 78 \times 13 = 1.723 \text{ W}$$

For the glass, the heat gain is calculated using the following equation:

$$Q_{glass} = A \times SHGF \times SC$$

For the occupant load, the heat gain is calculated using:

$$Q_{occupants} = n \times q$$

Example Calculation: Marketing 1 Room

The number of occupants is n = 8 people

The sensible heat gain per person is q = 150 W/person

$$Q_{occupants} = n \times q$$

$$Q_{occupants} = 8 \times 150 = 1.200 \text{ W}$$

For the lighting load, the heat gain is calculated using the following equation:

$$Q_{lighting} = \Sigma P_{lamp}$$

Where:

$Q_{lighting}$ = heat gain from lighting (W)

P_{lamp} = power of each lamp (W)

Example Calculation: Marketing 1 Room

The lighting system consists of:

a) 6 units of 9 W fluorescent lamps
b) 8 units of 9 W downlights

The lighting heat gain is calculated as:

$$Q_{lighting} = (6 \times 9) + (8 \times 9)$$

$$Q_{lighting} = 54 + 72 = 126 \text{ W}$$

For the equipment load, the heat gain is calculated using the following equation

$$Q_{equipment} = \Sigma P_{equipment}$$

Example Calculation: Marketing 1 Room
The electrical equipment in the room consists of:

a) PCs: 3 units × 250 W = 750 W
b) Laptop: 1 unit × 65 W = 65 W
c) Water dispenser: 1 unit × 350 W = 350 W

The total equipment heat gain is calculated as:

$$Q_{equipment} = 750 + 65 + 350 = 1.165 \text{ W}$$

For air infiltration, the heat gain is calculated using the following equation:

$$Q_{inf} = 1.2 \text{ x ACH x Volume x } \Delta T$$

Where:

Q_{inf}	= heat gain due to air infiltration (W)
ACH	= air changes per hour (1/h)
V	= room volume (m^3)
ΔT	= temperature difference between outdoor and indoor air (°C)

Example Calculation: Marketing 2 Room
Given:

ACH	= 0.5
V	= 144 m^3
Outdoor temperature	= 35 °C
Indoor temperature	= 26 °C

The infiltration heat gain is:

$$Q_{inf} = 1.2 \text{ x } 0.5 \text{ x } 144 \text{ x } (35\text{-}26)$$
$$= 1.2 \text{ x } 0.5 \text{ x } 144 \text{ x } 9$$
$$= 777.6 \text{ W}$$

The total cooling load is calculated using the following equation:

$$Q_{total} = Q_{occupants} + Q_{lighting} + Q_{equipment} + Q_{wall} + Q_{glass} + Q_{infiltration}$$

Example Calculation: Marketing 2 Room

$$Q_{total} = 1200 + 126 + 1165 + 1571 + 653 + 778$$
$$= 5493 \text{ W}$$

To obtain a more detailed representation of the cooling load distribution, the calculations were performed separately for each heat gain component in every room. The analyzed components include wall load, glass load, occupants, lighting, electrical equipment, and air infiltration. The calculations were carried out using the CLTD method in accordance with ASHRAE guidelines, employing the fundamental equations $Q = U \times A \times CLTDc$ for walls, $Q = A \times SHGF \times SC$ for glass, as well as specific equations for occupants, lighting, equipment, and infiltration. The results of the calculations are presented in Table 2, allowing the contribution of each component in each room to be clearly identified.

Table 2. Cooling Load Calculation by Component for Each Room

No	Room Name	Q Occupants (W)	Q Lighting (W)	Q Equipment (W)	Q Wall (W)	Q Glass (W)	Q Infiltration	Q Total (W)
1	R.Marketing 2	1200	126	1165	1571	653	778	5493
2	R. Marketing 1	1200	126	850	1571	653	778	5178
3	R. Rektor	520	117	610	1571	653	467	3938
4	Branch Campus Director Room	520	81	480	1571	653	467	3772
5	Head of Study Program Room	650	108	675	1999	653	778	4863
6	Permanent Lecturer Room	520	18	610	1571	653	467	3839
7	Financial & Academic Services Room	650	117	850	1571	653	1089	4930
8	Student Affairs & General Affairs Room	650	81	545	1571	653	1089	4589
9	BOP Room	520	153	1100	1403	653	633	4462
10	Meeting Room / Lecturer Waiting Room	1300	27	325	1122	653	233	3660
11	Main Lobby / Waiting Area	1500	135	260	1723	4860	680	9158
	TOTAL	9230	1089	7470	17244	11390	7459	53882

Heat Load of Each Component

Table 2 presents the calculated heat load for each component.

Table 2. Results of Room Heat Load Calculations

Component	Load (kW)	Percentage (%)
Walls	17,24	32,0
Glass	11,37	21,1
Occupants	9,22	17,1
Electrical Equipment	7,49	13,9
Infiltration	7,43	13,8
Lighting	1,08	2,0
Total	**53,88**	**100**

Evaluation of Air Conditioning Capacity by Room

The installed air conditioning capacity is 70 kW, which is approximately 30% higher than the actual cooling load. However, the distribution of capacity is not uniform: several rooms are under-capacity, while others are overcapacity. Table 3 illustrates the imbalance in the distribution of air conditioning capacity. The Marketing rooms experience undercapacity, resulting in suboptimal thermal comfort, whereas the Lobby and Administration areas are overcapacity, which may lead to unnecessary energy consumption. Overall, the installed air conditioning capacity exceeds the actual demand by about 30%, indicating an oversized system.

Table 3. Evaluation of Each Room

No	Room Name	Cooling Load (kW)	AC Capacity (kW)	Category
1	Marketing Room 2	5,49	3,96	Undercapacity
2	Marketing Room 1	5,18	3,96	Undercapacity
3	Rector's Office	3,94	9,24	Overcapacity (Significant)
4	Branch Campus Director's Office	3,77	3,96	Appropriate / Near Match
5	Head of Study Program Office	4,86	9,24	Overcapacity
6	Permanent Lecturer Office	3,84	3,96	Appropriate / Near Match
7	Finance & Academic Services Office	4,93	9,24	Overcapacity
8	Student Affairs & General Administration Office	4,59	9,24	Overcapacity
9	BOP Office	4,46	3,96	Undercapacity (Minor)
10	Meeting Room / Lecturer Waiting Room	3,66	9,24	Overcapacity
11	Main Lobby / Waiting Area	9,16	3,96	Undercapacity (Significant)

Analysis of Heat Load Components

The analysis of the total heat load composition indicates that the building envelope walls remain the largest contributor, accounting for 17,244 W (32.0%) of the total cooling load of 53,882 W. This condition is attributed to the high solar radiation intensity under the tropical climate of Cibubur (35 °C dry-bulb temperature) and the southwest building orientation at 14:00 Western Indonesian Time (WIB).

The heat gain through the window glazing reaches 11,390 W (21.1%), making it the second-largest contributor after the external walls. This value is influenced by the use of clear single glazing with a shading coefficient (SC) of 0.8, particularly in the lobby area, which has a relatively large glass opening area (18.9 m²). Occupant load contributes 9,230 W (17.1%), while equipment load accounts for 7,470 W (13.9%). Air infiltration load is recorded at 7,459 W (13.8%), indicating a significant contribution from outdoor air exchange. Meanwhile, the lighting load is relatively small at 1,089 W (2.0%). The complete composition is presented in Figure 3.

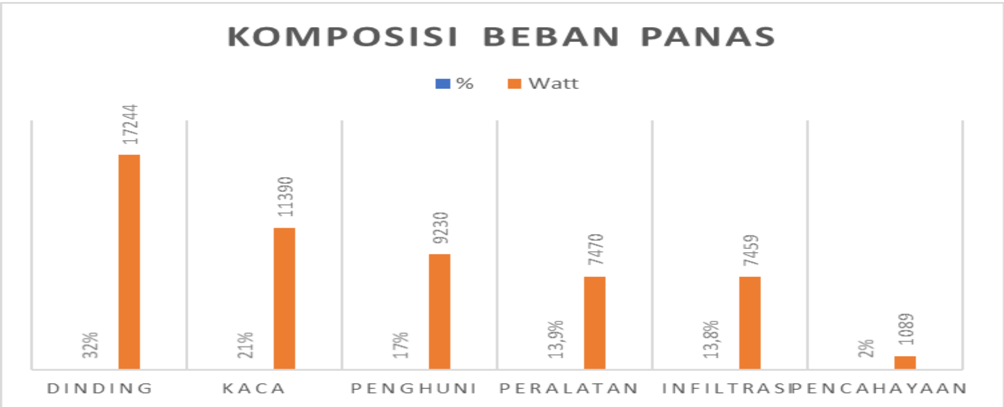

Figure 3. Total Heat Load Composition Chart of the 1st Floor (53,882 W)
The x-axis represents the heat load component categories, while the y-axis represents the percentage contribution of each heat load component (%).)

Discussion

The calculation results indicate that the total cooling load of the first floor is 53.88 kW (equivalent to 15.3 TR). The largest contributions originate from the external walls (32%) and glazing (21.1%), confirming that the building envelope plays a dominant role in cooling energy consumption. Internal loads from occupants (17.1%) and electrical equipment (13.9%) are also significant, demonstrating that user activities within the spaces substantially contribute to cooling load fluctuations.

These findings are consistent with the study by Oktay et al. (2020), which emphasizes the influence of building envelope materials on cooling load, as well as Al-Rabghi and Fathalah (1997), who highlight the importance of evaluating HVAC capacity on a zone by zone basis. The practical implication is the need to adjust air-conditioning capacity for each room according to its actual cooling load and to apply a combined system approach using split-type air conditioners for smaller rooms and cassette ceiling units for larger spaces to achieve more efficient air distribution and optimized energy consumption.

CONCLUSION

This study demonstrates that the total cooling load of the first floor of Dian Nusantara University Building is 53.88 kW (equivalent to 15.3 TR). The largest contributions originate from the building envelope walls (32.0%) and window glazing (21.1%), followed by occupants, electrical equipment, air infiltration, and lighting. These findings confirm that the building envelope and glazing materials are dominant factors influencing cooling energy consumption.

The evaluation of the installed air-conditioning capacity indicates an aggregate oversizing condition of approximately 30%. However, the distribution of cooling capacity among rooms is not evenly balanced. Several spaces, such as the Marketing rooms and the Main Lobby, experience undercapacity, resulting in suboptimal thermal comfort. In contrast, other rooms, including the Rector's Office and the Head of Study Program Office, exhibit overcapacity, which may lead to increased energy consumption without delivering proportional performance benefits.

The practical implication of these findings highlights the need to adjust the air-conditioning capacity in each room based on the actual cooling load. It is also recommended to apply a combination system, using split-type air conditioners for smaller rooms and cassette ceiling units for larger spaces such as the Lobby. Through this strategy, air distribution can be improved, thermal comfort can be enhanced, and overall energy consumption can be reduced. The resulting energy savings not only contribute to lowering the building's operational costs but also support energy conservation principles in educational buildings located in tropical climates..

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