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Comparative Analysis of Cooling Load Calculations: CLTD Method vs. Carrier HAP 5.01 Software for Hotel HVAC Design

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Abstract

This study examines the cooling load requirements of a hotel building by comparing two methodologies: the traditional Cooling Load Temperature Difference (CLTD) method and the Carrier Hourly Analysis Program (HAP) 5.01 software. The primary objective is to validate the accuracy and reliability of these methods in calculating cooling loads across different room types, from standard rooms to larger, more complex suites. The results show that the CLTD method consistently yields higher cooling load estimates, with discrepancies ranging from 3% to 14% compared to HAP 5.01 calculations. These differences are most significant in larger rooms, such as suites and owner's suites, which have more extensive glass areas, higher occupancy, and more heat-generating equipment. The findings indicate that while the CLTD method is valuable for quick, preliminary estimates, the HAP 5.01 software provides a more precise and comprehensive analysis, taking into account hourly variations, equipment schedules, and other factors that impact cooling loads. This research highlights the need for careful selection of the appropriate calculation method to ensure the efficient design of HVAC systems, maximizing energy efficiency, and maintaining occupant comfort. The study concludes that for projects requiring high accuracy, particularly in complex or large spaces, dynamic simulation tools like HAP 5.01 are preferable. Detailed cooling load results and comparisons are provided in the supplementary documentation, offering further insights into the analysis and its implications for HVAC design.

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1. Introduction

Indonesia's economic growth, consistently surpassing 5% in recent years, has driven substantial development across various sectors, particularly in tourism [1]. As the tourism industry expands, the demand for high-quality hotel accommodations has surged. A critical aspect of hotel infrastructure is the air conditioning system, which is essential for ensuring thermal comfort, energy efficiency, and occupant satisfaction. Proper airflow regulation within hotel environments typically involves the use of turbulent flow (non-unidirectional airflow), laminar flow (unidirectional airflow), and careful management of air pressure differentials between indoor and outdoor spaces [2].

Hotel buildings must not only provide thermal comfort but also achieve safety and energy efficiency, balancing these needs with cost considerations. The design of an air conditioning system, therefore, includes complex calculations of the hotel's cooling load, system selection, and energy cost assessments [3]. However, without thorough and accurate planning, these systems can lead to significant issues during implementation [4]. Poorly designed HVAC systems, often resulting from inadequate planning by Mechanical Electrical & Plumbing (MEP) consultants, can cause inefficiencies and operational difficulties, necessitating costly modifications post-installation [5].

A critical component of HVAC design is the accurate calculation of cooling loads, which ensures that the system meets the demands of the building while optimizing energy use. The Cooling Load Temperature Difference (CLTD) method and dynamic simulation software, such as the Carrier Hourly Analysis Program (HAP), are two prominent approaches for calculating cooling loads. The CLTD method is renowned for its simplicity and effectiveness, particularly in scenarios where quick estimates are needed and detailed data is not available. It incorporates factors such as solar radiation, ambient temperature, and the thermal properties of building materials to estimate cooling loads [6]. Studies have shown that, under steady-state conditions, the CLTD method can yield results comparable to more complex simulation tools, making it a valuable tool for engineers and architects during the preliminary design phases [7]–[9].

On the other hand, the HAP software offers a more sophisticated approach by using dynamic simulation techniques to account for hourly variations in internal and external conditions. This method provides a more detailed and accurate analysis of cooling requirements, particularly in buildings with fluctuating occupancy and equipment loads [10], [11]. Research comparing the two methods has indicated that while both can provide useful estimates, HAP's dynamic modeling often produces results more closely aligned with actual measured loads, especially in complex buildings [12].

The methodology employed in HAP includes the integration of various parameters such as outdoor temperature, humidity levels, and building orientation, which are crucial for accurate load calculations. The program's ability to model these variables allows engineers to predict the cooling requirements under different scenarios, ensuring that HVAC systems are appropriately sized and optimized for energy efficiency. For example, research has shown that cooling and dehumidification processes are vital in maintaining indoor air quality, particularly in environments with high humidity [13]. This is further supported by findings that indicate the necessity of understanding the relationship between supply air consumption and cooling load parameters [13].

Despite the advantages of each method, there is a gap in understanding their relative efficacy in specific contexts, particularly in hotel environments where both simplicity and accuracy are paramount. This study aims to address this gap by comparing the results obtained from the CLTD method and the Carrier HAP 5.01 software in the context of hotel building. By validating the air conditioning system design using both methods, the study seeks to identify the most reliable approach for ensuring optimal performance, energy efficiency, and cost-effectiveness in hotel HVAC systems.

2. Methods

Hotel and motel accommodations typically consist of single guest rooms equipped with a toilet and bathroom, positioned adjacent to corridors and flanked by other guest rooms. The structure of these buildings can vary widely, ranging from single-story to low-rise and high-rise buildings. In addition to guest rooms, hotels often include a variety of multi-purpose subsidiary facilities. These facilities may include shops, offices, ballrooms, dining rooms, kitchens, lounges, auditoriums, and meeting rooms. In luxury motels, similar facilities are often available, with some variations such as kitchenettes, multi-room suites, and exterior doors leading to terraces or balconies.

Hotels are generally categorized into different classes, ranging from luxury hotels to economy hotels and motels, each with distinct characteristics and service offerings. These classifications influence the design and amenities provided, as outlined in Table 1. The design and construction of a hotel can typically be divided into three main areas: guest accommodations, service areas, and public areas, each requiring specific considerations in terms of functionality and design [14].

Table 1. Hotel Design Criteria. Source: 1999 ASHRAE Handbook.

	Inside Design Conditions							
	Winter		Summer					
Category	Temperature	Relative Humidity[c]	Temperature	Relative Humidity	Ventilation[d]	Exhaust[d,e]	Filter Efficiency[f]	Noise, RC Level
Guest rooms	23 to 24°C	30 to 35%	23 to 26°C	50 to 60%	15 to 30 L/s per room	10 to 25 L/s per room	10 to 15%	25 to 35
Lobbies	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	–	35% or better	35 to 45
Conference/ Meeting rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	10 L/s per person	–	35% or better	25 to 35
Assembly rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	–	35% or better	25 to 35

[a] This table should not be used as the only source for design criteria. The data contained here can be determined from ASHRAE handbooks, standards, and governing local codes.
[b] Design criteria for stores, restaurants, and swimming pools are in Chapters 2, 3, and 4, respectively.
[c] Minimum recommended humidity.
[d] As per ASHRAE *Standard* 62, Ventilation for Acceptable Indoor Air Quality.
[e] Air exhaust from bath and toilet area.
[f] As per ASHRAE *Standard* 52.1, Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter.

The design criteria for air temperature in hotels generally align with the standards outlined in the 1999 ASHRAE Applications Handbook (SI), as detailed in Tables 1 and 2 of this study. For this research, the temperature data was selected based on summer design conditions specifically for guest rooms. The target temperature range used was between 23°C and 26°C, with a relative humidity (RH) of 50% to 60%, ensuring that the environmental conditions meet the thermal comfort standards required for hotel accommodations

Table 2. Design Criteria for Hotels. Source: 1999 ASHRAE Handbook.

Category	Inside Design Conditions	Comments
Kitchen (general)[b]	28°C	Provide spot cooling
Kitchen (pastry)[b]	24°C	
Kitchen (chef's office)[b]	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Housekeeper's office	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Telephone equipment room	Per equipment criteria	Stand-alone air conditioner; air conditioned all year
Wine storage	Per food and beverage manager criteria	Air conditioned all year
Laundry		Spot cooling as required at workstations

[a] Governing local codes must be followed for design of the HVAC.
[b] Consult Chapter 30 for details on kitchen ventilation.

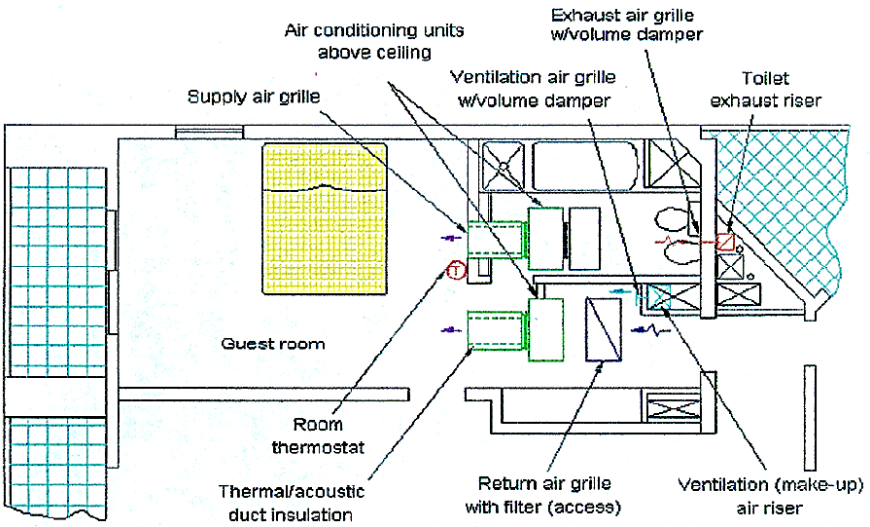


Figure 1. Location of Hotel Room AC Units

Table 3. Hotel room specification data

Room	Amount	Room Size		Total Room Area	
		Foot^2 area	Area m^2	Foot^2 area	Area m^2
Standard Type Room	90	242.84	22.56	21,855.6	2,030.4
Mid Type Room Internal	8	265.98	24.71	21.27.84	197.68
Mid Type Room External	8	270.82	25.16	21.66.56	201.28
Suite Type Living Room	3	339.70	31.56	1,019.1	94.68
Suite Type Bedroom	3	268.34	24.93	805.02	74.79
Owner's Suite Living Room	1	339.70	31.56	339.7	31.56
Owner's Suite Bedroom	1	268.34	24.93	268.34	24.93
Total	*114*	*1995,72*	*185.41*	*28,582.16*	*2,655.32*

The recommendations for the placement of the AC unit in this research are guided by the Design Criteria outlined in the 1999 ASHRAE Applications Handbook (SI). Specifically, for hotel rooms, the AC units should be installed above the ceiling in a hanging configuration [15], as depicted in Figure 1 and Table 3. This placement ensures optimal air distribution and aligns with industry standards for maintaining thermal comfort and system efficiency in hotel environments.

2.1. Experimental methods

This research method is designed to explore the intricacies of air conditioning systems, focusing on the various stages, regulations, procedures, and infrastructure required for their effective design, as shown in Figure 2. The methodology adopts a systematic approach, beginning with the identification of the core problem and the establishment of specific research objectives. Following this, a thorough literature review is conducted alongside a location survey to collect essential data. The research then progresses to calculating the cooling load and conducting a detailed analysis. The ultimate goal of this analysis is to develop precise specifications for air conditioning equipment that align perfectly with the cooling load demands of the hotel, thereby ensuring both efficiency and optimal performance of the system.

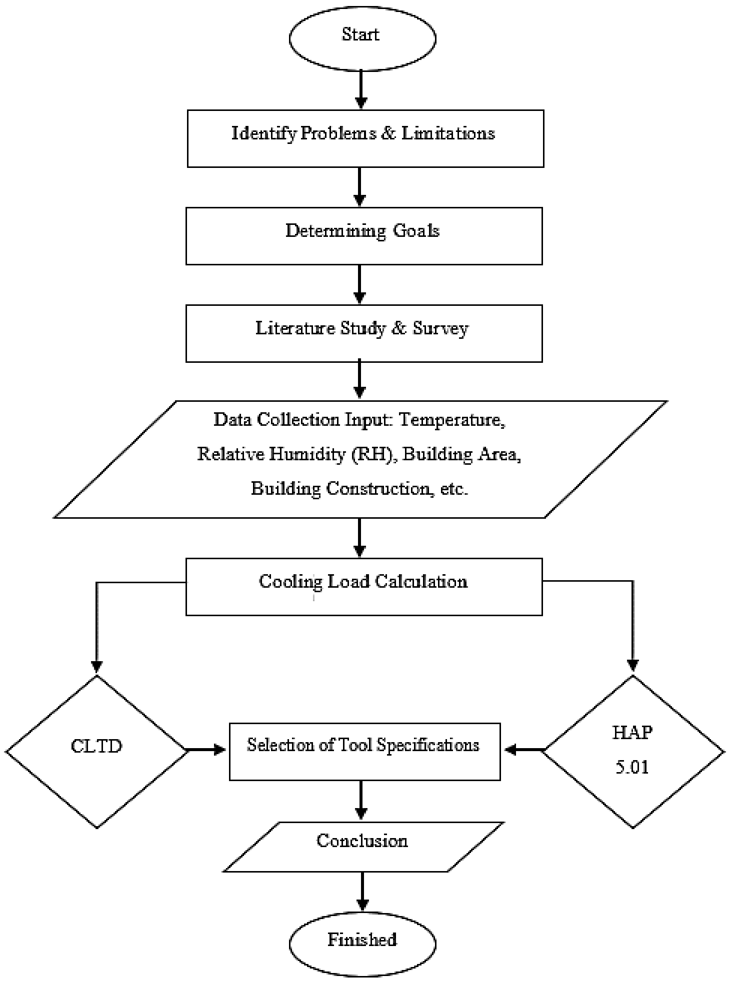


Figure 2. Research flow diagram

2.2. Cooling Load Temperature Differences (CLTD)

The cooling load represents the amount of heat that must be removed by the cooling equipment to maintain desired indoor conditions, accounting for heat sources both inside and outside the conditioned space. Accurate cooling load calculations are critical during the planning stage, as they form the foundation for selecting the appropriate type and capacity of cooling equipment. This process is complex, involving considerations of thermal mass, occupancy schedules, and identifying the most critical hours of operation.

The Cooling Load Temperature Difference (CLTD) method, based on the ASHRAE Handbook of Fundamentals (1981), provides a more precise approach to calculating cooling loads [16]. However, this method requires specific information to be effective:

1. Building Characteristics: Including material type, size, outer surface color, and shape.
2. Location and Orientation: The building's location and orientation, along with the degree of external shading provided by trees or adjacent structures.
3. Outdoor Design Conditions: The external environmental conditions that impact cooling load.
4. Indoor Design Conditions: Dry bulb temperature (DB), wet bulb temperature (WB), and ventilation levels.
5. Internal Heat Gains: Schedules for lighting, occupancy, equipment usage, and other internal processes contributing to heat gain.
6. Critical Days and Months: Determining which periods require careful cooling load calculations, often necessitating an initial comparison of the solar gain impact through roofs and glazing across different orientations.
7. Zoning Requirements: The division of the building into zones, each with specific cooling load needs.

2.3. External thermal load

External thermal loads refer to the heat loads that originate from outside the conditioned space and are directly influenced by the external environment. These loads contribute significantly to the overall cooling requirements and are primarily generated by the roof, walls, glass, and floor of the building. Accurately calculating these loads is essential for designing an effective air conditioning system.

The external cooling load components, including those from the roof, walls, glass, and floor, can be determined using specific equations. For instance, the heat load through the walls and roof can be calculated using the following equation [17].

$$q = U \times A \times CLTD_{corr} \tag{1}$$

where:

q : Roof cooling load, (Btu/hr)
U : Heat transfer coefficient of the roof, (Btu/hr.ft^2.°F)
A : Roof area, (ft^2)
$CLTD_{corr}$: The temperature difference between the design and the existing loads.

To find the corrected Cooling Load Temperature Difference ($CLTD_{corr}$) for the roof, the following equation can be used.

$$CLTD_{corr} = [(CLTD + LM) \times K + ((78 - T_r) + (T_o - 85))] \times f \tag{2}$$

where:

LM : Load modification factor, which accounts for latitude and month
K : Color correction factor, which adjusts for the roof color (typically 1.0 for dark colors). Color correction factor, which adjusts for the roof color (typically 1.0 for dark colors)
T_o : Outdoor design temperature, ($_o$F)
T_r : Indoor room design temperature, (°F)
f : Correction factor for channels above the ceiling (e.g., 0.75 if positive ventilation is present)

The radiation load through glass can be calculated using the following equation:

$$q = A \times SC \times SHGF_{max} \times CLF \tag{3}$$

where:

q : Glass cooling load via radiation, (Btu/hr)
A : Glass surface area, (ft2)
SC : Shading Coefficient for the type of glass used
SHGF : Solar Heat Gain Factor
CLF : Cooling Load Factor

Thermal loads through partitions, ceilings and floors can be obtained through the following equation

$$q = U \times A \times \Delta T \tag{4}$$

where:

- q : Cooling load due to heat transfer through partitions, ceilings, and floors, (Btu/hr)
- U : Heat transfer coefficient for the partitions, ceilings, or floors, (Btu/hr.ft^2.^{0}F)
- A : Surface area of the partition, ceiling, or floor, (ft^2)
- $\Delta T = (T_o - T_r)$: The temperature difference between design (T_r) and adjacent space (T_o), (^{0}F)

The internal thermal load generated by lamps can be calculated using the following equation:

$$q = 3.41 \times q_i \times F_u \times F_s \times CLF \tag{5}$$

where:

- q : Cooling load due to lighting, (Btu/hr)
- q_i : Total energy input of the lamps, (Btu/hr)
- F_u : Usage factor, representing the proportion of lights that are turned on (e.g., F_u=1 if all lights are on)
- F_s : Ballast factor, accounting for the efficiency of the lighting ballast

The load caused by human activities, specifically due to occupant presence, can be calculated using the following equations:

$$q_s = n \times \text{Sens HG} \times CLF$$
$$q_l = n \times \text{Lat HG} \tag{6}$$

where:

- q_s : Sensible load, (Btu/hr)
- ql : Latent load, (Btu/hr)
- n : Number of occupants
- Sens HG : Sensible Heat Gain per occupant
- Lat HG : Latent Heat Gain per occupant

The equipment load, which includes both sensible and latent heat gains, can be calculated using the following equations:

$$q_s = C_s \times q_r \times CLF$$
$$q_l = C_l \times q_r \tag{7}$$

where:

- Cs/Cl : Coefficient for equipment
- q_r : Total equipment input power, (Btu/hr)

The heat load from ventilation, which includes both sensible and latent heat transfer, can be calculated using the following equations:

$$q_s = 1.1 \times Q \times \Delta T$$
$$q_l = 4840 \times Q \times \Delta W \tag{8}$$

where:

- q_s : Sensible heat transfer rate from ventilation air, (Btu/hr)
- q_l : Latent heat transfer rate from ventilation air, (Btu/hr)
- Q : Volume of air flow, (CFM)
- ΔT : Temperature difference between the outside air and the design temperature, (°F)
- ΔW : Difference in humidity ratio between the outside air and the indoor air

The heat load from infiltration, which includes both sensible and latent heat transfer due to air infiltration, can be calculated using the following equations:

$$q_s = 1.1 \times CFM \times \Delta T \tag{9}$$

$$q_l = 4840 \times CFM \times \Delta W$$

where:

q_s : Sensible heat transfer rate of infiltrated air, (Btu/hr)
q_l : Latent heat transfer rate of infiltrated air, (Btu/hr)
ΔT : Difference between outside air temperature and indoor design temperature, (^oF)
ΔW : Difference in humidity ratio between outdoor air and indoor air
CFM : Air flow rate due to infiltration = ACH x Volume (ft^3)/ 60, (ft^3/min) [18]
ACH : Air Changes per Hour, the rate at which the air inside a space is replaced by outside air.

2.3. Hourly Analysis Program (HAP) 5.01 cooling load setup

The initial step in using the Hourly Analysis Program (HAP 5.01) involves opening the application and setting up the design weather data, which is crucial for accurately estimating cooling and heating loads. This weather data includes 24-hour temperature and humidity readings that reflect the typical sunlight conditions for each month.

The design parameters in HAP 5.01 encompass various critical factors such as:

- Geographic Location: This includes the region, specific location, and city of the building, which influence the climate data used in calculations.
- Design Conditions: This includes summer and winter design dry bulb (DB) and wet bulb (WB) temperatures, which are essential for determining the cooling and heating loads.
- Local Soil Conditions: Information on soil conductivity and reflectance is used to account for ground-related heat transfer.
- Time Specifications: The time zone, daylight savings adjustments, and the specific months used for cooling load calculations are set here.
- Data Source: The source of the climate data, such as the 1993 ASHRAE Handbook, is also indicated.

Design parameters encompass a range of critical information necessary for accurate cooling design calculations. These include the geographic location of the building, which influences climate and weather patterns, as well as the specific summer and winter design conditions that the HVAC system must accommodate. Additionally, local soil conditions, which can affect heat transfer, are considered, along with local time specifications and the month ranges that define the period of peak cooling demand.

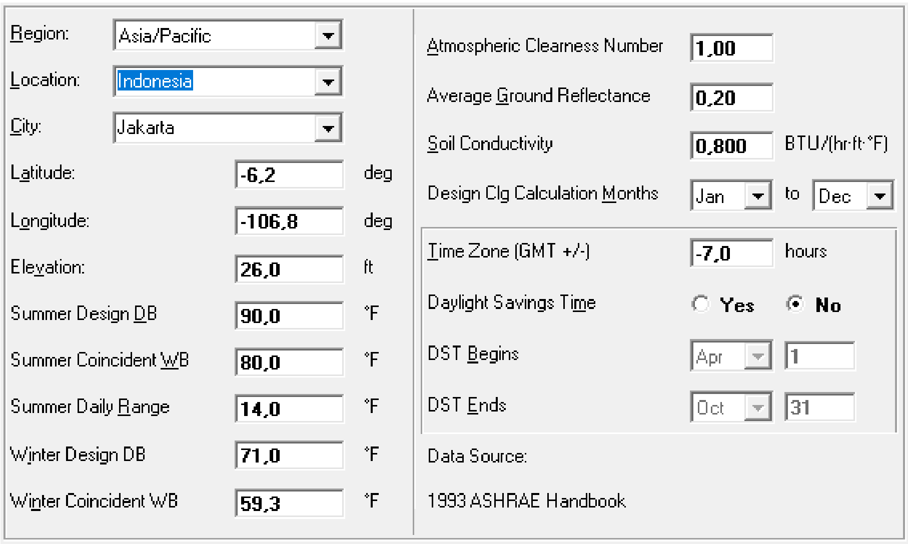


Figure 3. Design parameters inputs used for setting

The design temperature feature in HAP 5.01 is essential for defining the cooling temperature and humidity profile used in the load calculations. This profile outlines the expected daily variations in temperature and humidity, which are crucial for accurately simulating the cooling loads.

Monthly Max/Min

Month	Dry Bulb Max	Dry Bulb Min	Wet Bulb Max	Wet Bulb Min
Jan	90,0	76,0	80,0	75,5
Feb	90,0	76,0	80,0	75,5
Mar	88,0	74,0	79,0	73,5
Apr	86,0	72,0	78,0	71,5
Mei	83,0	69,0	77,0	68,5
Jun	81,0	67,0	75,0	66,5
Jul	80,0	66,0	74,0	65,5
Agu	82,0	68,0	75,0	67,5
Sep	85,0	71,0	77,0	70,5
Okt	86,0	72,0	78,0	71,5
Nov	87,0	73,0	79,0	72,5
Des	89,0	75,0	80,0	74,5

Hourly Detail View

Hour	Jan DB	Jan WB	Feb DB	Feb WB
0000	78,5	76,3	78,5	76,3
0100	77,8	76,1	77,8	76,1
0200	77,1	75,9	77,1	75,9
0300	76,6	75,7	76,6	75,7
0400	76,1	75,6	76,1	75,6
0500	76,0	75,5	76,0	75,5
0600	76,3	75,6	76,3	75,6
0700	77,0	75,8	77,0	75,8
0800	78,2	76,3	78,2	76,3
0900	80,1	76,9	80,1	76,9
1000	82,2	77,5	82,2	77,5
1100	84,5	78,3	84,5	78,3
1200	86,8	79,0	86,8	79,0
1300	88,5	79,5	88,5	79,5

Figure 4. Temperature design settings

The solar design feature in HAP 5.01 plays a crucial role in the cooling load calculations by incorporating peak heat loads caused by solar radiation. This feature allows users to view detailed data on the amount of heat load generated during peak solar conditions, which is essential for accurately sizing the cooling equipment.

Design Day Maximum Solar Heat Gains BTU/(hr·ft²)

Month	Multiplier	N	NNE	NE	ENE	E	ESE	SE	SSE	S
Jan	1,00	43,9	44,9	102,2	181,1	229,4	244,1	222,5	168,1	93
Feb	1,00	44,6	57,7	142,6	205,6	237,1	233,3	194,8	125,3	52
Mar	1,00	51,2	105,0	179,8	223,7	234,1	209,1	152,2	71,1	39
Apr	1,00	98,5	151,3	204,5	226,2	213,5	173,5	105,9	33,4	33
May	1,00	137,1	176,4	216,0	222,6	195,3	145,5	68,7	29,9	29
Jun	1,00	150,3	184,9	218,8	220,5	188,0	131,6	53,9	28,0	28
Jul	1,00	137,2	176,2	214,9	222,1	194,9	139,6	65,5	28,7	28
Aug	1,00	98,6	151,0	203,5	224,6	211,1	170,1	102,1	31,2	31
Sept	1,00	47,4	101,2	172,7	218,8	231,9	209,1	154,1	70,3	36
Oct	1,00	41,0	55,1	140,9	203,8	235,5	231,2	191,6	121,5	47
Nov	1,00	42,1	42,3	103,7	180,8	227,9	240,8	217,2	163,8	89
Dec	1,00	43,3	43,3	86,6	166,1	220,6	242,6	228,9	181,6	112

Figure 5. Solar design parameters

The simulation module in HAP 5.01 is essential for defining the weather data and energy simulation parameters used in the project. It includes detailed information about the simulated weather conditions throughout the year, which is critical for accurately predicting the building's energy consumption and cooling load requirements. Additionally, this module helps establish the operation calendar for energy simulations, allowing users to model different scenarios and operational schedules.

For thermal analysis, buildings are divided into units referred to as "spaces." A space typically represents a room or area within the building, consisting of various elements such as walls, roofs, windows, and internal heat loads. These elements influence the heat transfer dynamics into and out of the space. Each space is also equipped with one or more air distribution terminals, which are crucial for managing airflow and maintaining desired temperature conditions.

The airside system configuration is another critical aspect addressed in HAP 5.01. Users can choose between two primary methods for controlling the air distribution:

- Constant Air Volume (CAV): This method maintains a steady airflow rate, typically used in systems where consistent air delivery is essential.
- Variable Air Volume (VAV): This method adjusts the airflow rate based on the cooling demand, allowing for more precise temperature control and energy efficiency.

3. Results and Discussion

3.1. CLTD sensible load and latent load calculation results

The following section presents the results of the cooling load calculations performed using the CLTD method. These calculations include the sensible load, latent load, and the total load for each hotel room.

The graph of the CLTD calculation results, as shown in Figure 6, reveals that the highest sensible load is observed in the Suite Type Living Room and Owner's Suite Type Living rooms, with a peak value of 21,888 Btu/hr. This high sensible load is attributed to the larger wall, glass, and ceiling areas in these rooms, as well as the higher number of equipment, lighting fixtures, and occupants, all of which contribute significantly to the heat gain.

Similarly, the highest latent load is also found in the Suite Type Living Room and Owner's Suite Type Living rooms, with a value of 1,012 Btu/hr. This elevated latent load is primarily due to the increased presence of equipment, lighting, and occupants, which add moisture to the air, thereby raising the humidity levels that need to be controlled.

These findings highlight the varying cooling demands across different room types within the hotel, underscoring the importance of tailored HVAC design to effectively manage both sensible and latent loads.

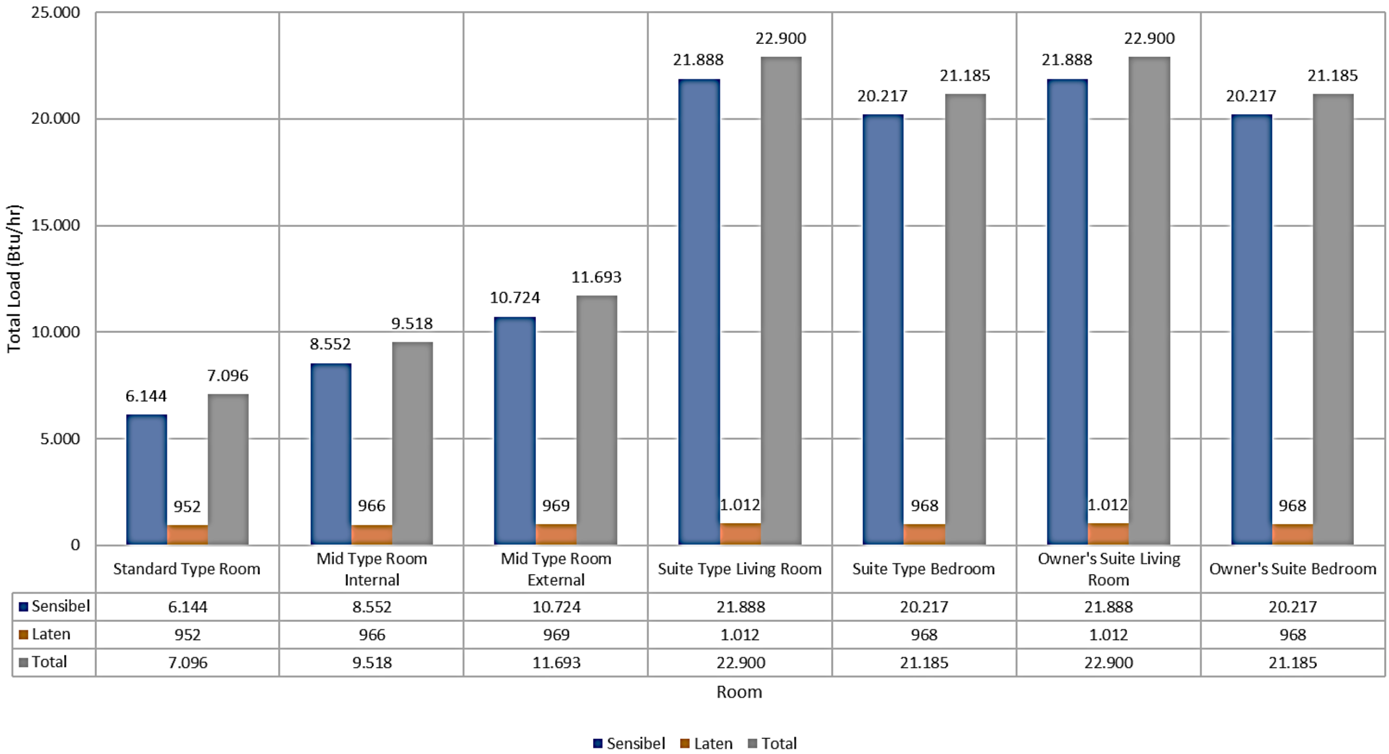


Figure 6. Sensible, latent & total CLTD load

The following table summarizes the calculated cooling capacities required for each room type in the hotel, based on the Cooling Load Temperature Difference (CLTD) method. Table 4 lists the sensible and latent cooling capacities as well as the total cooling load in BTU per hour (BTU/H) for each room type.

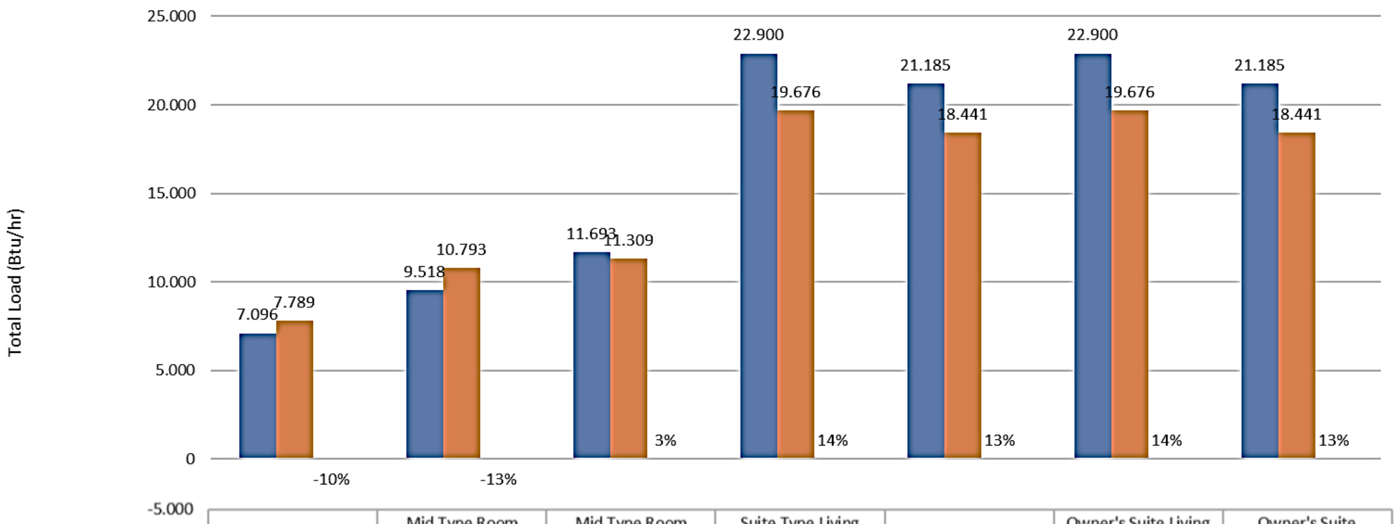
The table provides a detailed analysis of the calculated cooling loads for various room types in the hotel. The 90 Standard Type Rooms contribute the most significantly to the total cooling load in the hotel due to their large number, even though each room has a relatively moderate individual load. In contrast, the 3 Suite Type Living Rooms exhibit the highest individual sensible load at 21,888 Btu/hr, which is largely attributed to their larger size, increased number of heat-generating equipment, and more extensive glass and wall areas. Similarly, the Suite Type Bedrooms also display high cooling loads, reflecting the demand for larger spaces, higher occupancy levels, and potentially more heat-generating equipment and lighting. The substantial sensible loads in the suites and owner's rooms underscore the impact of these factors on the overall cooling demand.

Table 4. Total CLTD air conditioning capacity

Room Type	Amount	CLTD Capacity		
		Sensible	Latent	Total BTU/H
Standard Type Room	90	6,144	952	638,602
Mid Type Room Internal	8	8,552	966	76,146
Mid Type Room External	8	10,724	969	93,544
Suite Type Living Room	3	21,888	1,012	68,700
Suite Type Bedroom	3	20,217	968	63,555
Owner's Suite Living Room	1	21,888	1,012	22,900
Owner's Suite Bedroom	1	20,217	968	21,185
Total	*114*	*109,630*	*6,847*	*984,631*

3.2. HAP Software Cooling Load Calculation

This section compares the cooling load capacities calculated using the Cooling Load Temperature Difference (CLTD) method with those obtained from the Carrier HAP 5.01 software for each hotel room. The comparison reveals differences between the theoretical CLTD calculations, and the results generated by the HAP 5.01 software.



	Standard Type Room	Mid Type Room Internal	Mid Type Room External	Suite Type Living Room	Suite Type Bedroom	Owner's Suite Living Room	Owner's Suite Bedroom
CLTD	7.096	9.518	11.693	22.900	21.185	22.900	21.185
Simulation	7.789	10.793	11.309	19.676	18.441	19.676	18.441
Margin	-10%	-13%	3%	14%	13%	14%	13%

Figure 7. Comparison of total load generated by CLTD and HAP 5.01

According to Figure 7, the cooling load calculated using the CLTD method for Standard Type Rooms is approximately 10% higher than that calculated by the HAP 5.01 software, with the CLTD method represented by the orange line positioned above the HAP 5.01 results (blue line).

For Mid Type Internal Rooms, the CLTD method shows a difference of 13% greater than the HAP 5.01 calculation. In contrast, for Mid Type External Rooms, the CLTD calculation is 3% higher than the HAP 5.01 result. The discrepancies are more pronounced in the larger suite rooms: the Suite Type Living Room shows a 14% higher load when using the CLTD method, the Suite Type Bedroom is 13% higher, and both the Owner's Suite Living Room and Bedroom also show a 14% and 13% higher load, respectively, when compared to the HAP 5.01 software calculations.

These differences highlight the variability between the simplified theoretical calculations of the CLTD method and the more dynamic simulation approach of the HAP 5.01 software, which takes into account a wider range of factors and hourly variations, resulting in potentially lower calculated loads.

4. Conclusions

This research has undertaken a comprehensive analysis of the cooling load requirements for a hotel building by comparing the traditional Cooling Load Temperature Difference (CLTD) method with the more advanced Carrier HAP 5.01 software. The study revealed significant differences between the two methods, particularly in larger, more complex spaces such as suites and owner's rooms. The CLTD method consistently produced higher cooling load estimates compared to the HAP 5.01 software, with discrepancies ranging from 3% to 14%, depending on the room type.

These findings underscore the importance of selecting the appropriate calculation method based on the specific needs of the project. While the CLTD method is valuable for its simplicity and accessibility, it may overestimate cooling loads, leading to potentially oversized HVAC systems. On the other hand, the HAP 5.01 software, with its ability to incorporate hourly variations and a broader set of factors, provides a more precise estimation, which can result in more efficient and cost-effective system design.

In conclusion, for projects requiring a high degree of accuracy and efficiency, particularly in large and diverse spaces, the use of dynamic simulation tools like Carrier HAP 5.01 is recommended. However, the CLTD method remains a useful tool for preliminary design phases or simpler projects where quick estimates are needed.

Supplementary Documentation

More detailed CLTD and HAP cooling load results have been provided in the Supplementary Document. This additional information includes in-depth calculations, data tables, and comparative analyses that support the findings discussed in the main article. To access the Supplementary Document, please visit the article homepage.

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