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Cooling Load Analysis as a Basis for Determining Air Conditioning Capacity on the First Floor of the Two Sudirman Project Operational Office Building in Jakarta Using the CLTD Method

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***Abstract*— *Accurate determination of air-conditioning capacity is essential to maintain thermal comfort and to avoid inefficient use of installed cooling capacity in office buildings, particularly in tropical climates with relatively high outdoor temperature and humidity. This study evaluates the cooling load and installed air-conditioning capacity on the first floor of the Two Sudirman Project Operational Office Building in Central Jakarta, which is managed by China State Construction. The study applied a descriptive quantitative design using the Cooling Load Temperature Difference method. Field data included room dimensions, wall and glazing areas, occupancy, lighting, electrical equipment, indoor temperature, air infiltration, wall-panel thermal properties, and the nominal capacity of installed air-conditioning units. The analysis was performed at the selected peak-load condition of 14:00 local time for twelve conditioned zones. The calculated total cooling load was 57.305 kW, equivalent to approximately 16.29 tons of refrigeration. Occupants contributed the largest share of the load at 49.91%, followed by infiltration at 29.69% and electrical equipment at 13.55%. The installed capacity was 113.52 kW, indicating substantial aggregate overcapacity. However, zone-level evaluation identified eleven overcapacity zones and one undercapacity zone, namely the Corridor/Work Room, with a deficit of 2.550 kW. The theoretical requirement for the entire floor was 21.71 PK, while the recommended nominal capacity after zone-based adjustment was 25 PK or 66.00 kW. These findings show that aggregate capacity alone does not represent the adequacy of cooling distribution and that zone-based cooling-load analysis provides a more appropriate technical basis for capacity selection, operational scheduling, and corrective actions in project office buildings.*

***Keywords*— *Air-conditioning capacity, CLTD method, cooling load, HVAC system, office building.*

I. INTRODUCTION

Thermal comfort is an important factor in supporting productivity and smooth activities in office buildings. This issue becomes increasingly important in tropical regions such as Indonesia, where outdoor air temperature and relative humidity are relatively high. Air-conditioning systems must remove heat gains from the outdoor environment and indoor activities. Insufficient cooling capacity can prevent indoor thermal conditions from reaching the target, whereas excessive capacity can increase installed system capacity and operating costs. Therefore, air-conditioning capacity should be determined from a cooling-load analysis that considers the thermal characteristics of the building and its actual operating conditions.

The Cooling Load Temperature Difference (CLTD) method is an analytical approach used to calculate cooling loads from external and internal heat gains. The method considers heat transfer through walls and glazing, solar radiation, occupants, lighting, electrical equipment, and air infiltration [2], [3]. Taqwim and Komarudin [11] showed that CLTD can identify the contribution of each heat-load component and can be used to evaluate the suitability of installed air-conditioning capacity in educational buildings. However, educational buildings differ from project operational offices in occupancy patterns, equipment use, and the dynamics of work activities.

A research gap also exists in the characteristics of the building envelope. Previous CLTD applications have mainly examined educational buildings, hotels, and public facilities. The Two Sudirman Project Operational Office Building, managed by China State Construction, uses polyurethane-core sandwich wall panels with heat-transfer characteristics that differ from conventional walls. In addition, aggregate capacity evaluation may not reveal capacity mismatches in specific zones. These conditions indicate the need for room-level cooling-load analysis that integrates envelope characteristics, occupancy, equipment, and infiltration.

This study is practically important because the suitability of air-conditioning capacity affects the ability of the system to maintain thermal conditions and influences unit operating strategies. From a scientific perspective, a project operational office provides a specific context because variations in occupancy, use of work equipment, frequency of room access, and building-envelope characteristics can produce different load patterns. This study aims to calculate the total first-floor cooling load using the CLTD method, identify the dominant load components, evaluate the suitability of installed air-conditioning capacity, and determine the nominal capacity appropriate for each zone.

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The contribution of this study lies in applying CLTD to a construction-project operational office building with sandwich wall panels and dynamic work activities. The evaluation is performed at the zone level so that overcapacity and undercapacity conditions that are not visible in aggregate capacity comparisons can be distinguished. The findings are expected to extend the application of CLTD as an initial technical approach for tropical office buildings and provide a basis for building managers to determine air-conditioning capacity and operating strategies according to actual loads.

II. THEORITICAL REVIEW

The theoretical basis of this study comes from thermodynamics, heat transfer, and refrigeration systems. A refrigeration system transfers heat from a lower-temperature space to a higher-temperature environment through compression, condensation, expansion, and evaporation processes [3]. In buildings, heat transfer occurs through conduction, convection, and radiation. These mechanisms explain heat gains through the building envelope and determine cooling requirements. At the conceptual level, thermal comfort and cooling load describe the relationship among building conditions, occupant activities, and HVAC requirements. Thermal comfort is affected by air temperature, relative humidity, human activity, and clothing characteristics. ASHRAE [3] places the comfort range used in this study at approximately 22-26 °C and 40-60% relative humidity. Cooling load is the amount of heat that must be removed from a space to maintain the desired thermal conditions and comprises sensible and latent loads.

The CLTD method links heat-transfer theory with cooling-capacity evaluation. Wall heat gain is calculated using $Q = U \times A \times CLTDcorr$, where U is the heat-transfer coefficient, A is the surface area, and CLTDcorr is the corrected CLTD value. Glazing load is calculated from the glazing area, Solar Heat Gain Factor, and Shading Coefficient. Internal loads arise from occupants, lighting, and electrical equipment, whereas infiltration is determined from room volume, Air Changes per Hour (ACH), and the difference between outdoor and indoor air temperatures. The polyurethane sandwich-panel walls in the study object have a U-value of approximately 0.24 W/m²K based on material technical data and ASHRAE references.

Saragasan and Sies [10] compared manual cooling-load calculations with the Hourly Analysis Program (HAP) and showed that the manual method still produced estimates comparable to the software. Khorsheed and Danook [7] emphasized the importance of local weather data because temperature and humidity affect the accuracy of cooling-load calculations. Rahadi, Irawan, and Julianto [9] applied CLTD to the departure corridor area of Supadio Airport and showed that the method can be used for facilities with high activity levels.

Prawibowo and Komarudin [8] compared CLTD with Carrier HAP 5.01 for a hotel building. Their findings showed the advantages of CLTD in calculation simplicity and time efficiency for field-data-based analysis. Taqwim and Komarudin [11] applied CLTD to the first floor of the Universitas Dian Nusantara Building and demonstrated the ability of the method to identify heat-load contributions and evaluate installed air-conditioning capacity.

Previous studies confirm the usefulness of CLTD, but an empirical gap remains. The objects studied have mainly been educational buildings, hotels, and public facilities. Project operational offices have different fluctuations in occupancy, work-device use, access traffic, and operating patterns. Studies of buildings with sandwich wall panels are also relatively limited. In addition, aggregate capacity assessment can conceal undercapacity conditions in specific zones.

Based on this framework, the study positions internal and external heat sources as factors that determine the total cooling load, while the suitability of air-conditioning capacity is assessed by comparing the CLTD-calculated load with the nominal capacity of the installed units. A zone-based approach is used to complement previous studies by integrating envelope characteristics, occupancy dynamics, infiltration, and air-conditioning capacity in one technical evaluation.

III. RESEARCH METHOD

This study uses a descriptive quantitative design to measure actual building characteristics, calculate cooling loads numerically using the CLTD method, and evaluate the suitability of installed air-conditioning capacity. This approach was selected because the research variables are measurable quantities, including room dimensions, temperature, number of occupants, equipment power, building-envelope area, infiltration, and cooling capacity.

The study was conducted on the first floor of the Two Sudirman Project Operational Office Building managed by China State Construction, Jl. Sudirman RT 10/RW 11, Karet Tengsin, Tanah Abang District, Central Jakarta. Primary data were collected from May to June 2026, and the analysis continued until July 2026. Calculations focused on the peak-load condition at 14:00 local time. The main building facade faces west, so afternoon solar exposure was considered in selecting the peak-load condition.

The unit of analysis consists of 12 air-conditioned zones: CM Room, Activity Room, Mix Room, Small Meeting Room, Big Meeting Room, Safety Induction Room, Corridor/Work Room, Archive Room, Clinic, Musholla, Canteen, and VIP Room. The total analyzed area is approximately 679.16 m² with a volume of approximately 2,005 m³. Rooms without air-conditioning systems were excluded from the analysis. All zones that met the criteria were analyzed, so the study did not apply probabilistic sampling.

Primary data were obtained through field observation and measurement using a measuring tape or laser distance meter, AutoCAD, and a thermo-hygrometer. The data include room dimensions, wall and glazing areas, envelope materials, number of occupants, lighting power, electrical equipment, temperature, infiltration, and the number and capacity of air-conditioning units. Secondary data were obtained from the ASHRAE Handbook, material technical data, previous journal studies, and cooling-unit specifications. Microsoft Excel was used to support data processing and calculations.

Heat loads were calculated for occupants, lighting, electrical equipment, walls, glazing, and infiltration. Wall load

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was calculated using Q = U × A × CLTDcorr, glazing load using Q = A × SHGF × SC, and infiltration using Q = 1.2 × ACH × V × ΔT. The total cooling load for each zone was obtained by summing all components. The result was then compared with the installed air-conditioning cooling capacity in kW. The nominal air-conditioning requirement was converted using the study convention of 1 PK ≈ 2.64 kW of cooling capacity. An additional nominal COP analysis used the nominal cooling capacity and rated input of the units. Because actual compressor power was not measured separately, the resulting value was treated as the nominal system COP.

The research procedure was arranged sequentially from problem identification to the preparation of capacity recommendations and corrective actions. The research stages are presented in Fig. 1.

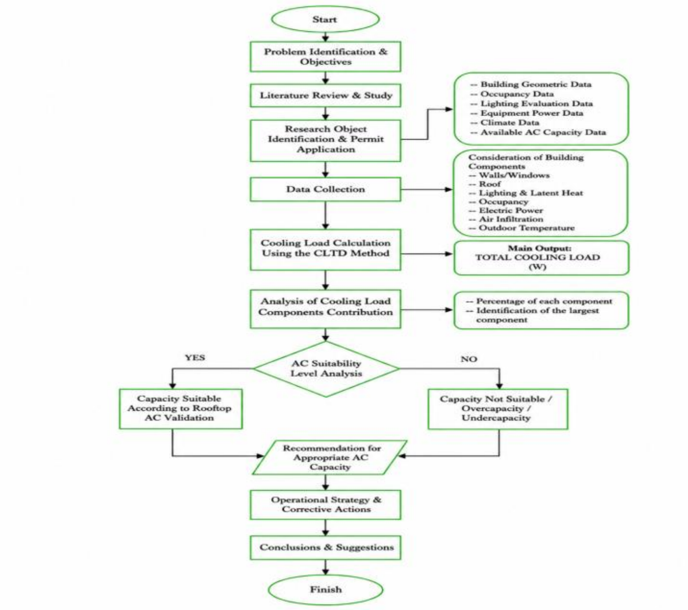

Figure 1 Research flowchart.

Data specifications include all data used in the CLTD cooling-load calculations. The data in this study were classified according to their type and function for cooling-load calculation, as presented in Tables 1 and 2.

TABLE 1. Characteristics of Research Zones and Installed Air-Conditioning Capacity.

Zona	Luas (m²)	Volume (m³)	Penghuni (orang)	Terpasang (PK)	Terpasang (kW)
CM Room	84,00	248	20	5,5	14,52
Activity Room	42,00	125	6	4	10,56
Mix Room	33,88	100	3	4	10,56
Small Meeting Room	31,57	93	14	4	10,56
Big Meeting Room	73,15	216	35	4	10,56
Safety Induction Room	50,82	150	12	2	5,28
Corridor/Work Room	219,00	645	64	6	15,84
Archive Room	22,50	67	4	2	5,28
Clinic	14,21	42	2	2	5,28
Musholla	15,19	45	8	1,5	3,96
Canteen	44,84	132	40	4	10,56
VIP Room	48,00	142	12	4	10,56
Total	679,16	2.005	220	43	113,52

TABLE 2. Components and Equations for Cooling-Load Calculation.

Komponen	Persamaan	Parameter utama	Sumber data
Dinding	Q = U × A × CLTDcorr	U, luas dinding, CLTD terkoreksi	ASHRAE dan data material
Kaca	Q = A × SHGF × SC	Luas kaca, SHGF, shading coefficient	ASHRAE dan pengukuran
Penghuni	Q = n × q	Jumlah penghuni, panas per orang	Observasi dan ASHRAE
Pencahayaan Peralatan	Q = Σ P lampu Q = Σ P peralatan	Jumlah dan daya lampu Jumlah dan daya peralatan	Observasi lapangan Observasi/data pabrikan
Infiltrasi	Q = 1,2 × ACH × V × ΔT	ACH, volume, beda temperatur	Observasi dan ASHRAE
Total	Qtotal = Σ seluruh komponen	Beban internal dan eksternal	Hasil perhitungan

IV. Results And Discussion

A. Results

Calculations at the peak-load condition of 14:00 produced a total first-floor cooling load of 57,305 W or 57.305 kW, equivalent to 16.29 TR. The largest load occurred in the Corridor/Work Room at 18.390 kW, followed by the Canteen at 8.330 kW, the Big Meeting Room at 7.073 kW, and the CM Room at 6.931 kW. These differences show that cooling requirements are influenced not only by room area, but also by occupancy, equipment, infiltration, and envelope characteristics. The load composition shows that occupants were the largest heat source at 28,600 W or 49.91%. Infiltration ranked second at 17,012 W or 29.69%, followed by electrical equipment at 7,767 W or 13.55%. Glazing accounted for 2,259 W or 3.94%, lighting for 1,296 W or 2.26%, and walls for 371 W or 0.65%. The composition is presented in Table 3.

TABLE 3. Composition of the First-Floor Cooling Load.

Komponen	Beban (W)	Beban (kW)	Kontribusi (%)
Penghuni	28.600	28,600	49,91
Infiltrasi	17.012	17,012	29,69
Peralatan listrik	7.767	7,767	13,55
Kaca	2.259	2,259	3,94
Pencahayaan	1.296	1,296	2,26
Dinding	371	0,371	0,65
Total	57.305	57,305	100,00

The total installed air-conditioning capacity is 43 PK or 113.52 kW, whereas the CLTD-based requirement is 57.305 kW. In aggregate, the installed capacity exceeds the requirement by 56.215 kW, or approximately 98.10% of the requirement. However, zone-level evaluation shows that 11 zones are overcapacity, while the Corridor/Work Room is undercapacity by 2.550 kW because its 18.390 kW load exceeds the installed capacity of 15.840 kW. The zone-level evaluation is presented in Table 4.

The theoretical requirement for the entire floor is 21.71 PK. After the requirement for each zone was adjusted to available nominal unit capacities, the total recommended

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capacity became 25 PK or 66.00 kW. This value is 47.52 kW, or 41.86%, lower than the installed capacity of 113.52 kW. For the Corridor/Work Room, the theoretical requirement is 6.97 PK and the recommended design capacity is 7.5 PK or approximately 19.80 kW. The recommended capacities are presented in Table 5.

TABLE 4. Zone-Level Evaluation of Cooling Load and Installed Air-Conditioning Capacity

Zona	Beban (kW)	Terpasang (kW)	Selisih (kW)	Status
CM Room	6,931	14,520	+7,589	Overcapacity
Activity Room	2,506	10,560	+8,054	Overcapacity
Mix Room	1,396	10,560	+9,164	Overcapacity
Small Meeting Room	2,370	10,560	+8,190	Overcapacity
Big Meeting Room	7,073	10,560	+3,487	Overcapacity
Safety Induction Room	3,269	5,280	+2,011	Overcapacity
Corridor/Work Room	18,390	15,840	-2,550	Undercapacity
Archive Room	0,923	5,280	+4,357	Overcapacity
Clinic	1,099	5,280	+4,181	Overcapacity
Musholla	1,523	3,960	+2,437	Overcapacity
Canteen	8,330	10,560	+2,230	Overcapacity
VIP Room	3,495	10,560	+7,065	Overcapacity

TABLE 5. Recommended Air-Conditioning Capacity Based on Actual Cooling Load.

Zona	Beban (kW)	Kebutuhan Teoritis (PK)	Rekomendasi (PK)	Rek. (kW)
CM Room	6,931	2,63	3	7,92
Activity Room	2,506	0,95	1	2,64
Mix Room	1,396	0,53	0,75	1,98
Small Meeting Room	2,370	0,90	1	2,64
Big Meeting Room	7,073	2,68	3	7,92
Safety Induction Room	3,269	1,24	1,5	3,96
Corridor/Work Room	18,390	6,97	7,5	19,80
Archive Room	0,923	0,35	0,5	1,32
Clinic	1,099	0,42	0,5	1,32
Musholla	1,523	0,58	0,75	1,98
Canteen	8,330	3,16	4	10,56
VIP Room	3,495	1,32	1,5	3,96
Total	57,305	21,71	25	66,00

The COP analysis for the Corridor/Work Room using the psychrometric chart produced an entering-air enthalpy of 58.36 kJ/kg dry air and a leaving-air enthalpy of 41.93 kJ/kg dry air, giving a specific cooling effect of 16.43 kJ/kg dry air. Based on a nominal cooling capacity of 15.84 kW and a total rated input of 4.77 kW, the nominal COP is 3.32. This value does not represent the actual compressor COP because compressor power was not measured separately [1], [3], [4]. The nominal system COP data are presented in Table 6.

TABLE 6. Nominal Capacity, Rated Input, and Nominal COP of the Air-Conditioning System.

Zona	Qe,nom (kW)	Wk,pendekatan (kW)	COP nominal
CM Room	14,52	4,20	3,46
Activity Room	10,56	3,18	3,32
Mix Room	10,56	3,18	3,32
Small Meeting Room	10,56	3,18	3,32
Big Meeting Room	10,56	3,18	3,32
Safety Induction Room	5,28	1,59	3,32
Corridor/Work Room	15,84	4,77	3,32
Archive Room	5,28	1,59	3,32
Clinic	5,28	1,59	3,32
Musholla	3,96	1,02	3,88
Canteen	10,56	3,18	3,32
VIP Room	10,56	3,18	3,32

B. Discussion

The 49.91% contribution from occupants shows the strong influence of occupancy on the cooling requirement of the project operational office building. The Corridor/Work Room accommodates 64 people and produces an occupant load of 8.320 kW. This finding is consistent with the ASHRAE cooling-load concept, which treats human activity as a source of sensible and latent heat. It also supports Rahadi, Irawan, and Julianto [9], who showed that CLTD can be applied to facilities with high activity levels. Infiltration contributes 29.69% of the total load and is the second-largest component. Its magnitude is influenced by room volume, ACH, and the outdoor-indoor temperature difference. This finding is consistent with Khorsheed and Danook [7], who emphasized that local weather conditions and environmental air parameters affect the accuracy of cooling-load analysis. In a project operational office building with frequent movement of people, controlling uncontrolled air infiltration is an important strategy without reducing the minimum ventilation requirement.

The wall contribution of 0.65% is relatively small compared with internal loads and infiltration. This condition is associated with the use of polyurethane sandwich wall panels with a U-value of approximately 0.24 W/m²K and with the calculation scope, which includes exposed exterior walls at the peak-load condition. However, this result should be interpreted in light of the basic CLTD assumption of 10 K because the specific characteristics of sandwich panels are not directly listed in the CLTD table used in this study.

The finding that 11 zones are overcapacity while the Corridor/Work Room is undercapacity is the main result of this study. The total installed capacity of 113.52 kW substantially exceeds the total requirement of 57.305 kW, but the excess capacity is not distributed according to the load of each zone. This finding extends the work of Taqwim and Komarudin [11], who demonstrated the usefulness of CLTD for evaluating installed air-conditioning capacity. Zone-based evaluation provides more operationally useful information than aggregate evaluation.

The results also support Saragasan and Sies [10] and Prawibowo and Komarudin [8] regarding the usefulness of CLTD as a practical analytical approach. The method can separate the contributions of heat sources and relate them to the required unit capacity without requiring complex dynamic simulation. Nevertheless, CLTD remains a simplified approach, so validation using long-term field data or simulation software can improve accuracy under rapidly changing load conditions.

From a practical perspective, the recommended capacity of 25 PK or 66.00 kW indicates an opportunity to improve the air-conditioning configuration and operating strategy. The 41.86% difference from the installed capacity represents a difference in nominal capacity, not evidence that energy consumption will decrease by the same percentage. In overcapacity zones, managers can apply staged operation, unit rotation, timers, and occupancy-based control. For the Corridor/Work Room, an alternative to increasing capacity to 7.5 PK is to retain three 2-PK units while reducing the load. The study scenario shows that removing one water dispenser

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and six lighting points reduces the load by 0.458 kW, while controlling infiltration from 1.00 to approximately 0.70 ACH can close the remaining capacity deficit. Corrective actions are summarized in Table 7.

TABEL 7. Summary of Corrective Actions for the Air-Conditioning System Based on Zone-Level Evaluation.

Zona	Permasalahan utama	Tindakan korektif/operasional	Target
CM Room	Overcapacity +7,589 kW	Operasikan 2 PK + 1,5 PK; satu unit 2 PK sebagai cadangan dan rotasi.	Kapasitas aktif 9,24 kW
Activity Room	Overcapacity +8,054 kW	Operasikan satu unit 2 PK; unit kedua aktif saat beban/okupansi meningkat.	Kapasitas aktif 5,28 kW
Mix Room	Overcapacity +9,164 kW	Operasikan satu unit 2 PK sesuai jadwal; unit kedua sebagai cadangan.	Kapasitas aktif 5,28 kW
Small Meeting Room	Overcapacity +8,190 kW	Operasikan satu unit 2 PK; unit kedua digunakan saat okupansi tinggi.	Kapasitas aktif 5,28 kW
Big Meeting Room	Overcapacity +3,487 kW	Gunakan dua unit saat rapat penuh; satu unit lebih dahulu pada okupansi rendah.	Operasi bertahap sesuai beban
Safety Induction Room	Overcapacity +2,011 kW	Atur jadwal operasi dan set-point 24-26 °C; matikan saat ruang tidak digunakan.	Durasi operasi sesuai kebutuhan
Corridor/Work Room	Undercapacity -2,550 kW	Pertahankan 3×2 PK; kurangi 1 dispenser, 6 lampu, dan infiltrasi efektif dari 1,00 menjadi ±0,70 ACH.	Beban turun menjadi 15,840 kW
Archive Room	Overcapacity +4,357 kW	Gunakan timer/termostat dan operasi sesuai jadwal akses dengan memperhatikan kondisi arsip.	Pengurangan durasi operasi
Clinic	Overcapacity +4,181 kW	Operasikan sesuai jam pelayanan dan okupansi; set-point 24-26 °C.	Operasi sesuai kebutuhan
Musholla	Overcapacity +2,437 kW	Operasikan menjelang dan selama waktu penggunaan; gunakan mode hemat setelahnya.	Operasi sesuai jadwal
Canteen	Overcapacity +2,230 kW	Gunakan dua unit pada jam makan; satu unit dapat dinonaktifkan di luar jam puncak.	Operasi mengikuti okupansi
VIP Room	Overcapacity +7,065 kW	Operasikan satu unit 2 PK; unit kedua saat okupansi meningkat, dengan rotasi berkala.	Kapasitas aktif 5,28 kW

Theoretically, the study shows that the distribution of internal loads and infiltration can determine cooling requirements more strongly than wall loads in a project operational building with insulated materials. Practically, the findings confirm the importance of zone-based capacity determination. The study limitations include the use of a basic 10 K CLTD assumption for sandwich panels, maximum occupant counts, ACH values, weather conditions, peak-load time, and the use of rated input as an approximation in the COP analysis. Further research should use data loggers, hourly load variations, occupancy diversity factors, actual power measurements, and comparisons with HAP, EnergyPlus, Radiant Time Series, or other dynamic simulation methods.

V. CONCLUSSION

The results show that the total cooling load on the first floor of the Two Sudirman Project Operational Office Building at the 14:00 peak condition reaches 57.305 kW or 16.29 TR. Occupants are the largest component at 49.91%, followed by infiltration at 29.69%, electrical equipment at 13.55%, glazing at 3.94%, lighting at 2.26%, and walls at 0.65%. The installed air-conditioning capacity of 113.52 kW or 43 PK indicates aggregate overcapacity, but zone-level evaluation identifies 11 overcapacity zones and a 2.550 kW undercapacity condition in the Corridor/Work Room.

The theoretical cooling requirement for the entire floor is 21.71 PK, and the recommended nominal capacity is 25 PK or 66.00 kW. This finding confirms that capacity suitability should be assessed at the zone level because excess total capacity does not guarantee adequate capacity in every room. Scientifically, the study extends the application of CLTD to a project operational office with sandwich wall panels and demonstrates the dominance of internal loads and infiltration in this context. Practically, the results can serve as an initial basis for determining the number of active units, selecting capacity, and controlling room loads.

Further research is recommended to use continuous measurements of temperature, humidity, occupancy, ACH, and power consumption. Validation using HAP, EnergyPlus, Radiant Time Series, or other dynamic methods is also required. Energy-consumption and life-cycle-cost analyses can be added so that capacity recommendations are assessed from thermal, energy, and economic perspectives.

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