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Estimation of Cooling Load in Hotel Public Areas

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***Abstract* - Data in 2021, as much as 48.95% of the total increase in business in the accommodation sector in Indonesia is in the form of star hotels. One of the most important components in running a hotel business is comfort, one of which is related to the air conditioning aspect. A good air conditioning system that remains energy and economically-efficient is important for business continuity. The purpose of this study is to determine the cooling load in public areas of one of Jakarta's hotels. This research uses analytical approach methods. The research results show that the hotel cooling load in public areas is 176.9 kW. Climatic aspects, occupancy levels, which are influenced by the type of day, such as holidays or weekdays, greatly influence the cooling load value.**

Keywords: ASHRAE, cooling load, energy consumption, Jakarta, Radiant Time Series.

I. INTRODUCTION

The building sector is one of the major contributors to greenhouse gas emissions, with buildings consuming about 30% of the world's resources and approximately 40% of the world's energy [1]. The global hotel industry, a multi-billion-dollar sector focused on guest comfort, faces challenges related to high energy consumption [2]. Each year, the tourism sector experiences rapid growth in both local and global economies, with an estimated annual growth rate of 3.3% worldwide by 2030 [3].

The distribution of accommodation businesses in Indonesia in 2021 continued to increase, with 48.95% being star-rated hotels [4]. Some sectors anticipate that the hotel business will enter a new phase of even higher growth following an improving economic condition and significant opportunities in the budget hotel market [5].

The function of the air conditioning system is to condition or regulate the air, temperature, humidity and air circulation, as well as purify or filter the air [6]. The first basic step in designing an HVAC system is calculating the building's cooling load. Current methods for estimating cooling loads are based on heat transfer from air systems as found in ASHRAE [7]. Cooling load refers to the rate at which heat must be removed from a room to achieve the desired comfort conditions through air conditioning and cooling equipment [8]. The cooling load is divided into two, namely external and internal cooling loads. External loads are caused by ventilation and solar radiation penetrating structures, such as walls, ceilings, windows and doors [9]. Internal heat gain consists of lighting, equipment, and occupant heat gain [10].

Indonesia is a country in the tropical region that is crossed by the equator, which results in a climate that tends to be generally warm and hot in the dry season. Regarding businesses that require an air conditioning system, precise estimates are needed to design air conditioning equipment that can operate well and remain economically and energy efficient. The purpose of this research is to determine the cooling load in the public areas of one of the hotels in Jakarta. It is hoped that this research can be a reference for designing the unit capacity that will be installed in the hotel.

II. METHODOLOGY

2.1 Research Methodology

This research uses an analytical approach method where the process is carried out manually and uses calculator software to calculate the cooling load. The analytical results will then be displayed in a graph to provide an idea of the size of the cooling load, as well as the graphic pattern or trend of the cooling load in hotels for predictions for 2024 based on the Indonesian government's work activity and holiday calendar.

Calculation of cooling capacity (cooling load) is carried out using the latest method, namely Radiant Time Series (RTS) which is recommended by the American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE) standards. The calculated heat load includes:

a. External heat gain (Walls, roofs, windows, partitions, ceilings, and floors)
b. Infiltration heat gain (Sensible & latent: Air leakage and moisture migration)
c. Internal heat gain (Sensible & latent: Lights, people, appliances, and equipment)

2.2 Data for Cooling Load Calculation

To calculate the cooling load of the space, detailed building information, location, weather data, internal design

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information, and operational schedules are required [11]. The data needed to calculate the cooling load at the hotel under study will be provided and explained in detail in each section.

2.2.1 Weather Data

Weather data refers to the temperature, humidity, and solar radiation conditions that affect the building and its HVAC equipment. This term also encompasses information about the building's geographical location, local time characteristics, and the properties of the local soil. Weather data related to the hotel cooling load calculation process is displayed in Table 1.

Table 1: Weather Data for Calculating Cooling Loads in Hotel

Parameters	Data
Location	Indonesia
City	Jakarta
Latitude	-6.2deg
Longitude	-106.8deg
Elevation	7.9 m
Dry Bulb Temperature	33.8 °C
Wet Bulb Temperature	25.8°C
Soil Conductivity	1.4 W/m/K
Time Zone (GMT +/-)	-7.0 hours

2.2.2 Building Thermal Conditions Data

The thermal comfort zone in conditioned buildings, specifically in workspaces, is standardized with a minimum dry bulb temperature of 25°C and a relative humidity of 55%. Meanwhile, in transit areas, the standard specifies a minimum dry bulb temperature of 27°C with no specific relative humidity standard [12].

2.2.3 Operational Schedule Data

The occupancy rate is a primary input parameter that influences building performance simulations [13]. The occupancy rate is related to the operational schedule. The operational schedule is divided into three categories: weekdays, weekends, and holidays. On weekdays, it is assumed that from Monday to Friday, the activity intensity or occupancy rate is set by 50%. On weekends and holidays, it is assumed that on Saturdays, Sundays, and national holidays, the activity intensity or occupancy rate is set by 100%. Table 2 shows the operational schedule data.

Table 2: The Operational Schedule Data

Condition	Simulation
Extreme	Neglecting for weekdays, weekends and holidays, as well as operational hours, the dependency is solely on climatic conditions.
Normal	The operational hours are from 08:00 AM to 10:00PM, divided into three conditions: weekdays, weekends, and holidays.

2.2.4 Hotel Building Material Data

The value of the heat transfer coefficient depends on the thickness and characteristics of the building material. Table 3 shows hotel building specifications that are declared to meet ASHRAE standards.

Table 3: Hotel Building Material Data

Building Components	Data
Walls	$1.2\ W/m^2 \cdot K$
Roof	$0.6\ W/m^2 \cdot K$
Floor	$5.2\ W/m^2 \cdot K$
Ceiling	$1.8\ W/m^2 \cdot K$
Glass	$3.2\ W/m^2 \cdot K$
Shading Coefficient of Glass	0.8

2.2.5 Hotel Space Area Data

A room consists of several elements such as walls, roofs, windows, and internal heaters that affect heat transfer in and out of the room. The data used is based on plans provided by the architect and follows the standards set by ASHRAE and SNI (Indonesian National Standard). The data regarding various types of rooms and their specifications are shown in Table 4 and Table 5.

Table 4: Hotel Space Area Data

Room Type	Floor Area (m^2)	Avg. Ceiling Height (m)
Room Meeting-1	39.0	4,5
Room Meeting-2	69.0	4,5
Pre-Function	43.0	4,5
Main Lobby Hotel	232.0	5.0
Service Station	28.0	5.0
Service Lift Lobby	5.4	5.0
BOH Corridor	27.0	5.0
Front Office Manager	7.5	5.0
Reservation Room	6.5	5.0
Washing Room	5.0	5.0
Passenger Corridor	59.0	5.0
Passenger Lift Lobby	15.0	5.0
SPA Room	52.0	5.0
Lobby Gym	94.0	5.0
Room Meeting-3	20.0	4.7
Room Meeting-4	73.0	4.7
Entrance Lobby	20.0	4.7
Break Room	40.0	4.7
Pre-Function	80.0	4.0
Ballroom	229.0	4.0

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Corridor-1	34.0	4.7
Mosque	20.0	4.7
Nursery Room	5.0	4.7
Server & Storage Room	13.0	4.0
IT Room	13.0	4.0
Service Station	27.0	4.0
Service Lift Lobby	5.0	4.0
Corrridor-2	36.0	4.0
Passenger Lift Lobby	37.0	4.0
Gym	139.0	4.0

Based on SNI, rooms have different air requirements based on their specific functions.

Table 5: Data Outdoor Air Requirement

Room Types	Outdoor Air Requirement	
	(L/s· person)	(L/s · m^2)
Room Meeting-1	2.5	0.3
Room Meeting-2	2.5	0.3
Pre-Function	3.8	0.3
Main Lobby Hotel	2.5	0.3
Service Station	3.8	0,6
Service Lift Lobby	3.8	0.3
BOH Corridor	-	0.3
Front Office Manager	2.5	0.3
Reservation Room	2.5	0.3
Washing Room	2.5	0.3
Passenger Corridor	-	0.3
Passenger Lift Lobby	3.8	0.3
SPA Room	2.5	0.3
Lobby Gym	2.5	0.3
Room Meeting-3	2.5	0.3
Room Meeting-4	2.5	0.3
Entrance Lobby	3.8	0.3
Break Room	3.8	0.3
Pre-Function	3.8	0.3
Ballroom	2.5	0.3
Corridor-1	-	0.3
Mosque	2.5	0.3
Nursery Room	2.5	0.3
Server & Storage Room	2.5	0.3
IT Room	2.5	0.3
Service Station	3.8	0.6
Service Lift Lobby	3.8	0.3
Corrridor-2	-	0.3
Passenger Lift Lobby	3.8	0.3
Gym	10.0	0.9

Based on SNI, the activity patterns of building occupants can affect the maximum cooling load and influence the required capacity of the cooling equipment. Table 6 displays data on heat released by humans.

Table 6: Data Heat Given Off by Human

Room Types	Sensible Heat (W)	Latent Heat (W)
Room Meeting-1	75	55
Room Meeting-2	75	55
Pre-Function	75	55
Main Lobby Hotel	75	55
Service Station	80	80
Service Lift Lobby	75	55
BOH Corridor	75	55
Front Office Manager	75	55
Reservation Room	75	55
Washing Room	75	55
Passenger Corridor	75	55
Passenger Lift Lobby	75	55
SPA Room	75	45
Lobby Gym	75	55
Room Meeting-3	75	55
Room Meeting-4	75	55
Entrance Lobby	75	55
Break Room	75	55
Pre-Function	75	55
Ballroom	75	45
Corridor-1	75	55
Mosque	75	45
Nursery Room	75	45
Server & Storage Room	75	45
IT Room	75	45
Pre-Function	75	55
Ballroom	75	45
Corridor-1	75	55
Mosque	75	45
Pre-Function	75	55
Ballroom	75	45
Corridor-1	75	55
Mosque	75	45
Nursery Room	75	45
Server & Storage Room	75	45
IT Room	75	45
Service Station	80	80
Service Lift Lobby	75	55
Corridor-2	75	70
Passenger Lift Lobby	75	55
Gym	210	315

Based on ASHRAE, the estimation of lighting load usage is determined based on the room function. Table 7 displays the lighting power densities using the space-by-space method.

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Table 7: Lighting Power Densities Using Space-by-Space Method

Room Types	Lighting Power Density (W/m^2)
Room Meeting-1	13.3
Room Meeting-2	13.3
Pre-Function	7.9
Main Lobby Hotel	11.5
Service Station	13.1
Service Lift Lobby	7.0
BOH Corridor	7.1
Front Office Manager	12.0
Reservation Room	12.0
Washing Room	6.5
Passenger Corridor	7.1
Passenger Lift Lobby	7.0
SPA Room	10.6
Lobby Gym	11.5
Room Meeting-3	13.3
Room Meeting-4	13.3
Entrance Lobby	11.5
Break Room	7.9
Pre-Function	7.9
Ballroom	13.3
Corridor-1	7.1
Mosque	16.5
Nursery Room	10.6
Server & Storage Room	18.4
IT Room	18.4
Service Station	13.1
Service Lift Lobby	7.0
Corridor-2	7.1
Passenger Lift Lobby	7.0
Gym	13.0

For the heat gain from electronic appliances, several heat gain levels are categorized with different requirements for each room. Table 8 shows the design of heat gain from electronic appliances or other equipment in the room.

Table 8: Data Heat Gain Given Off by Appliances

Heat Gain (W)	Categories
250	The design for the heat load from electronics in the room categories with minimal electronic equipment requirements.
1000	The design for the heat load from electronics in the room categories with moderate electronic equipment requirements.
2000	The design for the heat load from electronics in the room categories with high electronic equipment requirements.

The data from Table 1 to Table 8 will then be used as input data for the analysis process of calculating the amount of cooling load estimated to occur in hotels during the 2024 period.

III. RESULTS AND DISCUSSION

3.1 Cooling Load Estimation

Based on the data collection results in the hotel and by modelling using existing standards, the cooling load can then be calculated for each room in the hotel. Table 9 presents a summary of the results of estimating the amount of cooling load in each room in the research object hotel.

Table 9: Cooling Load of Hotel Public Areas

Room Type	Cooling Load (kW)
Room Meeting-1	4.0
Room Meeting-2	5.6
Pre-Function	2.7
Main Lobby Hotel	34.5
Service Station	3.8
Service Lift Lobby	1.6
BOH Corridor	1.0
Front Office Manager	0.7
Reservation Room	0.7
Washing Room	0.6
Passenger Corridor	5.3
Passenger Lift Lobby	2.3
SPA Room	4.9
Lobby Gym	18.5
Room Meeting-3	2.1
Room Meeting-4	5.8
Entrance Lobby	5.7
Break Room	2.1
Pre-Function	3.5
Ballroom	22.9
Corridor-1	1.8
Mosque	2.1
Nursery Room	0.7
Server & Storage Room	3.6
IT Room	2.1
Service Station	3.8
Passenger Lift Lobby	2.4
Gym	28.8
Total Cooling Load	176.9

From Table 9, it is known that the cooling load of the hotel in public areas is 176.9 kW. Thus, the unit capacity for each room and the minimum capacity for the hotel's chiller in public areas can be determined.

3.2 Energy Consumption

Figure 1 shows a curve illustrating the energy consumption for each month during extreme conditions. The curve indicates that the maximum energy consumption occurs in January, while the minimum occurs in July, with values of

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3,209.4 kWh and 2,363.0 kWh, respectively. This shows that climatic conditions have a significant effect on energy consumption, with January and July experiencing maximum temperatures of 33.8°C and 27.7°C, respectively.

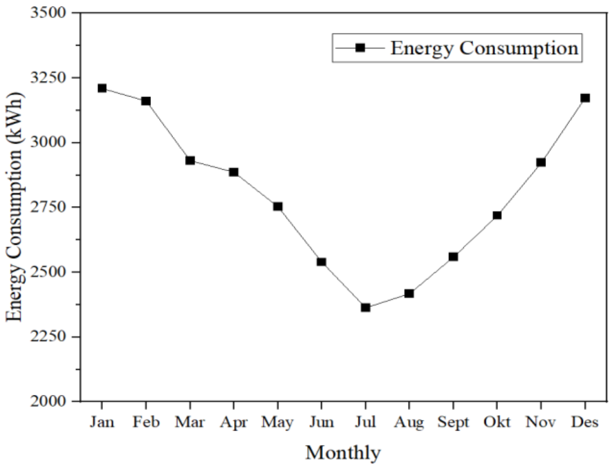

Figure 1: Energy consumption during extreme conditions

Figure 2 illustrates the energy consumption for each hour during holidays and weekdays. The curve shows that the maximum energy consumption occurs between 12:00AM to 3:00 PM during weekends, with an energy consumption of 144.1 kWh, and during weekdays, the energy consumption is 115.9 kWh. This is because the temperature during that time is the maximum, which can affect the cooling load and also energy consumption.

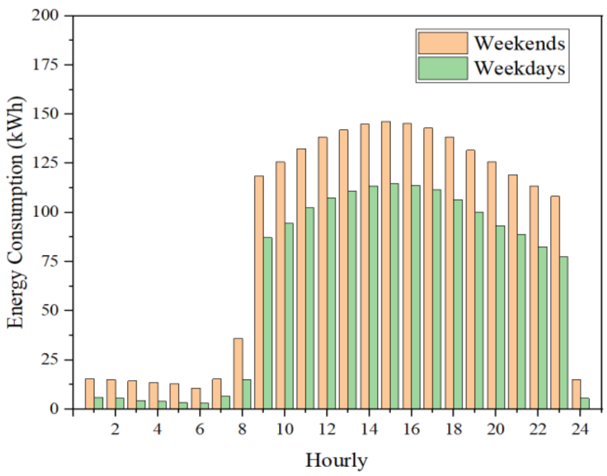

Figure 2: Comparison of energy consumption during weekdays and weekends

Figure 3 illustrates the pattern of the energy consumption curve during weekdays and weekends over a month. The curve shows a significant difference in energy consumption, with weekdays having a maximum energy consumption of 1,630.0 kWh and weekends having a maximum energy consumption of 2,122.0kWh. This demonstrates that activity intensity or the occupancy rate significantly influences the energy consumption rate.

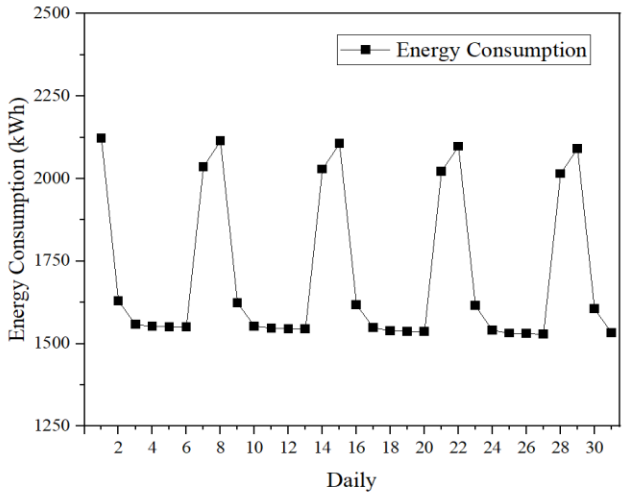

Figure 3: Pattern of energy consumption during weekdays and weekends over a month

Figure 4 illustrates the energy consumption curve for each month under normal conditions in the year 2024. Based on the 2024 calendar, April includes the Islamic holiday of Eid al-Fitr, which results in a long national holiday. Therefore, it can be seen from the curve that April has the highest energy consumption, with a value of 56,399.0 kWh. It can be concluded that the timing of national holidays or collective leave is crucial as it significantly affects energy consumption.

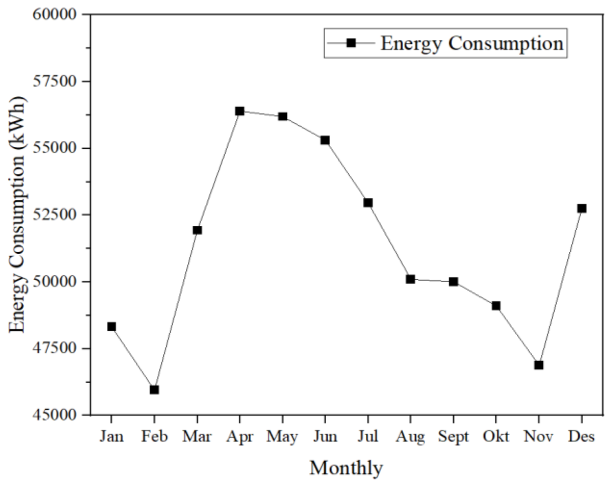

Figure 4: Energy consumption of each month during normal conditions in 2024

IV. CONCLUSION

The research results show that climatic conditions have a significant effect on the cooling load, with the peak load in January and the minimum in July. Weekday and weekend patterns also show variations, with weekdays having a lower load than weekends. Additionally, during holidays, the cooling

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load peaks at midday. April saw the highest cooling load due to the extended Eid al-Fitr holiday. If the cooling load increases, with the same time duration, energy consumption will also increase. These findings demonstrate the importance of considering climate variations and activity intensity when designing cooling systems for hotels in the Jakarta region, Indonesia.

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