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Mobile Software Development For Cooling Load Estimation And Air-Condtioning Equipment Sizing

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Abstract:
A significant challenge in air-conditioning installation is the precise calculation of the cooling load—the total heat that needs to be extracted from a space for effective cooling. Traditional methods for these calculations are either laborious manual computations or unreliable estimations based on simplistic rules of thumb, which can lead to inaccuracies in equipment sizing due to the complex nature of modern architectural designs. Most existing cooling load calculation software target HVAC professionals and are often expensive and impractical for wider usage in developing countries. This paper introduces a novel, user-friendly mobile application developed in Kotlin for Android platforms, which simplifies the process of air-conditioning equipment sizing for both residential and commercial buildings in Nigeria. The app leverages a modified cooling load temperature difference/solar cooling load factor/cooling load factor (CLTD/SCL/CLF) method, tailored with local weather data and building practices, and provides a straightforward interface that allows even users with basic smartphone skills to effectively participate in the equipment sizing process. Inputs such as room dimensions, types of walls, doors, windows, roof, and floor, as well as the equipment used, are considered by the software to estimate the heat load accurately. The app's performance was validated against manual calculations: the software estimated the cooling load of a model office space as 5.8 kW or 2.06 hp, compared to 6.2 kW determined manually, suggesting a 2.0 hp air-conditioning unit would be adequate. This tool not only reduces dependency on costly professional services but also mitigates the issue of incorrect unit sizing that leads to higher energy consumption and costs, demonstrating a significant improvement in accessibility and efficiency in cooling load estimation in Nigeria.

***Keyword**: HVAC, Cooling load, Kotlin, Android, Thermal engineering, CLTD*

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I. Introduction

Achieving environmental comfort is essential for human efficiency, particularly in residential and commercial spaces where people spend significant time[1]. Air-conditioning involves treating air to regulate temperature, humidity, cleanliness, and circulation to achieve comfortable and habitable indoor environments[2]. Cooling load estimation involves estimating the total heat needed to be extracted from a building to maintain habitable and comfortable conditions and is crucial for estimating and optimizing energy consumption in building design and maintenance[3,4]. Proper air conditioning equipment sizing ensures that air-conditioning units precisely remove heat from a space while optimizing energy consumption and maintaining a conducive indoor environment[5]. Over-sizing or under-sizing, due to inaccurate heat load calculation, leads to increased energy consumption, reduced efficiency, and higher costs, while also impacting occupant comfort and environmental sustainability[6]. The conventional approach to cooling load calculations relies on manual methods, which are often time-consuming, laborious, and prone to errors due to the need to reference charts, tables, and complex mathematical formulas[5,7]. In Nigeria, where hiring HVAC engineers may be costly, building owners often rely on guesswork or rules of thumb, which often oversimplify the design process by overlooking factors like building design and environmental conditions[5]. Such practices result in oversized or undersized systems, leading to excessive energy consumption, high costs, and inefficient indoor cooling[6].

This study aims to develop a user-friendly mobile application software for air-conditioning equipment sizing tailored to residential and commercial buildings in Nigeria by assessing existing cooling load calculation methods, designing an integrated method for estimating cooling loads, and developing a mobile software based on the designed method. The software was developed using the cooling load temperature difference/solar cooling load factor/cooling load factor (CLTD/SCL/CLF) method, which is modified using weather data for each Nigerian state since the existing software only has information for popular Nigerian cities like Lagos and Abuja thereby limiting its applicability across the diverse climatic conditions found in Nigeria[8,9]. The software is programmed in Kotlin due to its interoperability with Java, combined with modern and concise syntax that reduces boilerplate code and enhances developer's productivity[10]. The application is designed to be user-friendly with helpful features such as compass for identifying correct cardinal location of walls, windows, and doors, thereby enabling individuals with basic smartphone knowledge to participate in the equipment sizing process.

II. Cooling Load Calculation Methods

Cooling load calculation determines the rate of heat transfer in a building to maintain desired indoor temperatures. This process considers several factors, including outdoor and indoor temperature differences, insulation, room size, occupant activity, and lighting levels[11]. Previous literatures[2,3,12–14] have extensively expatiated on multiple methods that have been developed over time to improve accuracy and ease-of-use.

Total Equivalent Temperature Difference/Time Averaging (TETD/TA) Method: TETD is an early method involving averaging radiant heat gains but often over predicts cooling loads. The TETD/TA method considers both the conduction heat gain through walls, roofs, and windows and the effects of solar energy on these surfaces. It simplifies the heat balance approach by incorporating predefined equivalent temperature differences for a range of materials and conditions. This method is particularly suitable for manual calculations or basic software implementations, as it uses average values to estimate thermal loads under typical conditions. However, its reliance on fixed parameters limits its adaptability to diverse or non-standard scenarios[2,13]. TETD has also been observed to always give over-estimated cooling load[15].

Transfer Function (TF): TF method is a dynamic and accurate method using weighting factors but is the most complex because it requires complex computations. The TF method is a sophisticated technique derived from the heat balance method, employing mathematical functions to account for time-dependent heat transfers. It is highly accurate and widely used in HVAC design when precision is crucial, especially for dynamic building envelopes. This method requires advanced computation and is implemented in software like HAP or EnergyPlus. Despite its accuracy, the TF method's complexity makes it less accessible for manual calculations or small-scale applications[12,16].

Cooling Load Temperature Difference/Solar Cooling Load/Cooling Load Factor (CLTD/SCL/CLF): Simplifies load estimation using pre-tabulated values for surface heat gains, improving usability without significant accuracy loss. The CLTD/CLF method is a simplified approach derived from the TF method and heat balance techniques. It uses pre-tabulated values for cooling load temperature differences and cooling load factors, enabling quick and relatively accurate load estimations for building components like walls, roofs, and windows[13]. This method is ideal for regions with limited computational resources or expertise, as it is straightforward and user-friendly while maintaining reasonable accuracy. However, its reliance on static tabulated data may reduce accuracy for unconventional or extreme scenarios

Heat Balance (HB): The most accurate method reflecting true thermal physics but complex and computationally intensive. The HB method offers the most comprehensive and accurate representation of thermal processes within a building by solving detailed energy balance equations for all surfaces and air volumes. It is highly effective in accounting for interactions between external climate conditions, building materials, and internal heat sources. Despite its precision, the method's complexity and computational demands make it more suitable for high-level research or advanced software applications[13,17].

Radiant Time Series (RTS): The RTS method is a modern simplification of the HB method, focuses on breaking down radiant heat gains into time-distributed components to calculate their cooling load contributions. It strikes a balance between precision and usability, making it suitable for applications where moderate accuracy is acceptable without excessive computational overhead. However, like the TF method, its complexity limits its practicality for manual calculations[13,17]

Despite the advancements in cooling load calculation methods, the CLTD/SCL/CLF method was selected for this study due to its balance of simplicity and accuracy. While newer methods like HB, TETD, and RTS methods offer higher precision, they require sophisticated tools and detailed data input, which can be impractical for manual or preliminary calculations. The CLTD/SCL/CLF method simplifies the process by using pre-tabulated values and direct calculations, which allow users to estimate cooling loads efficiently while maintaining reasonable accuracy. Furthermore, the method can be adapted to various building orientations and climates, making it suitable for applications in regions like Nigeria, where cost constraints and technical expertise may limit access to advanced software tools. This project builds on the CLTD/SCL/CLF method with innovative modifications to address limitations, such as incomplete table values for cities outside North America, ensuring applicability in tropical regions.

III. Considerations And Assumptions

The design cooling load calculation incorporates all the potential thermal loads experienced by a building, based on certain assumptions. These assumptions include:

- Weather data used for the calculations is taken from a long-term statistical database. Although this data is representative of the building's location, it does not necessarily correspond to any specific year or day.
- Solar heat gain is assumed to occur under clear-sky conditions, with no haze or obstructions, during the month selected for the calculations.
- All building equipment and appliances are presumed to be operating at a typical, representative capacity.
- Both latent and sensible heat gains are accounted for, with latent heat assumed to contribute immediately to the cooling load. Sensible heat gain is partially delayed, depending on the thermal characteristics of the conditioned space. According to ASHRAE standards, sensible heat from occupants is assumed to be 30% convection (instant load) and 70% radiative (delayed load).
- Ventilation requirements are determined either based on air exchange rates or the maximum anticipated occupancy.
- It is assumed there is no additional moisture-gain from equipment or external sources.
- Windows are assumed to be constructed of standard glass, fitted without shading, and assigned a glass factor of 1.

IV. Methodology

The mobile application software is developed specifically for the Android Operating System using Kotlin programming language in Android Studio. Figure 1 shows the software's graphics user interface while Figure 2 shows the software's backend. The software's backend and coding details are available on our previous publication[18] (Ojo et al., 2024).

The CLTD/SCL/CLF method used in this study is based on information from the 1997 ASHRAE Handbook of Fundamentals[19]. The method accounts for time-lag in conductive heat gain through building components and delayed radiant heat gain converting to cooling load. The method and software were tailored specifically to weather conditions and building construction practices in Nigeria. Peak load time is assumed to occur at 4 PM on the design day[19].

In buildings, there are seven basic cooling loads, five of which are related to the envelope: roof, walls, floor, windows and infiltration. The other two loads are duct gains and internally generated heat. Internal heat gain can be attributed to the heat and moisture produced directly by the occupants as well as the appliance activities associated with daily living[14]. Therefore, thermal load sources for buildings are broadly classified into external loads, internal loads, infiltration and ventilation loads. The considered cooling load sources and estimation equations are given below:

External Cooling Loads

Includes thermal loads generated from the outside components of the space to be cooled which are exposed to solar radiation from the sun. They are further classified into walls, doors, roofs, glass thermal load and solar load calculation.

Roof

The basic conduction equation which was used for calculating heat gain is given as

$$Q = U \times A \times \Delta T \qquad (1)$$

Q = Heat gain in kW
U = Thermal Transmittance for roof in W/m^2K
A = area of roof in m^2
ΔT = Temperature difference in °C

The heat gain was converted to cooling load using the room transfer functions for the rooms with light, medium and heavy thermal characteristics. The equation is then modified as:

$$Q = U \times A \times (CLTD) \qquad (2)$$

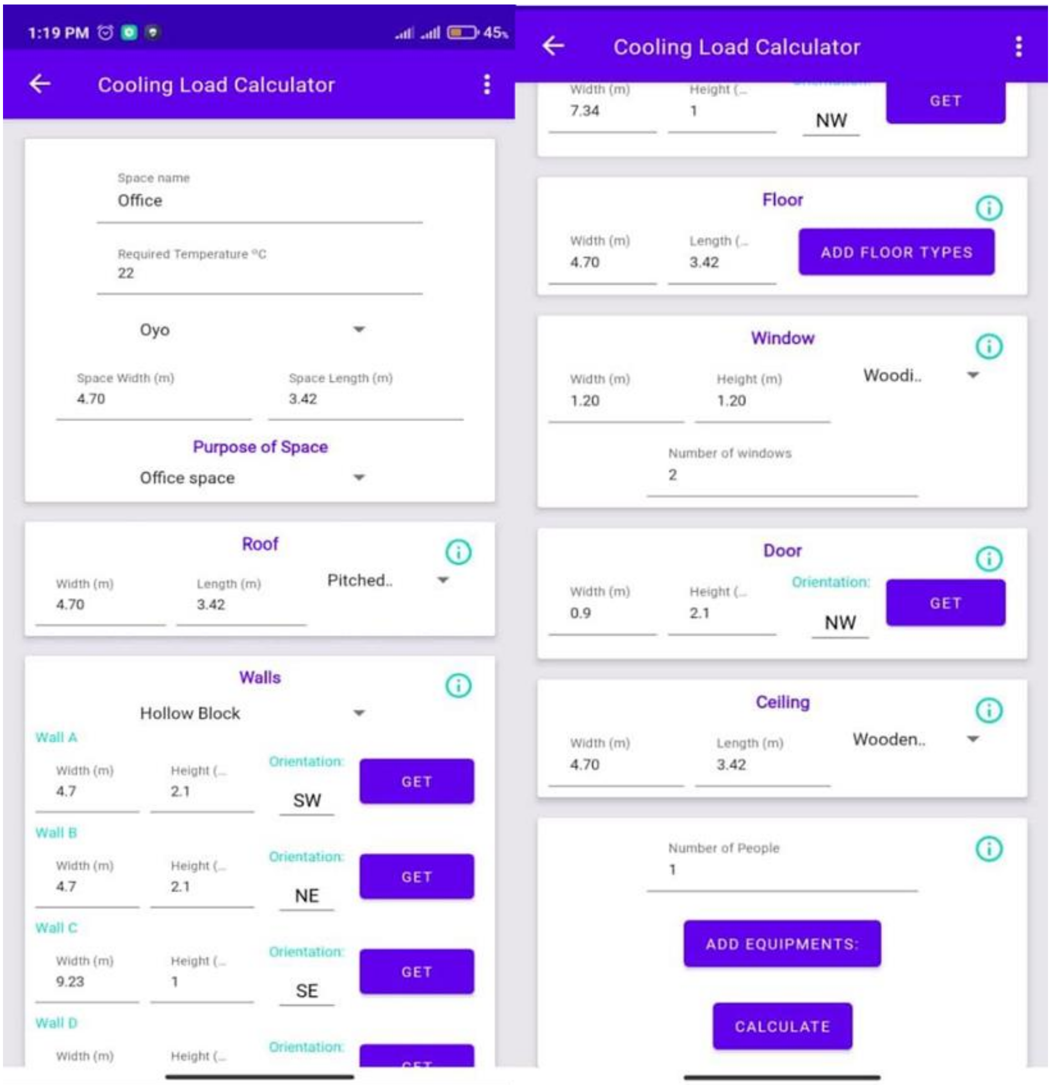

Figure 1: The software's graphics user interface (GUI) showing the imputed data for the estimation.

Where,
Q = Cooling load in kW
U = Coefficient of heat transfer or thermal transmittance for roof, wall or glass. This value was gotten based on the types of construction materials used. Values were gotten from Chapter 24, Table 4 and Chapter 29, Table 5 of ASHRAE HOF 1997 in W/m²K[19].
A = Area of roof in m^2
CLTD = Cooling Load Temperature Difference (°C). The values were determined from Chapter 28, Tables 32 and 34 of the ASHRAE HOF 1997 since the ASHRAE tables provide hourly CLTD values for one typical set of conditions[19].
Hence,

$$Q_{Roof} = U \times A \times CLTD_{RoofCorrected} \quad (3)$$

$$CLTD_{RoofCorrected} = (CLTD_{roof} + (78 - T_R) + (T_m - 85)) \quad (4)$$

$(78 - T_R)$ = indoor design temperature correction
$(T_m - 85)$ = outdoor design temperature correction
T_m = mean outdoor temperature = $T_{max} - (Daily\ Range) / 2$
In summary, the typical steps by which the roof loads were calculated are as follows:
Step 1: The overall heat transfer coefficient (U) was determined based on the roof construction material as seen in, Chapter 24, Table 4 and Chapter 29, Table 5 (ASHRAE HOF, 1997)[19].
Step 2: The roof number was gotten from ASHRAE Table 31 or Table 7.34 which is closest to matching actual roof construction used in Nigeria[19].

Step 3: The $CLTD_{Roof}$ for time of interest was selected, typically the peak load time also known as the design day temperature and here, 4pm was the hour selected for use as seen in Chapter 28, Table 32, 34 of ASHRAE HOF, 1997[19].

Walls

$$Q_{Walls} = U \times A \times CLTD_{wallscorrected} \quad (5)$$

Q_{Walls} = Cooling load for roof (kW)
U = Coefficient of heat transfer or thermal transmittance for walls. (W/m^2K)
A = Area of walls (m^2)

$$CLTD_{WallsCorrected} = (CLTD + (78 - T_R) + (T_m - 85)) \quad (6)$$

$(78 - T_R)$ = indoor design temperature correction
$(T_m - 85)$ = outdoor design temperature correction
T_m = mean outdoor temperature = $T_{max} - (Daily\ Range) / 2$
In summary, the typical steps by which the wall loads were calculated are as follows:

Step 1: The overall heat transfer coefficient (U) was determined based on the wall construction material as seen in Chapter 24, Table 4 and Chapter 29, Table 5 ASHRAE HOF, 1997[19].
Step 2: The wall type was gotten from ASHRAE Table 33[19] which is closest to matching actual wall construction types used in Nigeria.
Step 3: The CLTD Wall for time of interest was selected. Typically, the peak load time also known as the design day temperature and here, 4pm was the hour selected for use as seen in Chapter 28 Table 32, 34 of ASHRAE HOF, 1997[19].
Step 4: To calculate wall area (A), the architectural drawings were used to determine the actual value. Since the values for window and door losses were calculated separately, the areas of windows and door are extracted from wall area.

Glass Thermal Load

$$Q_{Glass\ Load} = U \times A \times CLTD_{GlassCorrected} \quad (7)$$

$Q_{GlassLoad}$ = Glass cooling load or conductive load in kW.
U = Thermal Transmittance for glass depending on glass type, presence or absence of indoor shade in Btu/ (W/m^2K)
A = Area of roof in m^2

$$CLTD_{GlassCorrected} = (CLTD_{Glass} + (78 - T_R) + (T_m - 85)) \quad (8)$$

$(78 - T_R)$ = indoor design temperature correction $(T_m - 85)$ = outdoor design temperature correction
T_m = mean outdoor temperature = $T_{max} - (Daily\ Range) / 2$

In summary, the typical steps by which the conductive thermal loads were calculated are as follows:
Step 1: For the glass types used the overall heat transfer coefficient (U) was selected from ASHRAE tables. The glass is the major contributor of heat gain in commercial buildings. Hence, the need to pay attention to effect of shading, reflective films, curtains and drapes as seen in Chapter 25, Table 5 of ASHRAE HOF, 1997[19].
Step 2: The CLTD Glass was selected for time of interest, typically on an hourly basis as shown in Chapter 28, Table 34 of ASHRAE HOF, 1997[19].
Step 3: To calculate wall area (A), the architectural drawing was used to determine the actual value

Solar Load through Glass

$$Q_{GlassSolar} = A \times SC \times SCL \quad (9)$$

A = Area of glass in m^2
SC = Shading Coefficient depending on glass type and shading type.
SCL = Solar Cooling Load factor.

In summary, the typical steps by which the glass solar loads were calculated are as follows:
Step 1: Shading Coefficient (SC) was determined from Chapter 27, Table 11 of ASHRAE HOF, 1997[19]
Step 2: Zone type was determined from Chapter 29, Table 35 B (ASHRAE HOF, 1997)
Step 3: Solar Cooling Load factor (SCL) was determined from Chapter 28, Table 36 ASHRAE HOF, 1997[19].

Step 4: The glass areas (A) were derived from the architectural plan.

Partitions, Ceilings and Floors

This calculation is applicable in situations where a conditioned space is adjacent to a space with a different temperature. The thermal load according to ASHRAE HOF 1997[19] is given as;

$$Q = U \times A \times (T_a - T_{rc}) \qquad (10)$$

U = coefficient of overall heat transfer between adjacent and conditioned space in W/m^2K from Chapter 24 of 1997 ASHRAE HOF[19].
A = area of partition in m^2, ceiling or floor which was calculated from building plans
T_a = temperature of adjacent space in °C
T_{rc} = Inside design temperature of conditioned space in °C (assumed constant)

Internal Cooling Load

In this study only the thermal loads generated from the internal components of the space to be cooled were put into consideration. They include loads generated from people, lights, partition loads and leakage air loads.

Lighting

$$Q = 3.41 \times W \times F_{UT} \times F_{SBA} \times (CLF) \qquad (11)$$

W = Watts input from electrical lighting plan or lighting load data.
F_{UT} = Lighting use factor, as appropriate.
F_{SBA} = special ballast allowance factor, as appropriate.
CLF = Cooling Load Factor, by hour of occupancy as determined from Chapter 28, Table 38 of 1997 ASHRAE HOF[19].
Note: CLF = 1.0, if operation is 24 hours or if cooling is off at night or during weekends. The total light wattage was obtained from the ratings of all lamps installed, both for general illumination and for display use.

People

For this study, the thermal loads generated from the occupants of the space to be cooled were put into consideration. The loads are further classified into latent and sensible loads and their values vary depending on the type of activities carried out within the space by the occupants.

Total Sensible loads $(Q_s) = N \times Q_s \times CLF \qquad (12a)$
Total latent loads $(Q_l) = N \times Q_l \qquad (12b)$

N = Number of occupants present in the space and as determined from Chapter 28, Table 3 of 1997 ASHRAE HOF[19].
Q_s, Q_l = Sensible and Latent heat gain from occupancy which were determined from Chapter 28, Table 3 of 1997 ASHRAE HOF[19].
CLF = Cooling Load Factor which is the ratio of the occupancy hours to total no of hours in one day and was determined from Chapter 28, Table 37 of 1997 ASHRAE HOF[19].
Note: CLF = 1.0 if operation is 24 hours a day or if cooling is off at night or during weekends.

Miscellaneous Loads

In this case, the thermal loads generated from the appliances of the space to be cooled were put into consideration depending on the application of the space. For example, a kitchen consists of components such as ovens, cookers, fridge et c. Often, the only information available about heat gain from equipment is that on its nameplate but when calculating, they are classified into latent and sensible loads. The formula below also applies to heat gain by ventilation air which is the amount of outdoor air required to make up for air leaving the space due to equipment exhaust, exfiltration and/or as required to maintain Indoor Air Quality for the occupants

$$Q_{Sensible} = Q_{in} \times F_u \times F_r \times (CLF) \qquad (13a)$$
$$Q_{Latent} = Q_{in} \times F_u \qquad (13b)$$

Q_{in} = rated energy input from appliances. This was determined from Chapter 28, and Table 5 through 9 of 1997 ASHRAE HOF. For computers, monitors, printers and miscellaneous office equipment, values were

gotten from Chapter 29, Tables 8, 9, & 10 of 1997 ASHRAE HOF (if the appliance nameplate provides the power ratings in Watts,
Q_{in} can be estimated as 3.14 x Wattage of equipment)[19].
F_u = Usage factor and was derived from Chapter 28, Table 6 and 7 (ASHRAE HOF, 1997).
Fr = Radiation factor and was derived from Chapter 28, Table 6 and 7 of 1997 ASHRAE HOF[19].
CLF = Cooling Load Factor, by hour of occupancy which was derived from Chapter 28, Table 37 and 39 of 1997 ASHRAE HOF[19].
Note 1: CLF = 1.0, if operation is 24 hours or of cooling is off at night or during weekends.
Note 2: latent load = 0 if appliance is under exhaust hood.

Ventilation and Infiltration Thermal Load

For this study, only the Ventilation and Infiltration Loads of the space to be cooled was considered. Ventilation loads are as a result of a deliberately designed air exchange system into and out of the room. Infiltration loads are as a result of outside air leakage into the space. They are both given as;

Sensible loads $(Qs) = 1.08 \times \Delta T \times CFM$ $(14a)$
Latent loads $(Ql) = 4840 \times \Delta w \times CFM$ (14b)

ΔT = Temperature difference in between indoor and outdoor (°C)
Δw = specific humidity difference between indoor and outdoor
CFM = required air volume needed in the space depending on space area and number of occupants (m^s/min) also known as the infiltration air flow rate and was derived from Chapter 25 of 1997 ASHRAE HOF[19].

Diversity Factor

The actual cooling load of the space was calculated as the total sum of the thermal loads generated from the external, internal and ventilation and infiltration loads. Since the design condition during the calculation will put the peak thermal loads into consideration, it should be noted that the building's cooling load will not always be at peak conduction, hence the need to apply diversity factors.

Diversity factors are factors of usage which will vary with location and type of application of buildings since the space will not always generate maximum heat if it is not always used to its maximum capacity[20]. In this study, the diversity factor was applied to loads from people and lights because the space will not always have 100% occupancy and lighting. Hence, the reduction in cooling loads from nonuse are real and were accounted for. A list of some typical diversity factors for people and lights is shown in Table 3.1. Equation 15 is adopted to estimate the cooling load for people and lights.

$$Q(kW) = People\ or\ Lighting\ Heat\ Gain\ (W) \times CLF\ \times Diversity\ Factor \qquad (15)$$

Table 2 outlines specific functions and actions for the software. The analysis of the relevance and implementation of these functions is given below.

1. Material - Get Thermal Transmittance: This function, labeled as *"convertToThermalTransmittance(material: String): Double"* computes thermal conductivity of different materials like roofs, walls, floors, and windows in the software to perform similar calculations to determine heat load based on material properties using detailed thermal data from 1997 ASHRAE HOF.
2. Cltd, meanTemp, requiredTemp - Calculate corrected CLTD: The function "*calculateCldtCorrected(cld, meanTemp, requiredTemp):Double"* is used for adjusting standard Cooling CLTD values based on local conditions, such as mean temperatures and required indoor temperatures.
3. Equipment - Get the equipment load value: The *"getEquipment(equipment): Int"* function computes load values for various equipment, which is essential for accurately estimating total cooling loads in each space, considering the internal heat gains from equipment.
4. Degree - Get Orientation based on degree: Corresponds to *"getOrientation(degree): String"* is a method used for determining the orientation of building components relative to the sun, which affects solar heat gain. This is crucial for the mobile app's functionality as orientation of components such as walls, doors, and windows significantly impact cooling load calculations.
5. State/Location - Get the temperature details: Through *"selectStateDetails(state): StateTempDetail"*, the app tailors the cooling load calculations to local weather conditions by retrieving the highest weather temperature for different 36 states of Nigeria. This is a novel feature since existing apps only provide data for popular cities in Nigeria like Lagos and Abuja.

6. Calculated Data - Save Calculated data from detail screen: The *"addCalculatedData(calculatedData): Void"* function allows saving calculated cooling load data to the database for future reference or analysis, enhancing the usability of the software by providing historical data access.

These functions are used to implement the development goals and methodologies of this project in the software so it can be used as a user-friendly, efficient, and locally adaptable tool for HVAC professionals and laypersons alike. The integration of such specific functions ensures the app not only performs basic load calculations but also adapts to complex real-world scenarios by considering local construction practices and climate variations. This level of detail supports the project's aim to mitigate the challenges of over-sizing or under-sizing air conditioning systems, thereby optimizing energy use and reducing costs.

Table 1: Typical diversity factors for People and lightings in various building types[19]

Types of Application	People	Lights
Office	0.75 to 0.90	0.70 to 0.85
Apartment, Hotel	0.40 to 0.60	0.30 to 0.50
Department Store	0.80 to 0.90	0.90 to 1.00
Industrial	0.85 to 0.95	0.80 to 0.90

Table 2: Defined functions and their Actions

Parameters	Function in plain English	Functions Defined	Actions
Material	Get Thermal Transmittance	Private fun convertToThermalTransmittance(material: String): Double	Computes thermal conductivity of any material from the list of type of roof, walls, floors, windows.
Cltd, meanTemp, requiredTemp	Calculate corrected CLTD	private fun calculateCltdCorrected(cltd, meanTemp, requiredTemp): Double	Computes the CLTD corrected from its parameters: 1. cltd - using the orientation) 2. meanTemp – gotten from space location 3. required Temperature
Equipment	Get the equipment load value.	private fun getEquipment(equipment): Int	Computes the loads value from selected equipment
Degree	Get Orientation based on degree	private fun getOrientation(degree: Int): String	Compute the orientation from degrees. Orientations are N, W, S, E, SE, NW, NE, SW
State/location	Get the temperature details	private fun selectStateDetails(state: String): StateTempDetail	Get any state details from the all the states details in the database.
Calculated data	Save Calculated data from detail screen	fun addCalculatedData(calculatedData: CalculatedData)	Save calculated data to the database

Figure 2: Operational flowchart of the software

V. Results And Discussion

To test the software (cooling load calculator), a model office space as shown in Figure 3 having the following characteristics was examined:

- Day; 12th April, time: 4PM, Room is to be maintained at 22ºC and 50% relative humidity, Location: Oyo State
- Room dimensions: length 4.70m, breadth 3.42m, height 2.1m
- Office room, accommodating 1 person using 1 Computer and 1 printer

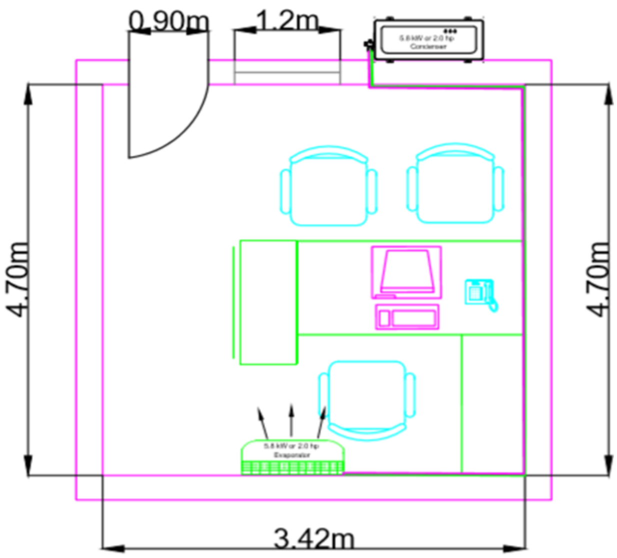

Figure 3: Office space plan with 2.0hp split air-conditioning unit

Estimated Result

The estimated cooling load given by the software was 5.8 kW or 2.06 hp as presented in Figure 4. This value is the maximum cooling load of the office space. A manual calculation was carried out by hand using the CLTD/CLF/SCL method which lasted about 5 hours and the value derived was 6.2 kW. But according to the software's estimated result, a 2.0 hp capacity air-conditioning unit will sufficiently cool the office space. A split air-conditioner can be used preferably with the evaporator as the indoor unit and the condenser as the outdoor unit.

What makes this software stand out is that it does not just measure the total heat load generated in the building space (by giving the result in Btu/hr only), it also gives the required AC capacity in kW, hp and ton. This is not the case in many other cooling load estimation software as further conversions are usually required by the user. This feature makes sourcing the equipment in the market a faster and easier process.

Evaluation of Software Performance

As seen in Figure 4, all the values imputed during the calculation process were displayed alongside the estimated results. Also, a save icon was added at the top bar of the interface. This is to aid the software's user friendliness by allowing the user to save all the room details alongside the estimated result for future use. Another feature that aids the accuracy of the final result is the integrated compass sensor which automatically derives the orientation of each wall. This feature is peculiar to this software. The cooling load calculation was carried out within five minutes of using the software, thereby fulfilling the software's purpose of saving time and easing the cooling load calculation process.

Software Performance Evaluation

The software was tested on five different phones with different users and the feedback from those users were that they found the software easy to use. Although, the compass sensor did not work on the phones of two users out of five. This will be corrected in subsequent updates.

Figure 4: The software's result output interface showing the generated result for the estimation.

VI. Conclusions

Based on this study, the following conclusions can be drawn:

i. the CLTD/SCL/CLF Method is considered the most flexible, affordable and relatively accurate method, best suitable for software development
ii. an integrated method of estimating cooling load for equipment sizing which is peculiar to Nigeria and the West African region was designed
iii. a user-friendly software for cooling load estimation has been developed

If given more time and resources, the developed software can be improved upon to include data for estimations outside the scope of Nigeria. In addition, a length measurement feature can be added to further the ease of use.

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