Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Conceptual Design of a Nigeria-Calibrated Cooling-Load Estimation Tool for Air-Conditioning System Selection A Conceptual Framework Paper

Victor Ojo
victor.ojo05@outlook.com
Ogbomosho, Nigeria
Mechanical and Building Services Engineering
Heating, Ventilation and Air-Conditioning (HVAC) Design

ARTICLE INFO

Received: 01 Nov 2019
Revised: 17 Dec 2019
Accepted: 28 Dec 2019

ABSTRACT

Air-conditioning equipment in Nigerian residential and light commercial buildings is frequently selected using rule-of-thumb factors that relate room floor area to compressor horsepower. These factors were not derived from the local climate and do not separate the sensible and latent components of the cooling load. The result is recurring oversizing in some installations and undersizing in others, both of which reduce comfort, raise running cost, and shorten equipment life. This paper presents the conceptual design of a cooling-load estimation tool calibrated to Nigerian conditions. The proposed framework adapts the component heat-gain approach described in established engineering references to the design temperatures, humidity levels, construction practices, and use patterns common in Nigeria. It defines the user inputs, the climatic data required for each location, the calculation sequence at room and building level, and the logic that converts an estimated load into a recommended equipment capacity. Two illustrative case studies, a residential room in Lagos and an office space in Abuja, are worked manually to show how the framework produces a defensible capacity figure and how that figure compares with a rule-of-thumb selection. The paper does not report a completed software product. It sets out the conceptual basis, the algorithmic logic, the proposed user interface flow, and a development roadmap covering prototype construction, expansion of the climatic database to cover Nigerian states and cities, field testing with practitioners, and validation against the measured performance of installed systems. The framework is offered as a preliminary design that requires further testing before it can be recommended for routine practice.

Keywords: cooling load; air-conditioning; equipment selection; Nigeria; HVAC design; sensible and latent load; building energy.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

1. Introduction

1.1 Background to Air-Conditioning Load Estimation in Nigeria

Cooling-load estimation is the engineering step that determines how much heat must be removed from a space to keep it at a chosen indoor condition. The estimate accounts for heat that enters through the building fabric, heat carried in by outdoor air, and heat released inside the space by people, lighting, and equipment. Once the load is known, an air-conditioning unit of matching capacity can be selected (ASHRAE, 2017; McQuiston, Parker, and Spitler, 2005). In much of Nigeria the demand for cooling is high throughout the year because the climate is hot and, across large parts of the south, also humid. Air-conditioning has become one of the largest consumers of electricity in serviced residential and office buildings, which makes the accuracy of equipment selection a matter of both comfort and operating cost.

Despite this demand, formal load estimation is not yet common practice for small projects. Many installations in homes, shops, and small offices are sized from experience or from simple area-based factors. Where a calculation is performed, it often uses procedures and data developed for temperate climates, with little adjustment for Nigerian outdoor design conditions or local construction. A locally developed software framework for cooling-load estimation has been proposed in the Nigerian literature and shown to give results comparable with manual calculation (Sangotayo, Adedeji, and Oladepo, 2017). That work confirms both the need for, and the feasibility of, a calculation aid suited to the Nigerian setting.

1.2 Practical Problems in Residential and Light Commercial Cooling Design

In residential and light commercial work the designer usually has limited information and limited time. Drawings may be incomplete, the building may already be standing, and the client expects a quick recommendation. Under these conditions the technician tends to fall back on a remembered ratio between room size and unit capacity. The ratio takes no account of which way the room faces, whether it sits under an exposed roof, how many people use it, what equipment it contains, or how humid the outdoor air is. Two rooms of the same floor area can therefore have very different real loads, yet receive the same recommendation.

A further problem is that the latent load, that is the heat associated with moisture in the air, is rarely treated on its own. In humid coastal locations such as Lagos and Port Harcourt the latent component is a large share of the total, and an air-conditioner selected on sensible load alone may cool the air without removing enough moisture, leaving the space cool but damp. Separating sensible from latent load is a basic requirement of sound design (ASHRAE, 2017; Pita, 2002), but it is seldom done in everyday practice.

1.3 Limitations of Generic or Foreign-Condition-Based Calculation Tools

Several calculation methods and software products exist internationally. The heat balance and radiant time series methods documented by ASHRAE are accurate and well supported (Spitler, Fisher, and Pedersen, 1997; ASHRAE, 2017), but they require detailed hourly weather files, full construction data, and a level of input that is out of reach for a routine residential job. Simpler tools usually ship with weather data and default assumptions tied to the country of origin. When such a tool is applied in Nigeria without changing its design temperatures, humidity values, and construction defaults, the output can be misleading. The tool may also express results in units, equipment classes, or comfort targets that do not match the products and habits of the Nigerian market, where capacity is commonly described in horsepower.

What is missing is a method positioned between the detailed hourly methods and the bare rule of thumb. Such a method would use a transparent component calculation, would carry default values drawn from Nigerian conditions, and would present its output in terms a local technician can act on. The framework described in this paper is intended to fill that position.

1.4 Purpose of the Proposed Framework

The purpose of this paper is to set out the conceptual design of a Nigeria-calibrated cooling-load estimation tool for selecting air-conditioning equipment in residential and light commercial buildings. The paper defines the inputs the tool requires, the climatic data it draws on, the calculation sequence it follows, and the logic by which it turns a load into a recommended capacity. It demonstrates the method through worked examples and sets out a roadmap for turning the concept into a tested software product. The paper is a design proposal rather than a report on a finished system, and the framework is preliminary pending the testing described later.

2. Statement of the Problem

2.1 Over-Reliance on Rule-of-Thumb Cooling Selection

The most widely used selection method in Nigerian residential and small commercial practice is a rule of thumb that assigns a fixed unit capacity to a band of floor area, for example one horsepower for a room up to a given number of square metres. Rules of this kind are quick and need no calculation, which explains their popularity. Their weakness is that floor area is only one of several quantities that determine the load. A rule based on area alone cannot respond to roof exposure, glazing area and orientation, occupant density, internal equipment, or the humidity of the outdoor air. As a result the same recommendation is given for spaces whose true loads differ widely, and the error is hidden because the unit, once installed, will run regardless of whether it is correctly sized.

2.2 Inconsistent Treatment of Nigerian Climatic Conditions

Nigeria spans several climatic zones, from the hot and humid coast in the south to the hot and dry north, with a transitional band and a higher, milder area on the Jos Plateau (Ogunsote and Prucnal-Ogunsote, 2002). The outdoor design temperature, the coincident humidity, and the balance between sensible and latent load differ markedly across these zones. A calculation that uses a single national design condition, or that borrows design data from another country, will misstate the load in most locations. Coastal humidity in particular is often ignored, even though it drives a large latent load that the equipment must handle. Consistent, location-specific treatment of climate is therefore a requirement for any tool intended for national use.

2.3 Risk of Oversizing and Undersizing Air-Conditioning Equipment

Both oversizing and undersizing carry penalties. An oversized unit reaches the thermostat set point quickly and then switches off, so it runs in short cycles. Short cycling reduces the time available for moisture removal, which leaves the space humid, and it increases wear from frequent starting. It also raises the purchase cost without delivering better comfort. An undersized unit runs for long periods without reaching the set point, so it fails to hold the indoor condition on hot afternoons, consumes energy continuously, and is stressed by long operation. The aim of estimation is to place the selected capacity close to the real peak load, with a modest margin, so that the unit cycles normally and controls both temperature and humidity.

2.4 Need for a Locally Adapted Estimation Method

The problems above point to a single need: a calculation method that is simple enough for routine use, accurate enough to separate the main load components, and calibrated to Nigerian climate and construction. The detailed hourly methods are accurate but too demanding for small jobs, while the rule

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

of thumb is convenient but too coarse. A locally adapted component method, supported by a database of Nigerian design conditions and presented through a clear tool, would give practitioners a practical middle path. Defining such a method is the task of this paper.

3. Aim and Objectives

3.1 Aim of the Study

The aim of this study is to develop the conceptual design of a cooling-load estimation tool, calibrated to Nigerian conditions, that supports the selection of air-conditioning equipment for residential and light commercial buildings.

3.2 Specific Objectives

The specific objectives are:

1. To review the established principles of cooling-load estimation and identify the components that matter most under Nigerian conditions.
2. To define the user inputs, climatic data, and default assumptions required by a locally calibrated estimation tool.
3. To set out the algorithmic logic by which the tool calculates load at room and building level and converts that load into a recommended equipment capacity.
4. To demonstrate the framework through worked case studies and to compare its output with rule-of-thumb selection.
5. To propose a development roadmap covering prototyping, database expansion, field testing, and validation.

3.3 Scope of the Proposed Tool

The proposed tool addresses peak design cooling load for the purpose of equipment selection. It is intended for single rooms and small multi-room buildings of the type found in residential and light commercial use, where construction is typically sandcrete block walls, concrete or sheet roofing, and single glazing. It is not intended for annual energy simulation, for large or complex commercial buildings, or for detailed duct and plant design, all of which call for the fuller hourly methods. The tool estimates load and recommends capacity; it does not select refrigerant circuits, design air distribution, or size piping.

3.4 Expected Practical Application

The expected users are HVAC technicians, building services engineers, contractors, and informed building owners. In practice the tool would be used at the point of sizing a split unit or a small group of units, replacing or checking a rule-of-thumb decision. By making the main load components visible, it would also serve as a teaching aid, helping users see why a particular room needs more or less capacity than its floor area alone would suggest.

4. Review of Cooling-Load Estimation Principles

4.1 Heat Gain in Buildings

Heat gain is the rate at which heat enters or is generated within a space. It is useful to distinguish heat gain from cooling load. Heat gain is the instantaneous rate at which heat reaches the space, while cooling load is the rate at which heat must be removed to hold the indoor condition. The two differ because part of the heat gain, especially the radiant part, is first absorbed by the building mass and released later, so the load lags the gain (ASHRAE, 2017; Threlkeld, 1970). For peak selection in lightweight construction this lag is modest, and simplified methods represent it with stored factors rather than an hour-by-hour balance.

External heat gains arise from conduction through walls, roof, and glazing driven by the temperature difference between outside and inside, and from solar radiation passing through glazing and warming opaque surfaces. Internal heat gains arise from occupants, lighting, and equipment. Air exchange with the outside, through deliberate ventilation and through infiltration, adds a further gain that has both a temperature and a moisture component.

4.2 Sensible and Latent Cooling Loads

The total cooling load is the sum of a sensible part and a latent part. The sensible load is associated with a change in air temperature and comes from conduction, solar gain, occupants, lighting, equipment, and the temperature difference of incoming outdoor air. The latent load is associated with a change in air moisture content and comes from the moisture given off by occupants and from the moisture carried in by outdoor air (ASHRAE, 2017; Pita, 2002). The ratio of sensible to total load, often called the sensible heat ratio, guides the choice of equipment, because a space with a high latent share needs a unit able to remove moisture as well as lower temperature. In humid Nigerian locations the latent share is significant and must be estimated explicitly rather than absorbed into a single total.

4.3 Occupancy, Lighting, Equipment, and Ventilation Loads

Occupants release both sensible and latent heat, and the split depends on activity and on the indoor temperature. Standard tables give heat-emission values for various activities (ASHRAE, 2017). Lighting contributes sensible heat equal, in steady operation, to the installed electrical power serving the space. Equipment such as televisions, computers, refrigerators, and kitchen appliances contributes sensible heat, and certain appliances also add latent heat. Ventilation is the deliberate supply of outdoor air for indoor air quality; the quantity for commercial spaces is guided by recognised standards (ASHRAE, 2016). The outdoor air must be cooled and, in humid conditions, dehumidified, so it adds to both the sensible and latent load.

4.4 Solar Radiation and Building Envelope Effects

Solar radiation affects the load in two ways. Radiation transmitted through glazing enters the space directly and becomes a gain that depends on the glass area, its orientation, the time of day, and any shading. Radiation absorbed by opaque surfaces raises their temperature above the air temperature, increasing the conducted gain; this effect is represented by the sol-air temperature or by tabulated temperature-difference values that combine conduction and absorbed solar effects (ASHRAE, 2017; McQuiston, Parker, and Spitler, 2005). The thermal properties of the envelope, the conductance of walls and roof and the shading coefficient of glazing, therefore have a direct effect on the load. In typical Nigerian construction the roof is often the largest single external gain because it receives the most intense radiation and is frequently uninsulated.

4.5 Climatic Variables Relevant to Nigerian Locations

The climatic variables that enter a cooling-load estimate are the outdoor design dry-bulb temperature, the coincident outdoor humidity expressed as wet-bulb temperature or moisture content, and the solar radiation appropriate to the latitude and orientation. Design values are chosen so that the indoor condition is held for all but a small fraction of the hottest hours, rather than for an absolute extreme, so that equipment is not sized for a rare event (ASHRAE, 2017). For Nigeria these values vary by zone. Coastal and southern locations combine a moderate dry-bulb temperature with high humidity, the far

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

north combines a very high dry-bulb temperature with low humidity, and the plateau is milder than both (Ogunsote and Prucnal-Ogunsote, 2002). A national tool must hold a design condition for each location it serves.

4.6 Existing Cooling-Load Calculation Methods

Several methods of differing complexity exist. The heat balance method solves an energy balance at each surface and in the air for every hour and is the reference method for accuracy. The radiant time series method is a simplified, non-iterative form of the heat balance approach that is well suited to peak design load calculation (Spitler, Fisher, and Pedersen, 1997; ASHRAE, 2017). Earlier tabular methods, such as those based on cooling-load temperature differences and cooling-load factors, combine conduction, solar, and storage effects into stored values that can be applied with a calculator or spreadsheet (McQuiston, Parker, and Spitler, 2005; Carrier, 1965). For the conceptual tool proposed here, a transparent component method in the tradition of these tabular approaches is the appropriate basis, because it captures the main physics while remaining simple enough for routine use and easy to calibrate with Nigerian data.

5. Proposed Nigeria-Calibrated Cooling-Load Framework

5.1 Conceptual Basis of the Framework

The framework rests on a component heat-gain method. The cooling load of a space is built up as the sum of separate gains, each calculated from a few inputs and a calibrated coefficient, and reported as a sensible part and a latent part. For a space the total sensible load is the sum of the conducted gain through walls, roof, and glazing, the solar gain through glazing, and the sensible gains from occupants, lighting, equipment, infiltration, and ventilation. The total latent load is the sum of the latent gains from occupants, infiltration, and ventilation. The method is expressed compactly as follows.

Qsensible = (U·A·CLTD) for walls and roof + (U·A·ΔT) for glazing + (A·SC·SHGF·CLF) for solar + Qpeople,s + Qlights + Qequip + Qinf,s + Qvent,s

Qlatent = Qpeople,l + Qinf,l + Qvent,l

Here U is the surface conductance, A is the area, CLTD is a cooling-load temperature difference that combines the temperature difference with absorbed solar and storage effects, ΔT is the outdoor-to-indoor temperature difference, SC is the shading coefficient of the glazing, SHGF is the solar heat-gain factor for the orientation and latitude, and CLF is a cooling-load factor. The calibration to Nigeria enters through the design temperatures, the solar factors appropriate to low latitude, the default conductances of local construction, and the humidity values used for the latent terms. The method follows the tradition of the tabular procedures (McQuiston, Parker, and Spitler, 2005; Carrier, 1965) while drawing its coefficients from conditions found in Nigeria.

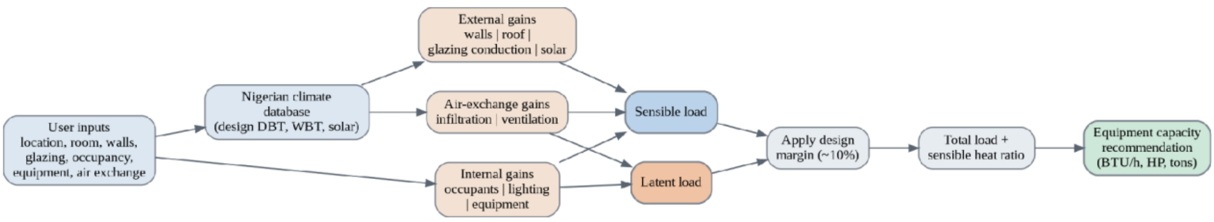

Figure 1. Conceptual structure of the component heat-gain framework, from user inputs and climate data through the sensible and latent components to the recommended equipment capacity.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

5.2 Required User Inputs

The tool asks the user for the minimum information needed to evaluate the components. The inputs are grouped so that a user can complete them quickly for a single room.

- Location, selected from a list of Nigerian cities, which sets the design climate.
- Space use, residential or one of a small number of commercial categories, which sets default occupancy and equipment values.
- Room dimensions: length, width, and height.
- Whether the space is on the top floor or has an exposed roof above it.
- For each external wall, its area and orientation, and the area of glazing in it.
- Glazing type and the presence of internal or external shading.
- Number of occupants, or acceptance of a default based on use and area.
- Installed lighting and major equipment, or acceptance of default densities.
- Indoor design condition, with a recommended default offered.

5.3 Climatic Data Inputs by Nigerian Location

For each location the tool holds an outdoor design dry-bulb temperature, a coincident wet-bulb temperature or moisture content, and the solar factors needed for the glazing calculation. These values are stored in a database that the user does not edit during normal use; selecting a city loads the correct set. The design values are chosen at a percentile that holds the indoor condition for all but a small fraction of the hottest hours, in keeping with standard practice (ASHRAE, 2017). A preliminary set of representative values for selected cities is given in Appendix C; these are illustrative and are to be refined during development using local meteorological records.

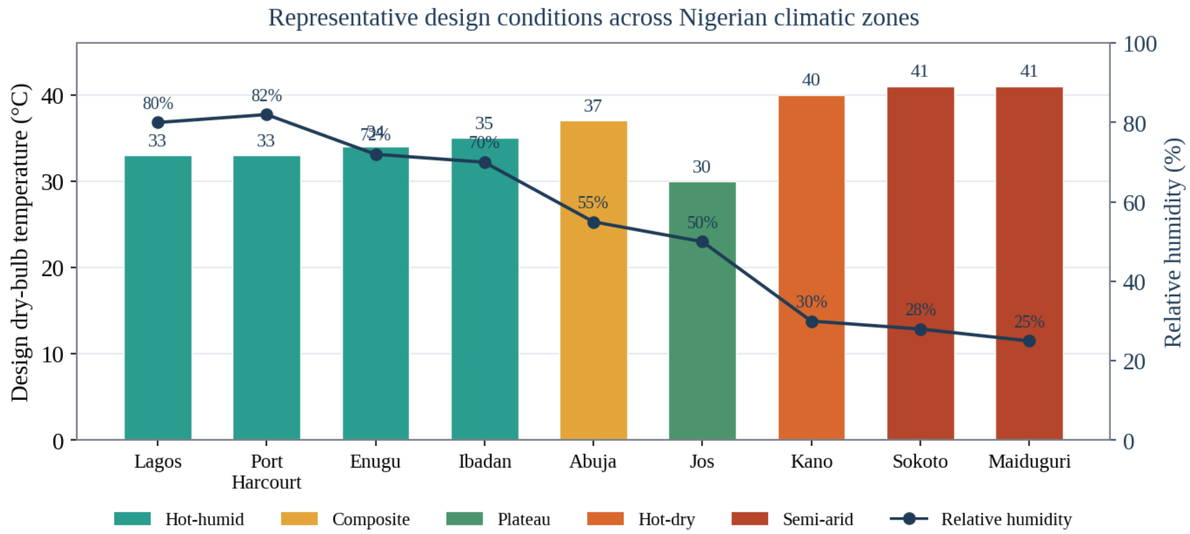

Figure 2. Representative outdoor design conditions for selected Nigerian cities, showing the spread of design dry-bulb temperature and relative humidity across the climatic zones. Values are illustrative and pending validation.

5.4 Building and Room Characteristics

The tool represents the space through its surfaces. Each wall is described by its area, its orientation, and its glazing. The roof, where exposed, is described by its area. Default conductances are assigned to each surface type from a small library of common Nigerian constructions, for example a plastered sandcrete block wall, a concrete roof slab, and a roof of metal or asbestos-cement sheet with a ceiling beneath. The user may accept these defaults or enter a known value. Glazing is described by its area and a shading coefficient that reflects the glass type and any curtains or blinds.

5.5 Occupancy and Internal Heat-Gain Assumptions

Occupant heat emission is taken from standard values for the activity associated with the space, split into sensible and latent parts (ASHRAE, 2017). For a residential bedroom or living room a seated or light-activity value is used; for an office a similar light-activity value applies. Lighting gain is set from an installed power density for the use type, and equipment gain from a default density that can be overridden where major appliances are known. The defaults are chosen to reflect equipment typical of Nigerian homes and small offices, and they are exposed to the user so that they can be adjusted.

5.6 Ventilation and Infiltration Assumptions

Infiltration is the uncontrolled entry of outdoor air through gaps and openings. It is estimated from the room volume and an air-change rate chosen for the construction quality, with louvered or poorly sealed windows assigned a higher rate than well-fitted casements. Ventilation is the deliberate supply of outdoor air; for residential spaces served by recirculating split units it is often taken as zero and the infiltration term carries the fresh-air effect, while for commercial spaces a ventilation rate is taken from a recognised standard according to occupancy and floor area (ASHRAE, 2016). Both terms contribute sensible load through the temperature difference and latent load through the moisture difference, and in humid locations the latter is large.

5.7 Safety Factors and Practical Design Margins

A modest margin is added to the calculated load to allow for inputs that cannot be known exactly and for future increases in internal gain. A margin of about ten per cent is typical and is large enough to cover ordinary uncertainty without leading to oversizing. The tool applies the margin after the component sum and reports both the calculated load and the load after margin, so that the basis of the recommendation is visible. The framework deliberately keeps the margin small, because a generous margin reproduces the oversizing problem that the method is meant to avoid.

5.8 Output Parameters for Equipment Selection

The tool reports the total sensible load, the total latent load, the total load, and the sensible heat ratio, each in watts and in the units commonly used for equipment in Nigeria, that is British thermal units per hour and refrigeration tons or compressor horsepower. It then recommends a unit or combination of units whose capacity matches the load after margin, and it notes the sensible heat ratio so that, where the latent share is high, a unit with strong dehumidification can be chosen. Where the load exceeds the capacity of a single common unit, the tool proposes a split into two or more units.

6. Algorithmic Logic of the Proposed Tool

6.1 Data Input Structure

Inputs are organised in a nested structure. At the top level is the project, which holds the selected location and therefore the design climate. Within the project are one or more rooms. Each room holds its dimensions, its roof exposure flag, a list of walls, a list of internal gains, and its air-exchange settings. Each wall holds its area, orientation, conductance, and glazing. Holding the data in this way lets the tool calculate each room independently and then combine rooms into a building total. The structure also makes validation straightforward, because each field has a known type and an allowed range.

6.2 Cooling-Load Calculation Sequence

The calculation proceeds in a fixed order for each room. First the tool loads the design climate for the project location. Second it evaluates the conducted gains through each wall, the roof, and the glazing, using the conductance, area, and the appropriate temperature-difference value. Third it evaluates the solar gain through each glazed area from its area, shading coefficient, solar heat-gain factor, and cooling-load factor. Fourth it evaluates the internal gains from occupants, lighting, and equipment, separating sensible from latent. Fifth it evaluates the infiltration and ventilation gains, again separating sensible from latent. Sixth it sums the sensible and latent components, applies the design margin, and forms the totals and the sensible heat ratio. Seventh it passes the totals to the equipment-selection step.

6.3 Room-Level Calculation Method

Each component is computed from a simple expression. Conducted gain through an opaque surface is the product of conductance, area, and the cooling-load temperature difference for that surface and orientation. Conducted gain through glazing uses the plain temperature difference. Solar gain through glazing is the product of area, shading coefficient, solar heat-gain factor, and cooling-load factor. Occupant gain is the number of people multiplied by the sensible and latent emission values for the activity. Lighting and equipment gains are the installed or default power densities multiplied by the floor area, taken as sensible. Infiltration and ventilation sensible gains are proportional to the air-flow rate and the temperature difference, and the latent gains are proportional to the air-flow rate and the moisture difference. The room sensible and latent loads are the sums of the respective components.

6.4 Building-Level Aggregation

For a building of several rooms the tool sums the room loads to a building total. Because the rooms in a small building usually reach their peaks at similar times under the same design day, the framework sums the room peaks directly rather than searching for a diversified coincident peak, which keeps the method simple and slightly conservative. The building total is used where a central or multi-zone system is contemplated, while the individual room loads are used where each room is served by its own unit, which is the common arrangement for split systems in Nigeria.

6.5 Equipment-Capacity Recommendation Logic

The selection step compares the load after margin with the capacities of common units. Capacities are held in the units used in the market, and the tool selects the smallest standard capacity that meets or slightly exceeds the load. Where the load lies between two standard sizes, the tool reports both and indicates the trade-off, so that the user can decide whether to round up for a margin or down to avoid short cycling. Where the load exceeds the largest single unit suited to the space, the tool proposes two or more units and divides the load between them. The sensible heat ratio is reported alongside the recommendation so that equipment with adequate dehumidification can be chosen for humid locations.

6.6 Error Checking and Input Validation

The tool checks inputs before and during calculation. Dimensions, areas, and counts must be positive, glazing area cannot exceed the wall that contains it, and the sum of wall areas should be consistent with the room dimensions within a tolerance. Orientations must be drawn from the allowed set, and the selected location must exist in the climate database. Where an input is missing, the tool offers the relevant default and marks that the value was assumed. If a result falls outside a plausible range, for example a load per unit area far above or below typical values, the tool warns the user and points to the inputs most likely responsible. These checks reduce the chance that a slip in data entry passes unnoticed into the recommendation.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

6.7 Proposed User Interface Flow

The interface guides the user through the inputs in the order of the calculation. The user first selects the project location, then adds a room and enters its dimensions and roof exposure, then adds each wall with its orientation and glazing, then sets or accepts the internal-gain and air-exchange values. As inputs are entered the tool shows a running estimate, so the effect of each input is visible. On completion the tool presents a result screen with the sensible, latent, and total loads, the sensible heat ratio, and the recommended capacity, together with a short breakdown of the components and any warnings. The user can then adjust an input and see the result update, which supports quick comparison of design options. A flowchart of this process is given in Appendix D.

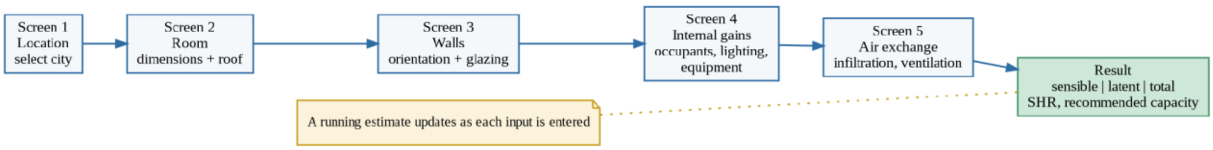

Figure 3. Proposed user interface flow. The user moves through location, room, walls, internal gains, and air exchange, with a running estimate that updates as inputs are entered, before reaching the result screen.

7. Illustrative Case Study

This section applies the framework to two spaces, a residential room in Lagos and an office in Abuja. The calculations are carried out by hand to show the method clearly. The design conditions are taken from the preliminary values in Appendix C. The coefficients used, such as the cooling-load temperature differences and the solar factors, are representative values chosen to illustrate the procedure and would be refined during development.

7.1 Sample Residential Room in Lagos

The room is a top-floor bedroom measuring 4.0 m by 3.5 m with a height of 3.0 m, giving a floor area of 14 square metres and a volume of 42 cubic metres. One external wall faces west and measures 4.0 m by 3.0 m, and it contains a window of 1.5 square metres, leaving a net wall area of 10.5 square metres. The roof is exposed above the room. The room is used by two people. Lighting is taken as 140 watts and equipment as 300 watts. The outdoor design condition for Lagos is taken as 33 degrees Celsius dry-bulb with high humidity, and the indoor design condition as 24 degrees Celsius, giving a temperature difference of about 10 kelvin after allowance for the daily range. Infiltration is taken at one air change per hour.

7.2 Sample Office Space in Abuja

The office is a top-floor open space measuring 8.0 m by 6.0 m with a height of 3.0 m, giving a floor area of 48 square metres and a volume of 144 cubic metres. Two external walls are exposed, with a combined gross area of 42 square metres and glazing of 6 square metres, leaving 36 square metres of net wall. The roof is exposed. The office is used by six people, with lighting of 576 watts and equipment, mainly computers, of 1,100 watts. The outdoor design condition for Abuja is taken as 37 degrees Celsius dry-bulb with moderate humidity, and the indoor design condition as 24 degrees Celsius, giving a temperature difference of about 13 kelvin. Infiltration is taken at half an air change per hour and a ventilation supply of 30 litres per second is provided for the occupants.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

7.3 Manual Calculation Demonstration

The two spaces are evaluated component by component. The results are shown in the tables below, with sensible and latent loads kept separate. Conducted gains use the product of conductance, area, and the temperature-difference value; solar gain uses the product of glazing area, shading coefficient, solar heat-gain factor, and cooling-load factor; air-exchange gains use the air-flow rate with the temperature difference for the sensible part and the moisture difference for the latent part.

Table 1. Component cooling load for the Lagos residential room.

Component	Basis	Sensible (W)	Latent (W)
West wall	U 2.3 x 10.5 m2 x CLTD 16 K	386	-
Roof	U 1.8 x 14 m2 x CLTD 32 K	806	-
Glazing, conduction	U 5.7 x 1.5 m2 x CLTD 8 K	68	-
Glazing, solar	1.5 m2 x SC 0.6 x SHGF 600 x CLF 0.7	380	-
Occupants (2)	Sensible 65 W, latent 55 W each	130	110
Lighting	Installed power	140	-
Equipment	Installed power	300	-
Infiltration	11.7 L/s, dT 10 K, dw 11.7 g/kg	144	410
Subtotal		2,354	520
Total (before margin)	Sensible + latent	2,874	
Total after 10% margin		3,161 W (10,785 BTU/h)	

Sensible heat ratio is about 0.82. The load after margin is about 3.16 kW, or roughly 0.90 refrigeration tons.

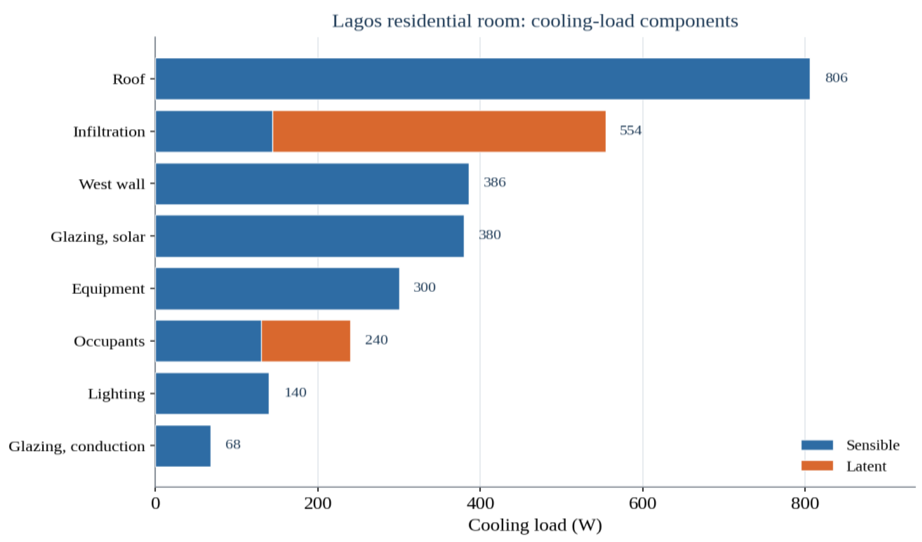

Figure 4. Component cooling load for the Lagos residential room. The exposed roof and the air-exchange term, the latter carrying a large latent share, dominate the load.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Table 2. Component cooling load for the Abuja office.

Component	Basis	Sensible (W)	Latent (W)
External walls	U 2.3 x 36 m2 x CLTD 18 K	1,490	-
Roof	U 1.8 x 48 m2 x CLTD 34 K	2,938	-
Glazing, conduction	U 5.7 x 6 m2 x CLTD 11 K	376	-
Glazing, solar	6 m2 x SC 0.5 x SHGF 600 x CLF 0.7	1,260	-
Occupants (6)	Sensible 75 W, latent 55 W each	450	330
Lighting	Installed power	576	-
Equipment	Computers and misc.	1,100	-
Infiltration	20 L/s, dT 13 K, dw 6 g/kg	320	360
Ventilation	30 L/s, dT 13 K, dw 6 g/kg	480	540
Subtotal		8,990	1,230
Total (before margin)	Sensible + latent	10,220	
Total after 10% margin		11,242 W (38,357 BTU/h)	

Sensible heat ratio is about 0.88. The load after margin is about 11.24 kW, or roughly 3.2 refrigeration tons.

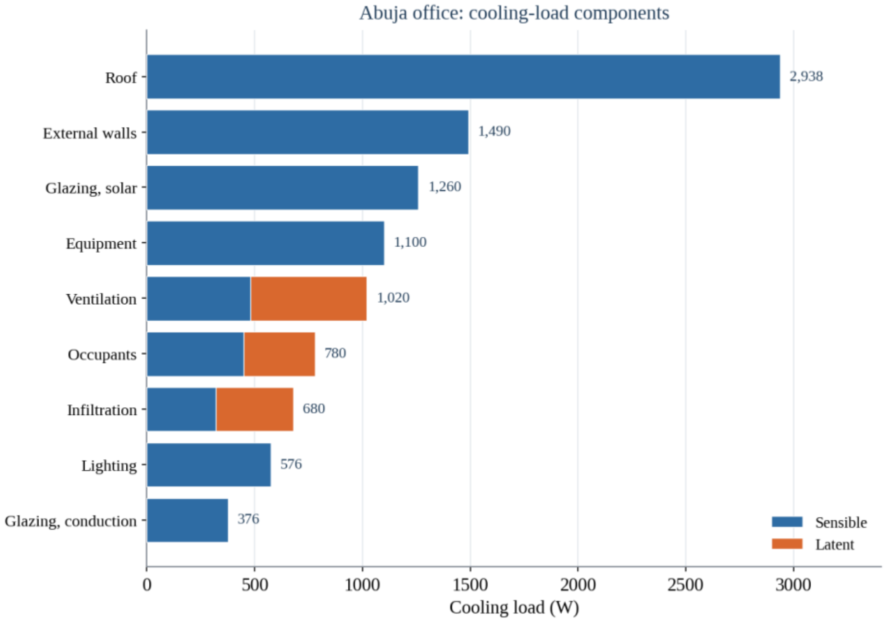

Figure 5. Component cooling load for the Abuja office. The roof again dominates, while ventilation for the occupants adds both sensible and latent load.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

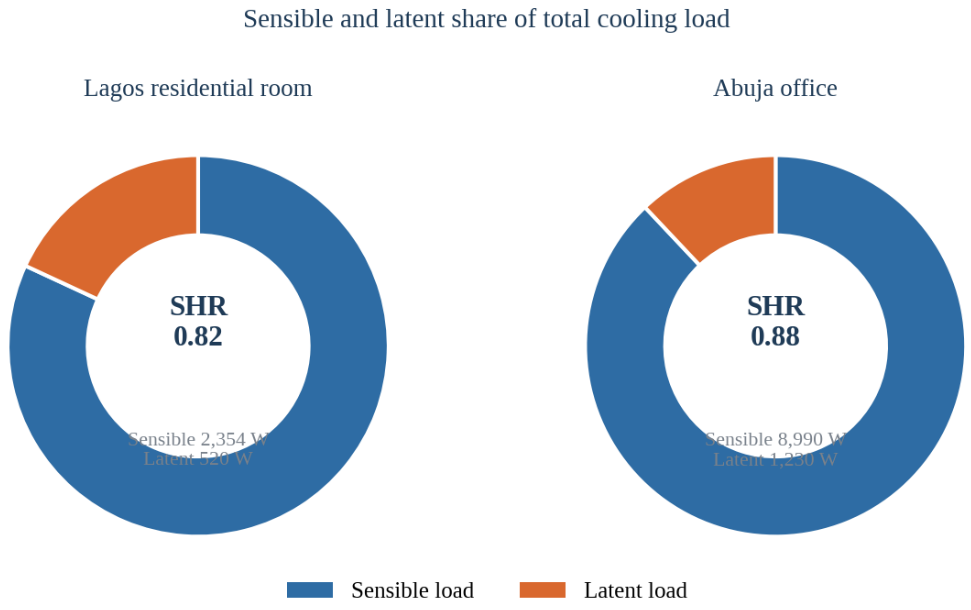

Figure 6. Sensible and latent share of the total load for the two spaces. The Lagos room carries the larger latent share, which calls for attention to dehumidification.

7.4 Proposed Tool Output Format

For the Lagos room the tool would report a sensible load of about 2.35 kilowatts, a latent load of about 0.52 kilowatts, a total after margin of about 3.16 kilowatts, and a sensible heat ratio of about 0.82. It would recommend a single split unit of about 12,000 British thermal units per hour, that is a unit of about one and a half horsepower in local terms, and would note that the relatively high latent share calls for adequate dehumidification. For the Abuja office the tool would report a sensible load of about 8.99 kilowatts, a latent load of about 1.23 kilowatts, a total after margin of about 11.24 kilowatts, and a sensible heat ratio of about 0.88. It would recommend a capacity of about 38,400 British thermal units per hour, met either by a single floor-standing unit of about four horsepower or by two wall units of about two horsepower each. A template for this output is given in Appendix E.

7.5 Comparison with Rule-of-Thumb Selection

A common rule of thumb in Nigerian residential practice assigns about one horsepower, near 9,000 British thermal units per hour, to a bedroom of this size. The component calculation gives about 10,800 British thermal units per hour after margin, which points to a one and a half horsepower unit. The rule of thumb would therefore undersize this room, mainly because it ignores the exposed roof and the west-facing glazing, which together contribute a large share of the sensible load. For the office, a rule of thumb of about one refrigeration ton for every ten square metres would give about 4.8 tons, near 57,600 British thermal units per hour, against the calculated 3.2 tons. Here the rule of thumb would oversize the office by roughly half. The two cases show that area-based rules can err in either direction, and that the direction of the error depends on factors the rule does not see.

Table 3. Calculated capacity against rule-of-thumb selection.

Space	Calculated (after margin)	Rule of thumb	Outcome of rule
Lagos bedroom	~10,800 BTU/h (1.5 HP)	~9,000 BTU/h (1 HP)	Undersized
Abuja office	~38,400 BTU/h (3.2 tons)	~57,600 BTU/h (4.8 tons)	Oversized

The component method places capacity closer to the real load in both cases.

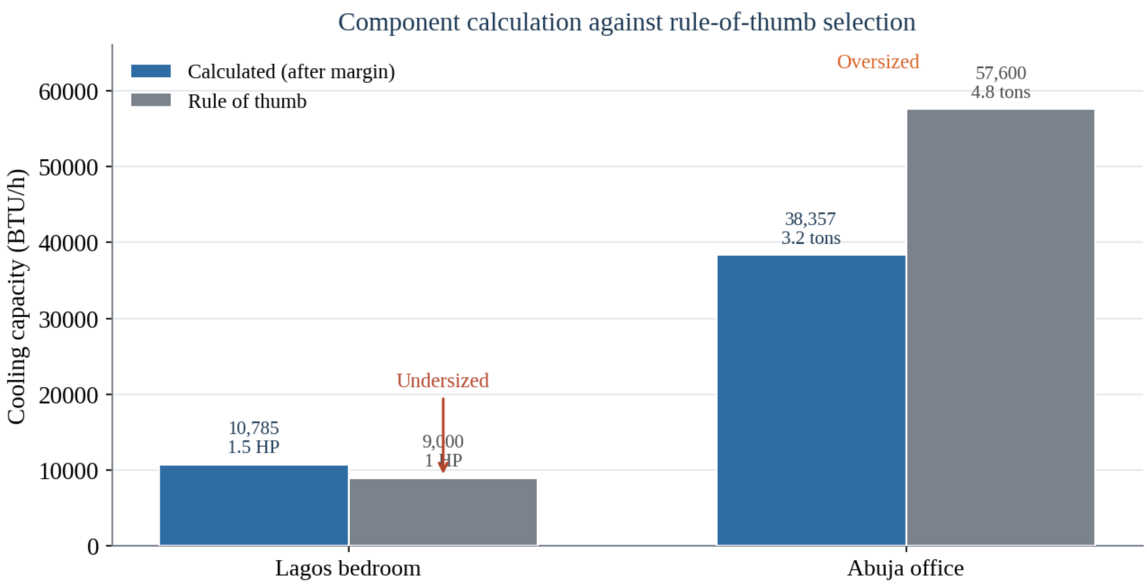

Figure 7. Calculated capacity against rule-of-thumb selection. The rule of thumb undersizes the Lagos room and oversizes the Abuja office, showing that area-based rules can err in either direction.

8. Discussion

8.1 Expected Benefits for Nigerian HVAC Practice

The framework offers a way to size equipment that is more reliable than a rule of thumb yet far quicker than a full hourly simulation. By separating the load into its components, it makes clear which features of a space drive its cooling demand, and it lets a designer test the effect of, for example, shading a window or insulating a roof. Because the climatic data and construction defaults are drawn from Nigerian conditions, the results are appropriate to the local setting rather than borrowed from a different climate. A locally developed estimation aid of this kind has already been shown to be workable (Sangotayo, Adedeji, and Oladepo, 2017), and the present framework extends that idea with explicit treatment of latent load and a structured selection logic.

8.2 Potential Reduction in Inaccurate Equipment Selection

The case studies suggest that the method can correct both undersizing and oversizing. Correcting undersizing improves comfort on hot afternoons and prevents the continuous running that wears equipment. Correcting oversizing reduces purchase cost and avoids the short cycling that leaves humid spaces uncomfortable. In humid locations the explicit latent estimate is particularly useful, because it draws attention to spaces where dehumidification, not just temperature reduction, governs comfort.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Over many installations, more accurate sizing would be expected to lower both energy use and the rate of comfort complaints, although confirming this requires the field study set out in the roadmap.

8.3 Value for Technicians, Engineers, and Building Owners

For technicians the tool offers a structured method that does not demand specialist software or detailed weather files. For engineers it offers a transparent estimate that can be checked and, where needed, taken as a starting point for a fuller analysis. For building owners it offers a basis for understanding why a particular capacity is recommended and for comparing options before committing to a purchase. The shared, visible breakdown of the load gives all three parties a common reference, which can reduce disputes over sizing.

8.4 Limitations of the Preliminary Framework

The framework is preliminary and has clear limits. The coefficients used in the worked examples are representative rather than measured, and the climatic data in Appendix C are illustrative pending compilation from records. The simplified component method does not capture the full time behaviour of heavy construction and is intended for the lightweight buildings common in the residential and light commercial sectors. The direct summation of room peaks ignores diversity and is slightly conservative for multi-room buildings. The method addresses load and capacity only, and does not design air distribution, refrigerant circuits, or controls. These limits are acceptable for a conceptual design but must be kept in view when interpreting results.

8.5 Areas Requiring Further Testing and Validation

Several questions must be settled before the tool can be recommended for routine use. The design temperatures and humidity values for each location need to be derived from local meteorological records at an agreed percentile. The default conductances for Nigerian constructions need to be confirmed by measurement or from a reliable local source. The cooling-load temperature differences and solar factors used in the simplified method need to be checked against a detailed reference method for representative cases. Finally, the recommendations need to be compared with the measured performance of installed systems, so that the margin and the selection logic can be tuned. These tasks form the core of the development roadmap.

9. Proposed Development Roadmap

The framework moves from concept to tested tool in five stages. Each stage produces a result that can be checked before the next begins, so that confidence is built step by step. The stages are summarised below and then described in turn.

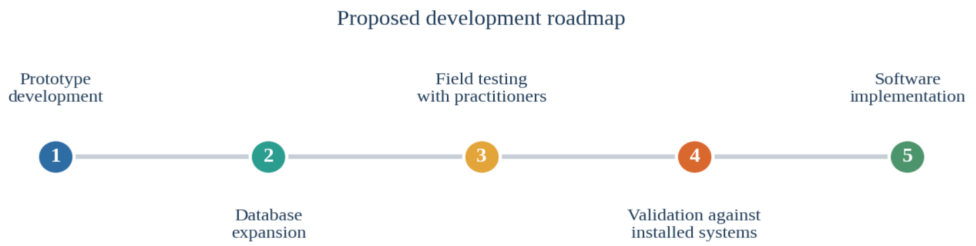

Figure 8. Proposed development roadmap, from a working prototype through database expansion, field testing, and validation to a finished software implementation.

9.1 Prototype Development

The first stage is to build a working prototype that implements the component method, the input structure, the validation rules, and the selection logic for a single location. The prototype would be developed as a simple application, with the climatic data and coefficient tables held separately from the calculation code so that they can be revised without changing the program. The prototype allows the method to be exercised on real rooms and its outputs examined for plausibility.

9.2 Database Expansion for Nigerian States and Cities

The second stage is to compile a climatic database covering the states and major cities of Nigeria. For each location the database would hold the outdoor design dry-bulb temperature, the coincident humidity, and the solar factors, derived from meteorological records at an agreed design percentile and organised by climatic zone (Ogunsote and Prucnal-Ogunsote, 2002). This database is what allows the tool to give location-specific results across the country.

9.3 Field Testing with HVAC Practitioners

The third stage is to place the prototype with practising technicians and engineers and to observe its use on real projects. Field testing would show whether the inputs are easy to gather on site, whether the defaults are appropriate, and whether the output is understood and acted on. Feedback from this stage would guide changes to the interface and the defaults.

9.4 Validation Against Installed System Performance

The fourth stage is to compare the recommended capacities with the measured performance of installed systems in a sample of buildings. Where indoor conditions, run-time, and energy use are recorded, the adequacy of the sizing can be judged directly, and any systematic tendency to over or undersize can be corrected by adjusting the margin or the coefficients. Validation against measured performance is the step that turns a plausible method into a trusted one.

9.5 Future Software Implementation

The final stage is to develop the validated method into a finished software tool suitable for wide use, whether as a mobile application, a desktop program, or a web service. At this stage attention would turn to a clear interface, reliable storage of projects, and ease of updating the climatic database as longer records become available. The staged roadmap keeps each step modest and testable, so that the tool earns confidence before it is relied on in practice.

10. Conclusion

This paper has set out the conceptual design of a cooling-load estimation tool calibrated to Nigerian conditions for the selection of air-conditioning equipment in residential and light commercial buildings. It identified the weaknesses of rule-of-thumb sizing and of foreign-condition tools, and it proposed a transparent component method that separates sensible and latent load, draws its data and defaults from Nigerian climate and construction, and converts an estimated load into a recommended capacity expressed in the units used in the local market. Two worked case studies showed how the method produces a defensible figure and how that figure can differ from a rule-of-thumb selection in either direction. The paper also set out the algorithmic logic, the proposed interface flow, and a development roadmap covering prototyping, database expansion, field testing, and validation. The framework is preliminary and requires the testing described before it can be recommended for routine practice, but it offers a practical path toward more accurate and locally appropriate cooling-load estimation in Nigeria.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

References

[1] ASHRAE. (2016). ANSI/ASHRAE Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.
[2] ASHRAE. (2017). 2017 ASHRAE Handbook: Fundamentals (SI Edition). Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.
[3] Carrier Air Conditioning Company. (1965). Handbook of Air Conditioning System Design. New York: McGraw-Hill.
[4] Chartered Institution of Building Services Engineers (CIBSE). (2015). CIBSE Guide A: Environmental Design (8th ed.). London: CIBSE.
[5] International Organization for Standardization (ISO). (2005). ISO 7730:2005. Ergonomics of the Thermal Environment: Analytical Determination and Interpretation of Thermal Comfort. Geneva: ISO.
[6] McQuiston, F. C., Parker, J. D., and Spitler, J. D. (2005). Heating, Ventilating, and Air Conditioning: Analysis and Design (6th ed.). Hoboken, NJ: John Wiley and Sons.
[7] Ogunsote, O. O., and Prucnal-Ogunsote, B. (2002). Defining climatic zones for architectural design in Nigeria: A systematic delineation. Journal of Environmental Technology, 1(2), 1-14.
[8] Pita, E. G. (2002). Air Conditioning Principles and Systems: An Energy Approach (4th ed.). Upper Saddle River, NJ: Prentice Hall.
[9] Sangotayo, E. O., Adedeji, K. A., and Oladepo, A. (2017). Development of a system framework that estimate cooling loads for air-conditioning system for residential and non-residential buildings. Innovative Systems Design and Engineering, 8(3), 11-18.
[10] Spitler, J. D., Fisher, D. E., and Pedersen, C. O. (1997). The radiant time series cooling load calculation procedure. ASHRAE Transactions, 103(2), 503-515.
[11] Stoecker, W. F., and Jones, J. W. (1982). Refrigeration and Air Conditioning (2nd ed.). New York: McGraw-Hill.
[12] Threlkeld, J. L. (1970). Thermal Environmental Engineering (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Appendices

Appendix A. Preliminary Cooling-Load Calculation Sheet

The sheet below organises a manual estimate for a single room. The user fills the input column for each component, applies the stated basis, and records the sensible and latent results. The subtotals are summed and the design margin applied to give the load used for selection.

Component	Calculation basis	Sensible (W)	Latent (W)
Walls	U x area x CLTD (per wall)		-
Roof	U x area x CLTD		-
Glazing, conduction	U x area x CLTD		-
Glazing, solar	area x SC x SHGF x CLF		-
Occupants	number x sensible and latent emission		
Lighting	installed power density x area		-
Equipment	installed power or default density		-

Component	Calculation basis	Sensible (W)	Latent (W)
Infiltration	1.23 x L/s x dT ; 3.0 x L/s x dw		
Ventilation	1.23 x L/s x dT ; 3.0 x L/s x dw		
Subtotals	sum of column		
Total before margin	sensible + latent		
Total after margin (10%)	x 1.10		
Recommended capacity	BTU/h and HP or tons		

Air-exchange formulas use flow in litres per second, temperature difference in kelvin, and moisture difference in grams per kilogram.

Appendix B. Proposed Input Fields for the Software Tool

Field	Type	Default or notes
Location	Selection from list	Sets design climate
Space use	Selection	Residential or commercial category
Length, width, height	Numbers (m)	Required
Exposed roof above	Yes or no	Default yes for top floor
Wall area and orientation	Number and selection	One entry per external wall
Glazing area	Number (m2)	Must not exceed wall area
Glazing type and shading	Selection	Sets shading coefficient
Wall and roof construction	Selection	Sets default conductance
Number of occupants	Number	Default from use and area
Lighting power	Number (W)	Default density by use
Equipment power	Number (W)	Default density by use
Indoor design condition	Number (deg C, %RH)	Default 24 deg C, 50% RH
Air-change rate	Selection or number	Default by construction quality
Design margin	Number (%)	Default 10%

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

Appendix C. Sample Climate Data Table for Selected Nigerian Cities

The values below are preliminary and illustrative. They are intended to show the form of the database and the spread of conditions across the climatic zones. Design values for the finished tool are to be derived from local meteorological records at an agreed design percentile.

City	Climatic zone	Design DBT (deg C)	Design WBT (deg C)	Design RH (%)
Lagos	Hot-humid, coastal	33	28	80
Port Harcourt	Hot-humid, coastal	33	28	82
Enugu	Hot-humid, inland	34	26	72
Ibadan	Hot-humid, transitional	35	26	70
Abuja	Hot, composite	37	24	55
Jos	Temperate, plateau	30	20	50
Kano	Hot-dry, savannah	40	22	30
Sokoto	Hot-dry, semi-arid	41	22	28
Maiduguri	Hot-dry, semi-arid	41	22	25

DBT is dry-bulb temperature, WBT is coincident wet-bulb temperature, and RH is relative humidity. Values are representative and pending validation.

Appendix D. Early Flowchart of the Calculation Process

The process flows from the selection of a location through component calculation to a capacity recommendation. Each step passes its result to the next. The validation step returns the user to the inputs when a check fails, and the result screen allows an input to be adjusted and the load recalculated.

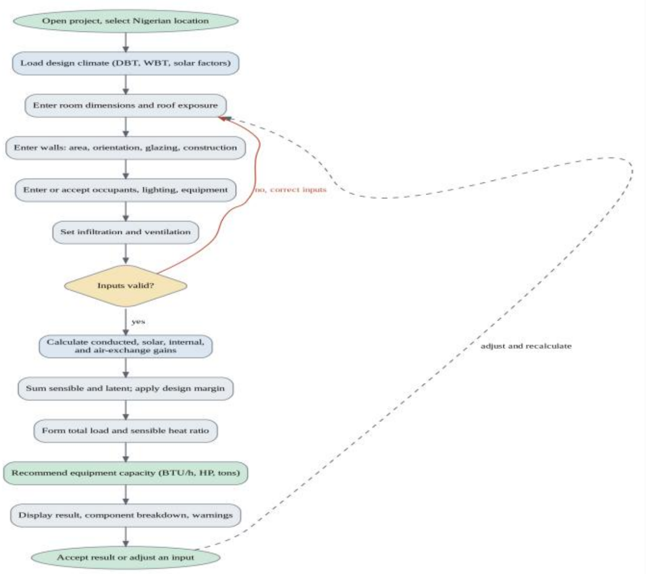

Figure 9. Flowchart of the proposed calculation process, from project setup and input entry through validation and component calculation to the equipment-capacity recommendation.

Journal of Information Systems Engineering and Management
2019, 4(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Appendix E. Sample Output Report Template

Field	Result
Project and location	(city, climatic zone)
Space	(name, use, floor area)
Design conditions	outdoor DBT and WBT; indoor deg C and %RH
Sensible load	kW and BTU/h
Latent load	kW and BTU/h
Total load before margin	kW and BTU/h
Design margin applied	%
Total load after margin	kW and BTU/h
Sensible heat ratio	value
Recommended capacity	BTU/h and HP or tons
Equipment note	single unit or split; dehumidification note
Component breakdown	walls, roof, glazing, internal, air exchange
Warnings	assumed defaults; out-of-range checks

The report records both the inputs and the basis of the recommendation, so that the sizing can be reviewed.