International Journal of Scientific Engineering and Science
Volume 10, Issue 9, pp. 75-81, September 2026. ISSN (Online): 2456-7361

Determination of Thermal Comfort in the Administrative Building of the Central Bank of Congo in Kinshasa

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***Abstract*—*Thermal comfort is a key factor in the quality of indoor environments, particularly in administrative buildings where occupants are exposed to thermal conditions that may affect their well-being, concentration, and work performance. This study aims to assess thermal comfort in the administrative building of the Central Bank of the Congo (BCC) in Kinshasa, based on environmental measurements and occupants' perceptions. The analysis mainly considers air temperature, relative humidity, air velocity, and operative temperature, together with the thermal comfort indices PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied). The results show that the average indoor air temperature ranges from 24 to 27 °C, while maximum temperatures can reach 34 to 37 °C. Relative humidity varies between 60 and 90%, while air movement remains low. Under the analyzed conditions, an operative temperature of 27.28 °C is associated with a PMV of +1.32 and a PPD of 41.68%, indicating a warm thermal sensation and a relatively high level of dissatisfaction. The subjective survey further shows that 70% of occupants would prefer a lower indoor temperature, while 64% consider the thermal conditions unacceptable. The consistency between the objective indicators and occupants' perceptions therefore highlights a significant level of thermal discomfort within the building. The study recommends improving air circulation, optimizing air-conditioning systems, and implementing appropriate strategies to reduce indoor thermal loads in order to improve occupants' thermal comfort.*

***Keywords*—** *Thermal comfort, PMV, PPD, operative temperature, air temperature, relative humidity, air velocity, administrative building, Central Bank of the Congo, Kinshasa.*

I. INTRODUCTION

Thermal comfort is a key component of indoor environmental quality. In office buildings, this is particularly important, as occupants typically spend several consecutive hours in enclosed spaces. Inadequate thermal conditions can lead to discomfort, decreased concentration, and a decline in working conditions.

In tropical regions, assessing and controlling thermal comfort presents a particular challenge. High temperatures, significant relative humidity, and slow air movement can contribute to a feeling of excessive heat. In Kinshasa, these factors are likely to be exacerbated by the architectural features of buildings, solar gain, facade orientation, building envelope properties, and the operating conditions of ventilation and air conditioning systems.

Thermal comfort, however, does not depend solely on air temperature. It results from the interaction of several environmental and individual parameters. Key environmental factors include air temperature, mean radiant temperature, air velocity, and relative humidity. Individual factors include, among others, the level of metabolic activity and clothing insulation.

PMV and PPD indices are commonly used indicators to quantitatively characterize average thermal sensation and the predicted percentage of dissatisfied occupants. Their use allows physical measurements to be complemented by an estimate of occupants' thermal perception.

This study focuses on the administrative building of the Central Bank of Congo (BCC) in Kinshasa. Its objective is to characterize the thermal conditions within the building and assess their influence on occupant comfort. The study combines measured environmental parameters, PMV and PPD indices, and subjective responses from occupants to obtain a more comprehensive understanding of the thermal conditions.

II. MATERIALS AND METHODS

2.1. Presentation of the study site

The study was conducted in the administrative building of the Central Bank of Congo, located in Kinshasa. This building constitutes a work environment occupied daily by a significant number of employees. Evaluating thermal conditions in this type of environment is of particular interest due to the length of time the premises are occupied and the importance of indoor conditions for employee well-being and performance.

2.1.1. Presentation of the building under study

The building envelope includes the walls, roof, windows, and openings that provide separation between the interior and exterior, aerial view

The building under study is primarily constructed of concrete and masonry, materials that are resistant but also prone to heat absorption. The roof and glazed surfaces also influence heat gain and interior temperature due to their exposure to solar radiation.

Thus, the materials of the building envelope play an important role in the thermal comfort and energy performance of the building.

The administrative building of the Central Bank of Congo (Figure 2.2) comprises several spaces intended for administrative and technical activities. The main areas observed are administrative offices, meeting rooms, reception areas, circulation corridors, and some technical rooms.

Figure 2.1. Satellite view of the Central Bank of Congo site in Goma and delimitation of the study area


Figure 2.2. Exterior view of the Central Bank of Congo building

These spaces are used daily for management activities, administrative processing and service coordination.

2.1.2. Building envelope and main materials

The building envelope includes the walls, roof, windows and openings that provide separation between the interior and exterior.

The building under study is primarily constructed of concrete and masonry, materials that are resistant but also prone to heat absorption. The roof and glazed surfaces also influence heat gain and interior temperature due to their exposure to solar radiation.

Thus, the materials of the building envelope play an important role in the thermal comfort and energy performance of the building.

2.1.3. Terms of use and technical systems

2.1.4. Occupancy conditions

1° Typology of premises

The administrative building of the Central Bank of Congo comprises several spaces dedicated to administrative and technical activities. The main areas observed are administrative offices, meeting rooms, reception areas, circulation corridors, and some technical rooms.

2. Operating Hours

The administrative building of the Central Bank of Congo operates mainly during administrative hours, from 7:30 a.m. to 3:30 p.m.

During this period, computer equipment, lighting and air conditioning systems are heavily used, which increases the internal thermal loads of the building.

3. Occupancy density and activities of occupants

The administrative premises accommodate a large number of occupants primarily engaged in office activities, including computer work, document processing, meetings and administrative tasks.

Occupancy density varies depending on the space and directly influences the indoor temperature as well as the thermal comfort conditions of the occupants.

4° Internal contributions (equipment, lighting, human presence)

Internal heat gains come mainly from electrical equipment, artificial lighting, and human presence.

Computers, printers, air conditioners, and other office equipment generate heat during operation. Artificial lighting and the simultaneous presence of occupants also contribute to increasing the indoor temperature, thus affecting thermal comfort.

2.2. Environmental parameters

The assessment of thermal comfort is based on several physical parameters that can influence the thermal sensation experienced by occupants. The main parameters considered are:

- air temperature;
- relative humidity;
- the speed of the air;
- the operative temperature;
- the mean radiant temperature, when available.

The individual parameters necessary for a complete assessment of thermal comfort are also taken into consideration, including:

- the level of metabolic activity;
- clothing insulation.

The main available environmental values are presented in Table 1.

TABLE 1. Main thermal characteristics observed

Setting	Observed value
Average air temperature	24 to 27 °C
Maximum temperature	34 to 37 °C
Relative humidity	60 to 90%
Air speed	Weak
Operating temperature	27.28 °C

2.3. Evaluation of PMV and PPD

The quantitative assessment of thermal comfort was supplemented by the PMV and PPD indices. The PMV allows for the estimation of the average perceived temperature of a

International Journal of Scientific Engineering and Science
Volume 10, Issue 9, pp. 75-81, September 2026. ISSN (Online): 2456-7361

group of occupants on a scale ranging from very cold to very hot. The PPD corresponds to the predicted percentage of occupants dissatisfied with the thermal conditions.
For the conditions studied, the results obtained are:

- PMV = +1.32;
- PPD = 41.68%;
- operative temperature = 27.28 °C.

A positive PMV value indicates a perceived temperature oriented towards warmth. A PPD of 41.68%, on the other hand, reflects a relatively high level of dissatisfaction.

2.4. Subjective evaluation from occupants

To complement the instrumental analysis, the occupants' thermal preferences and perceptions were also considered. The responses collected show that 70% of occupants would like a lower indoor temperature. Furthermore, 64% consider the thermal conditions unacceptable.

The joint analysis of physical and subjective data thus makes it possible to compare the thermal sensation predicted by the PMV/PPD indices with the actual perceptions expressed by the occupants.

III. Research Methodology

3.1. Research Design

3.1.1. Mixed approach (physical measurements and occupant perception)

This study is based on a mixed approach combining physical measurements of thermal parameters and an assessment of the perception of the occupants of the administrative building of the Central Bank of Congo.

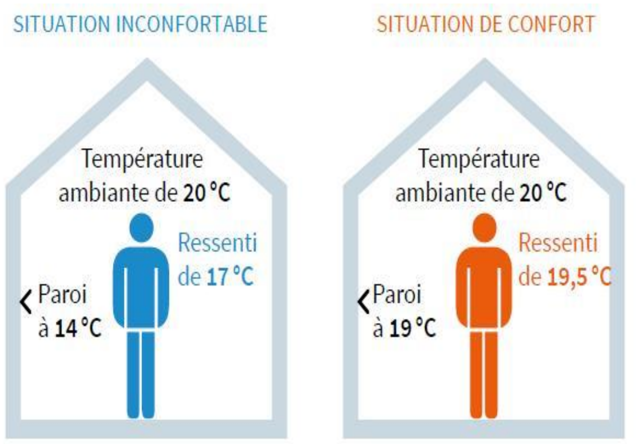

Figure 3.1. Influence of wall temperature on the perception of thermal comfort

Physical measurements make it possible to determine the actual thermal conditions inside the premises through the analysis of temperature, relative humidity, air velocity and radiant temperature (figure 3.1).

The operative temperature used in the study is expressed by the following relationship:

$$T_0 = \frac{T_a - T_r}{2} \quad (3.1)$$

With ;

- T_0 ; *température opérative*
- T_a ; *température de l'air*
- T_r ; *température radiante moyenne*

In parallel, surveys were carried out among the occupants to assess their thermal sensation, their level of satisfaction and their perception of comfort conditions inside the spaces studied.

3.1.2. Data triangulation principle

The principle of data triangulation consists of comparing several sources of information in order to obtain a more reliable analysis of the thermal comfort conditions of the building.
In this study, triangulation is primarily based on:

a) data from physical measurements;
b) observations made in the building;
c) the responses from the occupants obtained through the questionnaires.

This method makes it possible to compare the measured results with the thermal sensations actually felt by the occupants in order to identify situations of thermal comfort or discomfort in the administrative building studied.

3.1.3. Parameters studied

1° Physical parameters

According to ISO 7730 and ASHRAE 55 standards, the assessment of thermal comfort is primarily based on the analysis of the physical parameters of the indoor environment. In this study conducted within the administrative building of the Central Bank of Congo, the parameters studied are:

a) the temperature
b) humidity
c) air speed
d) radiant temperature

These parameters make it possible to assess the actual thermal conditions inside administrative premises and play an important role in the analysis of the thermal comfort of the occupants.

Air temperature directly influences the perceived temperature of the occupants. Relative humidity affects the heat exchange between the human body and the indoor environment. Air velocity promotes heat exchange by convection and contributes to improved thermal comfort. Radiant temperature represents the thermal influence of surrounding surfaces such as walls, windows, and the roof.

2° Human parameters

Human factors play a crucial role in assessing thermal comfort. According to Fanger (1970), thermal sensation depends primarily on the metabolism and clothing level of the occupants.

These parameters directly influence heat exchange between the human body and the indoor environment and play an important role in the assessment of thermal comfort according to ISO 7730 and ASHRAE 55 standards.

Metabolism refers to the amount of heat produced by the human body in response to physical activity. In the building studied, the occupants primarily perform sedentary administrative tasks such as computer work, document writing, and meetings, which correspond to a low metabolic rate.

Clothing represents the thermal insulation provided by the garments worn by the occupants. It influences the human

International Journal of Scientific Engineering and Science
Volume 10, Issue 9, pp. 75-81, September 2026.
ISSN (Online): 2456-7361

body's ability to retain or dissipate heat depending on the thermal conditions of the indoor environment.

Clothing insulation is generally expressed in clo units in accordance with the recommendations of thermal comfort standards.

3. Contextual parameters

In this study carried out within the administrative building of the Central Bank of Congo, the contextual parameters mainly concern the conditions of occupancy of the premises as well as the mode of operation of the building's technical installations.

These parameters include:

a) the density of space occupancy;
b) operating hours;
c) the use of electrical equipment;
d) the operation of the air conditioning and lighting.

The administrative building operates mainly between 7:30 a.m. and 3:30 p.m., a period during which the premises are heavily occupied and the technical equipment is under heavy strain.

The occupancy of spaces directly influences internal thermal loads due to the heat produced by occupants, computer equipment, and artificial lighting.

3.1.4. Instruments used

In accordance with the recommendations of ISO 7726, ISO 7730 and ASHRAE 55-2020 standards, several measuring instruments were used to evaluate the thermal parameters inside the administrative building of the Central Bank of Congo.

These instruments made it possible to collect the data necessary for the analysis of the thermal comfort conditions of the occupants.

1° Thermo-hygrometers

Thermo-hygrometers (Figure 3.2) will be used to measure air temperature and relative humidity in different areas of the Central Bank of Congo's administrative building.

Figure 3.2. Digital thermo-hygrometer used for measuring air temperature and relative humidity

In accordance with ISO 7726, these instruments allow for the simultaneous measurement of:

- Air temperatureT_a expressed in degrees Celsius (°C);
- Relative humidity expressed as a percentage (%).R_H

Air temperature is one of the main parameters influencing the thermal sensation of occupants, while relative humidity affects the heat exchange between the human body and the indoor environment.

2° Anemometers

Anemometers (Figure 3.3) will be used to measure air velocity in the administrative spaces studied.

Figure 3.3. Anemometers used for measuring air velocity

Air speed is expressed in meters per second (m/s) and allows us to assess air circulation inside the premises.V_a

In the building studied, the absence of a mechanical ventilation system results in poor natural air circulation in several administrative spaces. Measuring this parameter therefore made it possible to assess the influence of this poor ventilation on thermal comfort conditions.

3. Globe thermometer

The globe thermometer (figure 3.4) was used to measure the average radiant temperature in the different areas studied of the administrative building.

Figure 3.4. Thermal comfort measurement kit including a black globe thermometer

The average radiant temperature represents the thermal influence of surrounding surfaces such as walls, windows, ceiling and roof on the occupants. T_r

In accordance with ISO 7730, this parameter is involved in the calculation of the operative temperature, which allows for the evaluation of thermal comfort conditions.

3.1.5. Survey of occupants

As part of this study, a survey will be conducted among the occupants of the Central Bank of Congo's administrative building to assess their perception of thermal comfort conditions inside the spaces studied.

This survey will be based on the recommendations of ISO 7730 and ASHRAE 55-2020 standards relating to the assessment of the thermal comfort of occupants.

3.2. Calculation of thermal loads

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Volume 10, Issue 9, pp. 75-81, September 2026. ISSN (Online): 2456-7361

The internal heat load can be expressed by the following relationship:

$$Q_i = Q_o + Q_e + Q_l \quad (3.2)$$

With ;

- Q_i ; *charge thermique interne totale*
- Q_o; *chaleur produite par les occupants* ;
- Q_s; *chaleur dégagée par les équipements* ;
- Q_l ; *chaleur produite par l'éclairage*.

These parameters allow us to better understand the influence of the actual operating conditions of the building on thermal performance and occupant comfort.

Concrete walls and glazed surfaces absorb a significant amount of heat from solar radiation. This is compounded by internal heat loads generated by computers, printers, lighting, and the occupants of the administrative offices.

The absence of mechanical ventilation also promotes the accumulation of heat inside the spaces studied.

3.2.1. Energy balance

The building's energy assessment made it possible to estimate the cooling power needed to maintain a target indoor temperature of 24°C despite the external climatic conditions in Kinshasa.

This analysis takes into account:

a) the thermal loads of the building;
b) the operation of the air conditioning;
c) the conditions of occupancy;
d) the absence of mechanical ventilation.

The simplified thermal balance of the building can be expressed by the following relationship:

$$Q_{clim} = Q_t + Q_{evac} \quad (3.3)$$

With :

- : cooling power required;Q_{clim}
- Q_t: total thermal load;
- Q_{evac}: heat removed by existing systems.

This analysis makes it possible to assess the energy needs required to maintain thermal comfort conditions in the administrative spaces studied.

3.2.2. Critical analysis of the current regulatory system

1. Evaluation of the existing system

The administrative building of the Central Bank of Congo mainly uses an air conditioning system operating according to a fixed regulation mode during administrative hours, i.e. from 7:30 a.m. to 3:30 p.m.

The air conditioning system cools the administrative areas to maintain thermal conditions suitable for professional activities. However, the lack of mechanical ventilation limits the renewal of indoor air and promotes heat accumulation in certain areas of the building.

Analyzing the existing system will allow us to evaluate:

a) the operating conditions of the air conditioning;
b) the thermal performance of spaces;
c) the evolution of indoor temperatures;
d) the actual needs of the occupants.

The analysis of thermal data and the operating conditions of the building will make it possible to identify several situations of energy inefficiency and thermal discomfort.

The likely inefficiencies to be observed will concern:

a) significant residual humidity during the early morning hours;
b) a gradual accumulation of heat in areas exposed to the sun;
c) thermal overheating during the afternoon;
d) heavy use of air conditioning systems;
e) poor air circulation due to the absence of mechanical ventilation.

IV. Presentation, Analysis and Discussion of Results

4.1. Presentation and analysis of results

4.1.1. Temperature conditions

Measurements indicate that average temperatures observed in the building range between 24 and 27°C. This temperature range can, under certain conditions, be compatible with an acceptable level of comfort. However, temperature cannot be interpreted independently of other environmental and individual parameters.

Maximum temperatures, ranging from 34 to 37°C, indicate significantly more challenging thermal conditions when observed in occupied spaces. Such values are likely to cause a feeling of intense heat and increase the risk of discomfort.

4.1.2. Relative humidity

Relative humidity varies between 60 and 90%. Higher values, especially those approaching 80 to 90%, can intensify the feeling of heat when the air temperature is already high.

High humidity limits the effectiveness of physiological cooling through sweat evaporation. The combination of high temperature and high humidity can therefore lead to a feeling of being warmer.

4.1.3. Air speed

The air velocity observed in the spaces studied is low. This situation can contribute to increased discomfort, particularly when temperature and humidity are high.

Sufficient air circulation promotes heat exchange between the human body and its environment. In a warm environment, a controlled increase in air speed can also promote the evaporation of perspiration and improve the feeling of coolness.

4.1.4. PMV and PPD

The results obtained show a PMV value of +1.32 for an operative temperature of 27.28 °C. This positive value indicates that the average thermal sensation of the occupants tends towards a warm environment.

The PPD of 41.68% also indicates that a significant proportion of occupants are likely to be dissatisfied with the thermal conditions. This result is particularly significant in the context of an office building, where occupants typically spend several hours in their workspaces.

4.1.5. Occupant preferences and acceptability

Analysis of subjective responses confirms the trend highlighted by the PMV and PPD indices. Indeed, 70% of

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Volume 10, Issue 9, pp. 75-81, September 2026. ISSN (Online): 2456-7361

occupants would like a decrease in the indoor temperature, reflecting a clear preference for cooler thermal conditions.

Furthermore, 64% of occupants consider the thermal conditions unacceptable. This result is an important indicator of the thermal dissatisfaction felt in the spaces studied (Table 4.1).

TABLE 4.1. Thermal comfort indicators and occupant perception

Indicator	Result
Operating temperature	27.28 °C
PMV	+1.32
PPD	41.68%
Occupants wanting a lower temperature	70%
Occupants deemed the conditions unacceptable	64

4.2. Discussion

The results obtained highlight thermal conditions characterized by a tendency towards heat in the studied administrative building. The PMV value of +1.32 indicates a perceived temperature oriented towards warmth, while the PPD of 41.68% reveals a significant level of dissatisfaction.

This trend is consistent with the responses provided by the occupants. The fact that 70% of them would like a lower temperature confirms that the current conditions are perceived as too hot by a majority of those surveyed. Similarly, the 64% of occupants who consider the thermal conditions unacceptable confirms the existence of a comfort problem that cannot be explained solely by physical measurements.

The operative temperature of 27.28 °C is an important element of this analysis. It reflects the combined effect of air temperature and radiative heat exchange between occupants and their environment. At this temperature, perceived temperature also depends heavily on humidity, air velocity, metabolic activity, and clothing.

The combination of high temperatures, relative humidity reaching up to 90%, and low air velocity is an aggravating factor. Poor air circulation limits convective heat exchange and can reduce the efficiency of perspiration evaporation. Under these conditions, occupants may feel hotter and require a greater reduction in temperature or an increase in air movement.

The comparison between calculated indicators and subjective responses is therefore of particular interest. Both approaches converge on the finding of significant thermal discomfort. Objective analysis indicates a feeling of heat and a high percentage of dissatisfied individuals, while the survey reveals a majority preference for a lower temperature and limited acceptability of the existing conditions.

However, the results should be considered within the context of the assumptions used to assess PMV and PPD. The indices depend, in particular, on the level of activity and clothing insulation. Individual differences between occupants may also explain some variations between the predicted and actual reported sensations.

Further analysis at different times of day, in several areas of the building, would allow for a better characterization of the spatial and temporal variability of thermal comfort. It would also be relevant to study air-conditioned and unair-conditioned spaces separately, as well as areas with different orientations and solar exposures.

V. Recommendations

In view of the results obtained, several actions can be considered to improve the thermal comfort of the occupants of the administrative building of the Central Bank of Congo.

First, it is recommended to improve air circulation in workspaces. When conditions allow, a moderate increase in air speed can help improve the feeling of freshness.

Secondly, air conditioning systems should be regularly inspected to verify their operation, settings, and ability to maintain appropriate thermal conditions. Thirdly, reducing solar heat gain should be considered through the use of suitable solar shading devices, particularly on facades highly exposed to solar radiation.

Fourth, simultaneous monitoring of temperature and relative humidity should be implemented to identify periods of the most unfavorable conditions. Fifth, it would be relevant to take additional measurements in different offices, floors, and orientations of the building to identify any areas particularly exposed to thermal discomfort. Finally, periodic surveys of occupants would allow for monitoring changes in their perception of temperature and evaluating the effectiveness of the corrective measures implemented.

VI. Conclusion

This study made it possible to evaluate the thermal comfort conditions in the administrative building of the Central Bank of Congo in Kinshasa by combining environmental parameters, PMV and PPD indices and the perception of the occupants.

The results show average temperatures between 24 and 27 °C, maximum temperatures reaching 34 to 37 °C, relative humidity ranging from 60 to 90%, and low air velocity. Under the analyzed conditions, an operative temperature of 27.28 °C is associated with a PMV of +1.32 and a PPD of 41.68%, indicating a perceived temperature skew towards warmth and a significant level of dissatisfaction.

The results of the survey of occupants reinforce this finding: 70% would like a reduction in the indoor temperature, while 64% consider the thermal conditions unacceptable. The convergence between physical indicators, PMV/PPD indices, and subjective perceptions thus shows that the building presents a significant level of thermal discomfort under the conditions studied.

Improving thermal comfort should therefore rely on a comprehensive approach combining better air circulation, optimized air conditioning systems, reduced solar heat gain, and regular monitoring of thermal parameters. Further investigations incorporating mean radiant temperature, activity levels, clothing insulation, and the spatial and temporal variability of conditions would allow for a more refined assessment and the development of improvement strategies better suited to Kinshasa's climate.

Thanks

Volume 10, Issue 9, pp. 75-81, September 2026.
ISSN (Online): 2456-7361

At the end of this work, we would like to thank all those who contributed to the writing of this article, in particular Professor KONZI PANISE SIAMO Edouard and Professor LEMA NKWALU Blaise, as their availability and advice were a valuable help.

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