BUILDING OCCUPANCY & THERMAL PERFORMANCE: A CASE STUDY IN DIFFERENT CLIMATE ZONES IN BRAZIL

USO DE EDIFICAÇÕES & CONFORTO TÉRMICO: ESTUDO DE CASO EM DIFERENTES ZONAS BIOCLIMÁTICAS BRASILEIRAS

OCUPACIÓN DE EDIFICIOS Y DESEMPEÑO TÉRMICO: UN ESTUDIO DE CASO EN DIFERENTES ZONAS CLIMÁTICAS EN BRASIL.

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ABSTRACT

This study investigates the difference in buildings' thermal performance due to different parameters of home permanence from those proposed by Thermal Standards in distinct climate zones. It is based on the changes in the occupation of residential buildings in recent years, due to the greater flexibility of remote work, for instance. Different scenarios were performed through the building design of single-family houses and 4-story multifamily buildings, using as variables: the use of equipment, presence of people, windows opening, and four climate zoning. The pattern of building use recommended by the Brazilian Standard regards only night residence occupancy, while the study considers alternative scenarios by day and night occupancy. Results show that alternative scenarios presented the lowest percentage of hours in the thermal comfort range and higher annual thermal discomfort degrees-hours. Also, great differences are observed in results between cold and hot climates. Those finds indicate the need for standards updates to match the reality of residential building uses and suggest that design solutions should be climate-specific, aiming for greater thermal comfort for the user and, at the same time, potentiating the energy efficiency of the building.

KEYWORDS

Thermal performance; building uses, building design thermal simulation.

RESUMO

Este trabalho investiga diferenças no conformto térmico de edificações devido a diferenças de uso em edificações residenciais (permancência de pessoas) aos padrões de uso previsto na norma brasileira de Conforto, considerando diferentes zonas bioclimáticas. O trabalho se baseia na diferença de ocupação das residências nos últimos anos, especialmente devido à maior flexibilidade e trabalho remoto, por exemplo. Diferentes cenários foram simulados, considerando um projeto arquitetônico de uma casa residencial e um edifício de 4 pavimentos, tendo também como variáveis uso de equipamentos, presença de moradores, janelas abertas e 4 zonas bioclimáticas. O padrão de uso preconizado pela Norma Brasileira considera a presença de pessoas nas residencias somente no turno da noite, enquanto este estudo investiga cenários alternativos, com ocupação das residências noite e dia. Os resultados mostram que os cenários alternativos apresentam menores percentuais anuais de horas na faixa de conforto térmico e maiores horas-graus em desconforto. Também aponta diferenças nos resultados entre as zonas de climas frio e quentes. Os resultados *sugerem a necessidade de atualização da normatização para adequação á novas realidades de ocupação residencial e sugerem que as definições de projeto devem ser específicas para cada clima a fim de melhorar o conforto térmico das residências e ao mesmo tempo potencializar a eficiência energéticas das edificações.*

PALAVRAS-CHAVE

Conforto térmico, uso de edificações, simulação energética de projeto.

RESUMEN

Este trabajo investiga las diferencias en el confort térmico de los edificios debido a las variaciones en el uso en edificaciones residenciales (permanencia de personas) con respecto a los estándares de uso previstos en la norma brasileña de Confort, considerando diferentes zonas bioclimáticas. El trabajo se basa en la variación en la ocupación de las residencias en los últimos años, especialmente debido a una mayor flexibilidad y trabajo remoto, por ejemplo. Se simularon diferentes escenarios, considerando un proyecto arquitectónico de una casa residencial y un edificio de 4 plantas, teniendo como variables el uso de equipos, la presencia de residentes, ventanas abiertas y 4 zonas bioclimáticas. El estándar de uso recomendado por la Norma Brasileña considera la presencia de personas en las residencias solo durante el turno nocturno, mientras que este estudio investiga escenarios alternativos, con ocupación de las residencias de día y de noche. Los resultados muestran que los escenarios alternativos presentan menores porcentajes anuales de horas dentro del rango de confort térmico y mayores horas-grado en incomodidad. También señala diferencias en los resultados entre las zonas de climas fríos y cálidos. Los resultados sugieren la necesidad de actualizar la normativa para adaptarse a las nuevas realidades de ocupación residencial y sugieren que las definiciones de proyecto deben ser específicas para cada clima con el fin de mejorar el confort térmico de las residencias y, al mismo tiempo, potenciar la eficiencia energética de los edificios.

PALABRAS CLAVE

Desempeño térmico; usos de edificios, simulación térmica del diseño de edificaciones.

1. INTRODUCTION

Reducing energy and natural resource consumption is on the discussion agenda in different countries, and the construction sector plays an important role. Prakash et al. (2021) argue that, over the past decade, a relevant energy consumption increase has been observed due to development and changes in living standards. McNeil et al. (2008) point out a substantial change in energy consumption in residential scenarios due to the greater ease of acquiring individual air conditioners, for example.

The relationship between energy efficiency and building thermal performance should be increasingly addressed, aiming to reduce buildings' thermal loads to minimize energy consumption. (Ling-Chin et al., 2019; Qiao and Liu, 2020). According to Varela Luján et al. (2019), implementing energy-saving strategies is the current imperative to reduce energy consumption in the building sector.

However, studying building thermal performance is complex. Many issues must be considered and updated when establishing standards and parameters, such as climate change, construction systems, specific climate criteria (zone, humidity), and user behavior.

As Garay et al. (2022) indicated, the climate change phenomenon highlights the need for public policies to ensure minimum thermal comfort parameters. Therefore, climate change is a significant issue and affects our overall well-being, specifically thermal comfort. In this context, policies formulated by the government or other relevant institutions should address the impact of climate change by establishing and enforcing standards or guidelines to ensure that people have a certain level of thermal comfort consistent with the changing climate conditions. These policies may include measures such as improving building insulation, implementing energy-efficient heating and cooling systems, or developing urban planning strategies that mitigate the effects of extreme temperatures.

Many studies have been investigating construction systems, new materials, and elements to improve the thermal performance of the building, aiming to reduce the energy consumption for new construction or even to adapt existing buildings, envelopes, and façades in different contexts and cities (Barbaresi et al., 2020; Varela Luján et al., 2019, Rathore et al., 2022).

However, how buildings are operationalized by their users is an essential and complex variable in the building's thermal performance and deserves special attention (DeKay and Brown, 2014; Li et al.,2020).

Predicting users' use and operational behavior is challenging because it is strongly linked to users' habits and involves greater diversity, especially in the residential segment (Balvedi et al., 2018; Mahdavi, 2011). For example, using natural ventilation by window opening is rare in most centrally air-conditioned buildings, typically commercial ones, contrary to what happens in residential buildings (Chen et al., 2021; DeKay and Brown, 2014)

Passive or active measures may address the thermal performance of residential buildings. The first approach involves implementing passive measures, which focus on improving the building's envelope (the structure's outer shell) through design choices and materials. These measures aim to reduce heat transfer and maintain comfortable conditions inside the building without relying heavily on active systems. The second approach involves using active systems, such as air conditioning or heating systems, to regulate and control the indoor temperature. These systems can maintain a constant temperature within the building for extended periods, regardless of the external climate conditions. Active measures provide an advantage over passive ones because they provide greater indoor environment control (Garay et al., 2022)

However, Li et al. (2020) report that when dissatisfied with the ambient temperature and/or shading of the windows, the user intervenes with manual adjustments, which must be incorporated into the concept of user-centered buildings. This manual tuning of automated conditions reflects the need to understand specific aspects of user behavior, and such interventions and manual adjustments in controlled systems are not necessarily compensatory for the energy efficiency of buildings (Ding et al., 2021)

A widely used way to analyze the thermal performance of a building is through simulation software, thus being an analytical tool through which decision-makers can gain insight into complex phenomena. Specific software predicts buildings' thermal performance through digitally modeled design simulations based on methods prescribed by standards, usually regarding different variables, mainly related to the building (size, construction materials, and system), the location and climate, and the use of the building (occupant habits).

The thermal analysis must consider occupancy and user behavior, not only by the presence of people – whose occupation generates sensible and latent heat – but also by their actions (Sorgato et al., 2016). For example, the decision to open or close windows or turn on the air conditioning equipment (Balvedi et al., 2018; Sorgato et al., 2016). The effects of an occupant are classified into three main categories: occupancy, interactions, and behavioral efficiency (Mahdavi, 2011). The occupancy is related to arrivals, departures, permanence duration, and number of occupants. As an interaction, the authors point out air conditioning, lighting, electrical appliances, and windows opening. Behavioral efficiency is about the people's education and conscience approaches.

The usual simulation methods follow static models, adopting standardized cultural and local configurations. However, usage follows stochastic models with no repetitive pattern. Several studies show the need to update the thermal performance methods in the Brazilian context, where this study was performed. In common, researchers claim that Brazilian standard methods do not adequately represent the thermal behavior of buildings within their climatic context, and they highlight the lack of simulation use and operation parameters and variables, which have a high influence on the analyses (Mazzaferro et al., 2020; Melo et al., 2014; Oliveira et al., 2017).

In Brazil, thermal comfort parameters for internal spaces are set by Regulatory Norm NR 17 - Ergonomics and NBR 16401 Brazilian Standard. Both limit thermal comfort conditions to commercial environments with restricted temperature and air velocity ranges. Therefore, the thermal comfort assessment in indoor environments is mainly carried out according to the American Standard ASHRAE 55 (Thermal environmental conditions for human occupancy, last revision - 2017), which deals only with thermal environmental conditions for human occupancy (Lamberts et al., 2021)

However, it is essential to consider that simulation information cannot always express results from reality. For example, Zou et al. (2019) found that the actual energy consumption can be twice to five times higher than predicted by the simulation models. The difference between the expected energy consumption in the design stage and the energy consumption in the post-occupancy phase (called the performance gap) has a significant financial and environmental impact. Thus, special attention is needed to the parameters used in the thermal performance simulations to represent the occupancy phase of the buildings better.

In this context, this study focuses on the perception of changes in the occupation of residential buildings in very recent years. Before 2020, it was reasonable to assume a precise scenario of most residential buildings being generally occupied at night while commercial buildings were occupied during the day. However, the current scenario considerably changed due to the COVID-19 pandemic and social isolation. Following Pacini et al. (2023), during pandemic isolation, the home office practice growth is equivalent to 30 years of pre-pandemic home office growth. For instance, energy consumption in Norway apartments increased by up to 27% during social isolation because of remote work (Ding et al., 2021). In the post-pandemic, the expectation of a drastic reduction of home office did not occur in some sectors, especially in the upper classes of society. The study by FGV's Brazilian Institute of Economics (IBRE) shows that the home office practice has grown, with the expectation of continuing to grow (Pacini et al., 2023).

Therefore, changes in the way of life that affect the occupancy of buildings must be considered when establishing thermal comfort parameters because the demand for equipment and energy consumption tends to follow the activities of the people who use a particular space (DeKay and Brown, 2014).

This study investigates the difference in thermal performance of buildings through context simulation that adopts the pattern of building use recommended by the Brazilian Standard compared to alternative contexts regarding day and night occupancy and different windows opening.

2. RESEARCH METHOD

The investigation consisted of the simulation of the residential design, considering four cities from different Brazilian climate zones. The study was conducted through simulation, adopting the Energy Plus software, version 9.3. EnergyPlus is a free computer program distributed by the US Department of Energy, widely used by engineers, architects, and researchers to model the energy performance of a building.

2.1 Variables

The studies were conducted through simulations, considering the main variables in Brazilian social housing. In this work were considered:

a) Residential building design: can determine the envelope's exposure level to weather and climate variations and the heat storage capacity.

b) Climate zoning: identifies the level of exposure to different regional climatic realities.

c) Building use: considers the thermal load determined by the length of stay of users in the rooms of prolonged stay in the house, in addition to the metabolic rate of users, lighting systems, and equipment.

d) Natural ventilation: considers the influence of window opening and closing operations during the day.

2.1.1 Buildings design type: Single-family house and multifamily building

Two types of residential buildings adopted in social housing in Brazil were investigated. The housing programs of the Brazilian government indicate some types of construction, which basically should be buildings, isolated houses, or semi-detached houses. This study considers a single-family residence in a detached house (H), with an area of 40m², and the other is a multifamily four floors apartment building (B), with a 38m² area for each housing unit. (Figure 1).

Both buildings' architectural program comprises a living room, kitchen, bathroom, and two bedrooms, considering a four people family as a typical user. Also, the construction system is structural masonry with ceramic blocks (19cm), plaster, and cement mortar as internal and external coatings for both. Table 1 presents the thermal characteristics of the external walls construction system wall, based on the Brazilian standard NBR ISO 10456.

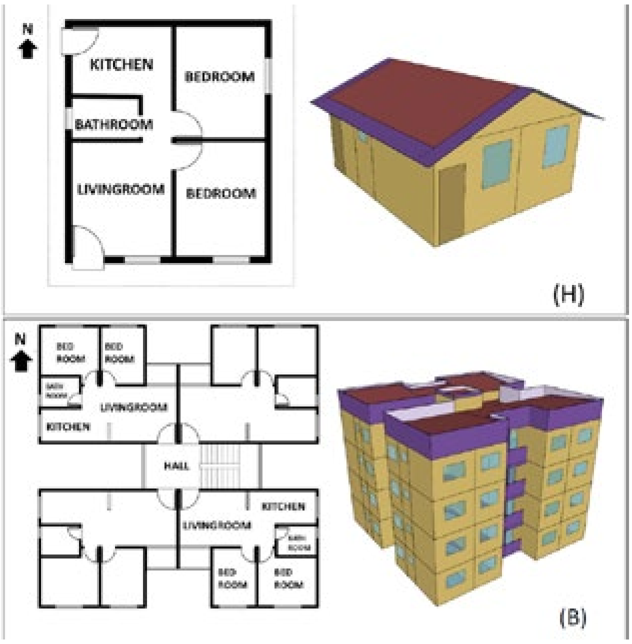
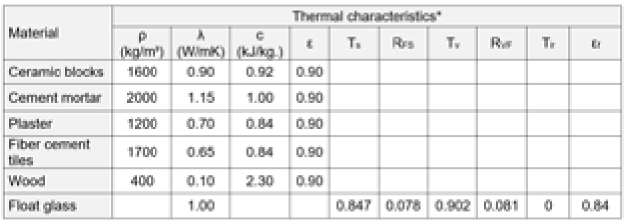


Figure 01: Single-family house (H) and multifamily building (B) .



Material	Thermal characteristics*									
	ρ (kg/m³)	λ (W/mK)	c (kJ/kg.)	ε	T_s	R_{FS}	T_v	R_{VF}	T_{ir}	ε_f
Ceramic blocks	1600	0.90	0.92	0.90						
Cement mortar	2000	1.15	1.00	0.90						
Plaster	1200	0.70	0.84	0.90						
Fiber cement tiles	1700	0.65	0.84	0.90						
Wood	400	0.10	2.30	0.90						
Float glass		1.00			0.847	0.078	0.902	0.081	0	0.84

Table 01: External walls construction system Thermal characteristics.

It was considered a roof with a concrete slab (10cm) and fiber cement tiles (0.6cm), doors made of wood (3cm), and windows with clear float glass (0.4cm). The external walls' color absorbs solar radiation (α) of 0.58. The float glass: Ts - Solar Transmittance = 0,847; RFS - Solar Reflectance = 0.078; Tv - Visible Transmittance = 0.902; RVF - Visible Reflectance = 0.081; Tir - Infrared Transmittance = 0; εf - Infrared Hemispherical Emissivity = 0.84.

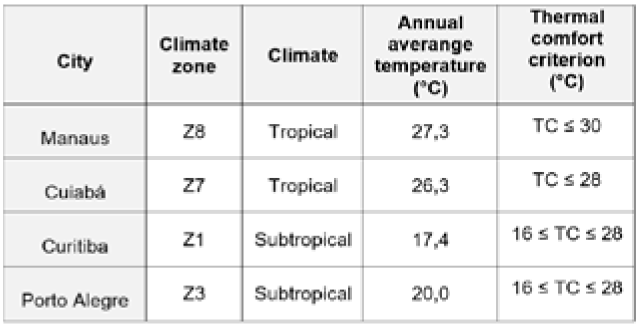
2.1.2 Climate zoning: Z1, Z3, Z7, and Z8

The Brazilian Bioclimatic Zoning is the result of crossing data such as: parameters of human thermal comfort, climatic data, constructive strategies, and passive thermal conditioning, with the objective of establishing criteria to provide thermal comfort in residential buildings.

Currently, there are 8 climate zones, with zone 1 being the one that groups the coldest regions and zone 8 with the regions identified as warmer. Although these differences expressed in the characterization of the climatic zones have the objective of considering the climatic diversity of Brazil, it is still possible to find the same building project in regions with different climatic characteristics. Unfortunately, there is still a standardization in architectural design that, to provide thermal comfort, requires the use of active thermal conditioning (air conditioning systems, humidifiers, dehumidifiers, etc.).

The simulations were performed considering four Brazilian cities representing different climatic zones (Z): Curitiba, climate zone 1 (Z1); Porto Alegre, climate zone 3 (Z3); Cuiabá, climate zone 7 (Z7); and Manaus, climate zone 8 (Z8). Table 2 shows the location of the cities, the annual average temperature (dry bulb) (TBSm ºC), and the interval considered as the thermal comfort criterion range for each one by Brazilian standard.

As shown in Table 2, Zones 1 and 3 are classified as Subtropical Climate, while Zones 7 and 8 as Tropical Climate. For Zones 1 and 3, the criterion for defining thermal comfort is the same, with internal temperatures that can vary between 16 °C and 28 °C, despite representing cities with different average annual temperatures. On the other hand, differences in annual temperature averages are considered for cities in Zones 7 and 8 through different criteria. Thus, for the city of Cuiabá, located in Zone 7, the criterion that defines thermal comfort is a temperature equal to or less than 28 °C, while for Manaus, thermal comfort is indicated for a temperature equal to or less than 30 °C.



City	Climate zone	Climate	Annual averange temperature (°C)	Thermal comfort criterion (°C)
Manaus	Z8	Tropical	27,3	TC ≤ 30
Cuiabá	Z7	Tropical	26,3	TC ≤ 28
Curitiba	Z1	Subtropical	17,4	16 ≤ TC ≤ 28
Porto Alegre	Z3	Subtropical	20,0	16 ≤ TC ≤ 28

Table 02: Brazilian cities used in this study, their climate, and Thermal Confort (TC) Criterion.

2.1.3 Building use: permanence in extended-stay rooms

The variables related to the use and operation refer to the permanence of the occupants in the extended-stay rooms (bedrooms and living room). The study considered the building use parameters recommended by the Brazilian standard NBR 15575-1 , called "Standard Use." Which considers that occupants of residential buildings remain at home at night (from 6 PM to 6 AM). The investigation proposes an alternative scenario that regards occupants staying home during night and day, called "Night and Day Use". Table 3 and 4 show the heat sources of presence of people, lighting, and equipment for one day long (24h) in the two studied scenarios.

Table 5 shows the heat sources (generated by the occupants, lighting systems, and equipment) based on NBR 15575-1 . For the bedroom environment, the main activity considered was rest and sleep, which are activities of low metabolic rate and consequently low thermal load. For the modeling of the living room, the metabolic rate adopted refers to the activity of watching TV sitting down, with the thermal load of the TV turned on also being considered during the users' occupancy. For the bedroom environment, the main activity considered were resting and sleeping, both activities of low metabolic rate and consequently low thermal load. In the modeling of the living room, the metabolic rate adopted refers to the activity of watching TV sitting down, with the thermal load of the TV turned on also being considered during the users' occupancy.

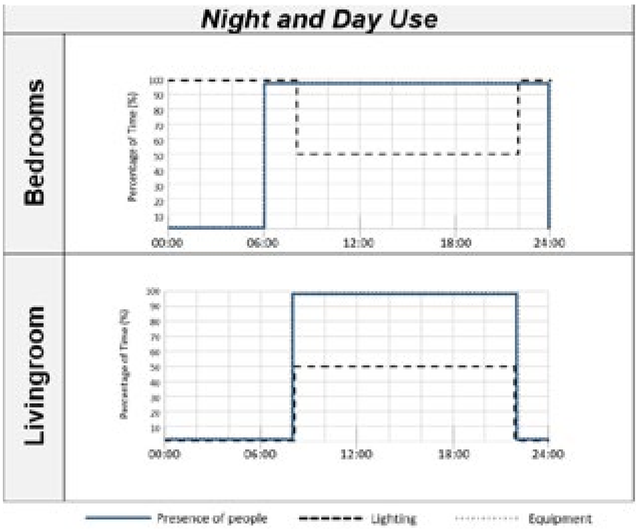


Table 03: The daily presence of people, lightning, and equipment (%) of buildings in "Night and day" use.

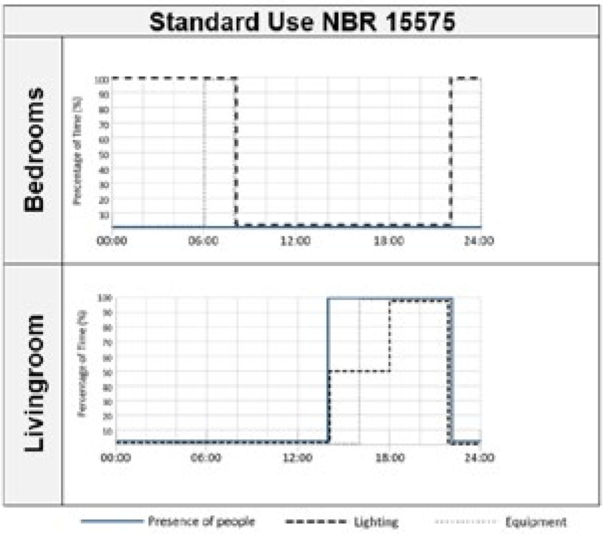
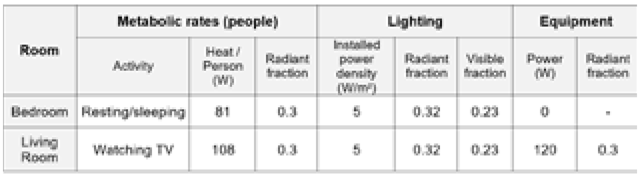


Table 04: The daily presence of people, lightning, and equipment (%) of buildings in "Standard" use scenario.



Room	Metabolic rates (people)			Lighting			Equipment	
	Activity	Heat / Person (W)	Radiant fraction	Installed power density (W/m²)	Radiant fraction	Visible fraction	Power (W)	Radiant fraction
Bedroom	Resting/sleeping	81	0.3	5	0.32	0.23	0	-
Living Room	Watching TV	108	0.3	5	0.32	0.23	120	0.3

Table 05: Heat sources considered in the parameters of use.

2.1.4 Natural ventilation

The single-family house (H) and the multifamily building (B) were simulated regarding two natural ventilations, called "Selective Ventilation" (following standard patterns) and "Daytime Ventilation" (alternative patterns).

"Selective Ventilation" regards windows opening by the users, following the parameters of Brazilian standard

NBR 15571-1 when: (1) occupying bedrooms or living rooms; (2) indoor temperature equal to or greater than 19°C; and (3) indoor temperature greater than the outdoor temperature. In addition, bathroom windows are considered open, and internal doors are kept open, except for external doors and bathroom doors, which are permanently closed. In "Daytime Ventilation" scenarios, the windows opening occurs during the day, regardless of the presence of people or the indoor or outdoor temperature.

2.2 Simulations

The analysis of results considered the entire annual period, regarding two measurements: percentage of hours occupied within thermal comfort temperature range; and discomfort degrees-hour for cooling and heating out of thermal comfort range. The thermal performance of naturally ventilated buildings is done by analyzing the number of hours of discomfort and number of degree-hours of discomfort, calculated from the total hours of the year in which the internal temperatures of the rooms exceed the limits established as comfortable.

To verify the influence of occupancy patterns on the thermal performance of buildings, we started with three types of occupancy defined according to occupancy patterns. The first refers to the standard occupancy; the second the thermal load variation resulting from the presence of users, and the third considers variation the window opening and closing operations. Figure 2 represents the variables considered to investigate different scenarios of thermal performance through design simulation.

Thus, the time that windows are open is considered as the main variable, which can be: "Standard Use" with "Selective Ventilation", consisting of 8h for the bedrooms and 2h the living rooms; "Night and Day" with "Selective Ventilation", consisting of 24h for the bedrooms and 14h the living rooms; "Night and Day" with "Daytime Ventilation", consisting of all windows open during the day for 10 consecutive hours.

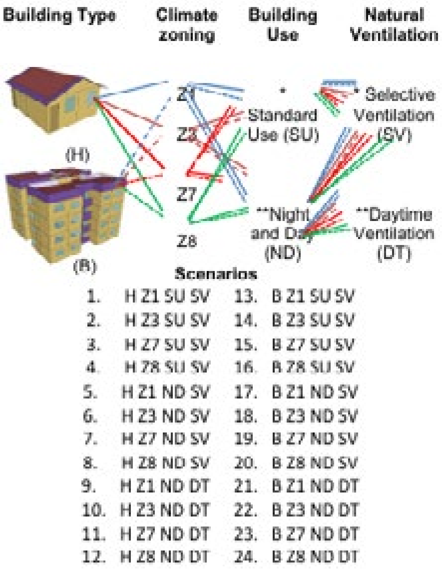


Figure 2: Thermal performance simulation variables and scenarios.

In total, 24 scenarios were performed considering the variables shown in Figure 2, allowing the comparison of the thermal performance of houses and buildings according to the patterns established by NBR 15220/2005 with alternative usage patterns, considering 4 Brazilian bioclimatic zones.

3. RESULTS

The results are presented in terms of the percentage of annual hours in thermal comfort and the discomfort degree-hours for cooling and heating. Figure 3 shows the percentage of hours per year within the thermal comfort due to temperature limits for a single-family house and multifamily building. In both buildings, the thermal performance considering Brazilian Standard patterns of use and ventilation, called "Standard Use" (SU), is compared with the thermal performance of alternatives buildings' use and ventilation, "Night and Day Use" with "Selective Ventilation" (ND SV) and "Daytime Ventilation" (ND DV).

In the buildings, the alternative uses presented a lower percentage of hours in thermal comfort than the standard use for zones 3, 7, and 8. In the building models generated for the coldest Brazilian climate zone, "Night and Day" use with "Selective Ventilation" presented higher hours in thermal comfort.

The models generated for single-family houses showed differences depending on the climatic characteristics of the analyzed cities. In cities with a warmer climate, located in climate zones 7 and 8, "Standard Use," a few hours with natural ventilation, presented a higher percentage of hours in thermal comfort than models with "Night and Day" use. In the coldest Brazilian climate zones 1 and 3, the highest percentage of hours in thermal comfort in the houses occurred with opening and closing windows for natural ventilation. In this sense, the greater area of exposure to the sun on the external walls may have helped to reach more suitable temperatures, as well as opening the windows at certain times can allow the entry of warmer air.

These results indicate that the presence of people at home during the day decreases the time within the supposed thermal comfort zone, especially in hot climates, as in zones 8 and 7. The only exception, where the alternative scenario showed the best results from the standard use and ventilation, was in the house simulation in zone 1 (cold climate). Results also show that the difference in the ventilation (when comparing "night and day use – selective ventilation with "night and day use – daytime ventilation) is less perceived in hot climates than in cold climates. Moreover, the thermal performance was very similar in single-family and multifamily buildings. However, in zone 1 and 3, the kind of ventilation showed inverse behavior: in the multifamily building, daytime ventilation showed the best result than selective ventilation.

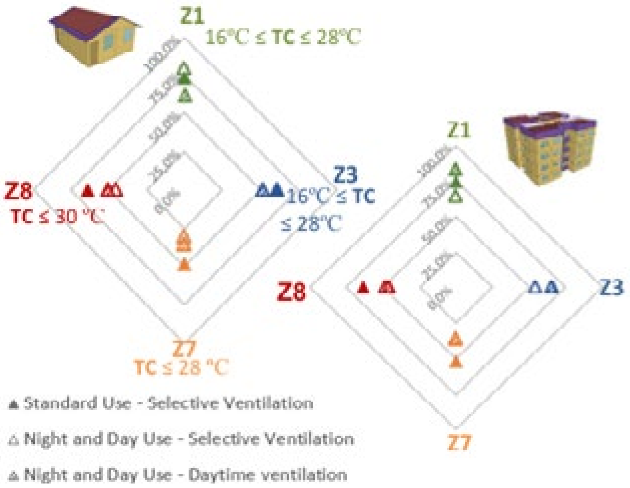


Figure 3: Percentage of annual hours in thermal comfort (TC).

Results of annual thermal discomfort (Figure 4) in zones 1 and 3 are the sum of degrees-hours in discomfort due to cold and heat (TD due to heat + TD due to cold), while results of annual thermal discomfort in zones 7 and 8 are only due to heat.

The annual thermal discomfort from Figure 4 indicates a greater difference among the studied variables. However, it is observed very similar behavior when comparing the standard parameters between the single-family house and multifamily building.

When simulating the alternative's parameters, the presence of the people during the day showed a considerable increase in the thermal discomfort indicator, especially in zone 7. There are also behavioral differences between the two cities from cold and hot climates and between the two types of buildings.

In zone 1, all scenarios showed greater thermal discomfort due to cold, while in zone 3, the thermal discomfort is mainly due to heat. In both zones, daytime ventilation led to higher indicators of thermal discomfort in the multifamily building.

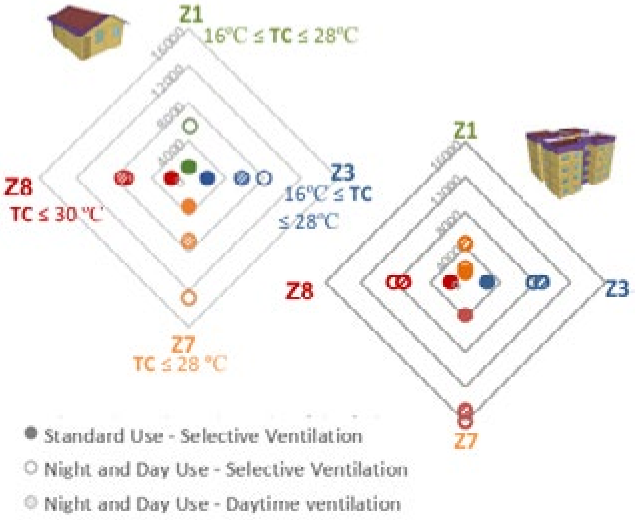


Figure 4: Annual Degrees-hours (ºC) in thermal discomfort (TD)

Simulations in Zone 7 indicate the highest thermal discomfort in all scenarios. The alternative parameters of building use showed an increase in annual discomfort by up to 4 times compared to the parameters predicted in the Brazilian standard. Scenarios from Zone 8 presents similar results to zones 1 and 7 when the standard parameters are considered. The variables proposed for use show an annual increase in thermal comfort of up to 5 times.

4. FINAL DISCUSSION

The consideration of the occupation of houses during daytime periods, different from the pattern predicted by the Brazilian standard, showed a decrease in the percentage of hours in thermal comfort and higher degrees hour in discomfort in the scenarios in a zone with the highest annual temperature. Comfort indicators in the multifamily building scenarios were lower than the single-family house, indicating a loss of thermal performance in the case of multifamily buildings, with an exception for the "Standard Use" scenarios in Zone 8.

The four façades of the single-family house having windows or doors allow cross ventilation, which may have influenced the results. Except for Zone 8, results regarding standard use show better thermal comfort in single-family house scenarios than the alternative uses (selective ventilation). In the context of the multifamily building, results from standard use with selective ventilation presented high variations compared to the alternative uses scenarios. The analysis of daytime ventilation results showed higher variation than selective ventilation in single-family houses and multifamily buildings. In these cases, the increase in air exchange was also possible because of the air inlet and outlet on the four facades.

Except for the "Standard Use" in Zone 8, the degrees hour in discomfort due to the heat of the other scenarios were higher in the simulations with the multifamily building than those with the single-family house. The cold indicators were lower, suggesting internal temperatures were higher annually.

In Zones 1 and 3, "Night and Day Use" scenarios showed higher thermal discomfort due to heat than in 'Standard Use" in Zones 7 and 8, 4 to 5 times higher.

The more significant thermal discomfort in scenarios' Day and Night Use" can be explained due to the intensive exposure of the user to indoor temperatures during the daytime. Those results suggest that the factors contributing to the variation of the values of the thermal discomfort are internal heat gains in colder zones (Zones 1 and 3) and, in warmer zones (Zones 7 and 8), the user exposure to residential environments.

"Daytime Ventilation" presented losses in thermal performance (indicated by lowest hours in comfort %) in simulations in Zones 1 and 3 and gains in Zones 7 and 8, in comparison with results from "Selective Ventilation" based on NBR 15575-1 (ABNT, 2021).

This behavior occurs due to climatic differences, assuming that 'Daytime Ventilation" causes greater air exchanges. Consequently, there is a reduction in internal temperatures, influencing the increase in discomfort due to cold in zones 1 and 3 and the reduction in discomfort due to heat in all zones. Furthermore, this behavior explains why thermal comfort improves in warmer climate conditions (Zones 7 and 8), with degree-hour discomfort only for heat.

Building use and operation showed more than 15% variation in thermal comfort (hours%) and more than 300% in thermal discomfort. Thus, a significant influence of users on the thermal behavior of buildings is observed, therefore, on their thermal comfort, as highlighted by (Balvedi et al., 2018; Ding et al., 2021).

Results showed that the prolonged use of the residences, which occurs in scenarios of "night and day use," tends to increase the internal temperatures (internal heat gains). Thus, in zones with colder climates, such as Zone 1 and Zone 3, this behavior was generally satisfactory in thermal performance, reaching a 7.9% increase in thermal comfort compared to standard use. These results are similar to those (Eli, 2020), which observed higher cooling thermal loads in scenarios with a prolonged occupation and lowered in scenarios with a predominantly nocturnal occupation pattern.

In colder zones, natural daytime ventilation showed a reduced thermal performance related to the increased thermal discomfort due to cold. In zones with a warmer climate, there was a tendency to increase thermal comfort and decrease thermal discomfort. In Zone 7 (the city of Cuiaba, with a hot and dry climate), there were different results comparing the single-family house and the multifamily building. The single-family showed greater thermal performance than the multifamily building. In Zone 8 (city of Manaus – hot and humid climate), thermal performance increased in all scenarios.

Those results demonstrate the vital role of users in building operations and occupation, significantly altering the conditions of comfort and thermal performance based on their habits. So, the building use should be deeply studied when possible since it can be used in favor of thermal performance and energy efficiency (Balvedi et al., 2018; DeKay and Brown, 2014; Ding et al., 2021).

Furthermore, the effects of the occupation of users on building thermal performance must be increasingly studied to reproduce the influence of different scenarios of users' behavior in building simulations coherently. Those studies may even consider a possible growing number of people working from home due to the changes in work relationships caused by isolation during the Covid 19 pandemic, creating a scenario closer to the alternative called "Night and Day" than the night stay scenario provided for by the standard ("Standard Use").

5. CONCLUSIONS

Scenarios with alternative parameters building use show different thermal behavior from those with parameters prescribed by the Brazilian Standard. The variation was more than 15% fewer hours (%) in thermal comfort (hours%) and more than 300% in degrees hours (ºC) in thermal discomfort in scenarios considering people staying at home during the day and night with windows opening. Also, results differed from results in the cities with the highest and lowest average annual temperature among those studied.

Considering that the alternative scenarios with people staying at home can be assumed to be more like what has been happening because of current work models, with a tendency to remain or increase in the future, these findings reinforce the need to update the parameters recommended by the thermal performance standards for residential buildings, as pointed out by the bibliography (Lamberts et al., 2021; Oliveira et al., 2017; Prakash et al., 2021). Engineers and architects may also consider results from this study in the search for design strategies aimed at choices and definitions that can increase the thermal performance of the building according to the climate zone in which the building will be built.

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