ARTIGO

CLIMATE AND DESIGN: IMPACTS ON THERMAL COMFORT IN SH OF THE PMCMV

CLIMA E PROJETO: IMPACTOS SOBRE O CONFORTO TÉRMICO EM HIS DO PMCMV

CLIMA Y DISEÑO: IMPACTOS SOBRE EL CONFORT TÉRMICO EN VIS DEL PMCMV

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ABSTRACT:

Brazilian Social Housing (SH) offered by the Minha Casa, Minha Vida program (PMCMV) has been contributing to situations of thermal stress and unhealthiness, exhibiting limited resilience to the climate. In this context, the article presents the results of a Post-Occupancy Evaluation (POE) conducted in a case study of horizontal social housing developments (SHD) under the MCMV program, located in the city of Uberlândia (MG), in Bioclimatic Zone 4. Technical analyses and impact assessment questionnaires were performed in two SH developments implemented in different periods and with distinct construction characteristics. The evaluation aimed to understand the existence and magnitude of impacts resulting from interactions between climate and design on thermal comfort, considering the users' perspective in the case study. It was observed that thermal discomfort is a perceived problem, with significant discomfort related to both heat and cold. Additionally, the presence of health problems caused by heat and cold is substantial, supporting the perception that the housing units contribute to situations of thermal stress and impose high social costs on their beneficiaries. The results also indicated that it is not possible to affirm trends of improvement in thermal comfort and the occurrence of health problems in housing units after enlargements. Thus, they contribute to expanding knowledge regarding the relationships between the construction characteristics of in-use horizontal SH and thermal comfort from the user's standpoint. Furthermore, they provide support for technical assistance aligned with the real needs and priorities of residents of in-use SH, with a focus on enhancing their resilience.

KEYWORDS: resilience; thermal comfort; impact; social housing.

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RESUMO:

Habitações de Interesse Social (HIS) brasileiras ofertadas pelo programa Minha Casa, Minha Vida (PMCMV) têm favorecido situações de estresse térmico e insalubridade, manifestando reduzida resiliência aos rigores do clima. Diante desse contexto, o artigo apresenta resultados de Avaliação Pós-Ocupação (APO) empreendida em estudo de caso de conjuntos habitacionais de interesse social (CHIS) horizontais do PMCMV em uso situadas na cidade de Uberlândia (MG), Zona Bioclimática 4. Análises técnicas e questionários de avaliação de impacto foram aplicados em dois CHIS implantados em épocas distintas e com diferentes características construtivas. A avaliação almejou compreender a existência e magnitude de impactos derivados das interações entre clima e projeto sobre o conforto térmico, considerando a perspectiva dos usuários em estudo de caso. Constatou-se que o desconforto térmico é um problema percebido, com grande incômodo relacionado ao calor e ao frio. Além disso, a existência de problemas de saúde gerados pelo calor e frio é expressiva, corroborando para a percepção de que as moradias favorecem situações de estresse térmico e elevados custos sociais para seus beneficiários. Os resultados também mostraram que não é possível afirmar tendências de melhora no conforto térmico e ocorrência de problemas de saúde em moradias após ampliações. Com isso, contribuem para expandir o conhecimento quanto às relações entre características construtivas de HIS horizontais em uso e o conforto térmico do ponto de vista do usuário. Ademais, subsidiam a prestação de assistência técnica alinhada às reais necessidades e prioridades de moradores de HIS em uso, com enfoque na ampliação de sua resiliência.

PALAVRAS-CHAVE: *resiliência; conforto térmico; impacto; habitação de interesse social.*

RESUMEN:

Las Viviendas de Interés Social (VIS) brasileñas, a través del programa Minha Casa, Minha Vida (PMCMV), presentan desafíos significativos en términos de estrés térmico e insalubridad, revelando una baja resiliencia climática. Un estudio de caso en Uberlândia (MG), Zona Bioclimática 4, evaluó conjuntos de viviendas de interés social (CVIS) horizontales en uso. Mediante análisis técnicos y cuestionarios de impacto, se buscó comprender la influencia del clima y diseño en el confort térmico desde la perspectiva de los usuarios. Se identificó un notable malestar térmico, con molestias considerables por calor y frío, además de problemas de salud significativos relacionados con las condiciones climáticas. Estos hallazgos respaldan la percepción de que las viviendas propician situaciones de estrés térmico, generando costos sociales elevados para sus residentes. Los resultados también sugieren que las expansiones no garantizan mejoras sustanciales en el confort térmico ni en la salud de los habitantes. Este estudio contribuye al entendimiento de las relaciones entre las características constructivas de las VIS horizontales en uso y el confort térmico desde la perspectiva del usuario. Además, respalda la implementación de asistencia técnica que aborde las necesidades y prioridades reales de los residentes, con un enfoque en fortalecer su resiliencia.

PALABRAS CLAVE: *resiliencia; confort térmico; impacto; vivenda de interés social.*

INTRODUCTION

Accelerated urban transformations have increasingly exposed the most vulnerable populations to the negative effects of climate and its changes (ELIAS-TROSTMANN *et al*., 2018). Simultaneously, horizontal Social Housing (SH) provided by the Minha Casa, Minha Vida (PMCMV) Program in Brazil has led to situations of thermal stress and unhealthiness due to their climatic inadequacy (BORTOLI and VILLA, 2020; MORENO, MORAIS and SOUZA, 2017). This, combined with lot densification resulting from unsupervised, spontaneous renovations conducted by SH users themselves, impairs ventilation and solar radiation in the homes, leading to thermal discomfort, increased energy demand, and health problems associated with the habitual experience of extreme temperatures (SIMÕES and LEDER, 2022; SIMÕES, LEDER and LABAKI, 2021; LOCHE, FONSECA and CARLO, 2018). Since natural ventilation is the main passive resource for achieving thermal comfort in Brazilian homes (BUONOCORE, 2023; NAZAROFF, 2021), its obstruction is a factor of vulnerability to climate and its rigors, especially in the context of SH (TRIANA, LAMBERTS and SASSI, 2017). Consequently, horizontal HIS in use have been dealing with climate impacts in a non-resilient manner.

Resilience is understood here as the ability of the built environment to positively handle various impacts imposed over time without losing its essence and functionality, according to certain skills that vary based on the nature of the impact (GARCIA and VALE, 2017; RODIN, 2015; PICKETT *et al*., 2014). Brazilian SH needs to be especially resilient to optimize the use of resources allocated for their production and subsequent maintenance, providing quality of life, well-being, health, and economy throughout their lifespan. This requirement translates into desirable attributes of the built environment, among which thermal comfort stands out. Research conducted by the [MORA] Housing Research group[1], from the Faculty of Architecture, Urban Planning, and Design at the Federal University of Uberlândia (FAUeD/UFU), has highlighted problems in horizontal and vertical social housing develpments in the city of Uberlândia (MG) related to the lack of this attribute (BORTOLI *et al*., 2023; VILLA *et al*., 2022). These problems are related to the physical aspects of the homes and the behaviors of their users.

In this regard, Shweiker (2020) problematizes the human behavior component in achieving resilience through thermal comfort. He emphasizes the need to shift the focus from optimal solutions limited to the physical environment to understanding the relationship between design and operation that enhances human resilience and interactions with the environment. Thus, he suggests that an association between the resilience of people and of the building itself has a direct impact on the experience of the thermal environment and the magnitude of electricity consumption to deal with the climate. As a contribution, he defines skills not only of the buildings but also of the people, which contribute to reducing exposure/vulnerability and achieving resilience through thermal comfort in the face of the climate:

- Building Resilience: Depends on the building's characteristics (thermal mass, difference between external and internal temperatures, openings, controls, etc.), which can provide resistance, robustness, and elasticity against climatic impacts.
- People's Resilience: Depends on personal characteristics (physiological, behavioral, perceived control, personality, knowledge, etc.), which can provide resistance, adaptability, and recoverability against climatic impacts.

The research group is currently developing solutions for renovations aimed at enhancing the resilience of social housing through thermal comfort[2]. It is considered that "to improve the

1 To which authors of the present study are affiliated. See more at: https://morahabitacao.com/

2 In the scope of the research "[RESILIENT HOUSE] Design strategies for promoting resilience in social housing through post-occupancy evaluation methods," ongoing from 2022 to 2025, funded by the National (CNPq) under

resilience of a system, you need to know where you are starting from – which implies measuring something" (GARCIA and VALE, 2017). Concurrently, Attia *et al*. (2021) have defined essential issues to be considered in designing thermally resilient buildings, such as: understanding the climatic impacts and events against which buildings must be resilient; the scale of the system being evaluated; the chronology and stages of resilience; the critical comfort limits and conditions of the system; and the factors that influence a building's ability to be resilient to climate, focusing on cooling capacity.

This highlights the importance of understanding the impacts to which SH (including both the residents and the physical spaces they inhabit) are subjected as a preliminary step to effectively promoting resilience. Understanding the impacts on the building and their influence on the perception of thermal comfort supports the development of intervention strategies (renovation solutions) and their appropriate prioritization, according to the identified attributes.

This understanding is achieved through Post-Occupancy Evaluation (POE), a widely used methodology to assess project quality through consistent diagnostics related to the characteristics of the built environment (ONO *et al*., 2018), which is frequently applied by the group. Consequently, an impact assessment tool entitled "impact questionnaire" (referred to as IQ) was developed by the group, aiming to measure the level of disturbance caused by various impacts on horizontal SH, thereby supporting the understanding of the impact scenario, including climate-related impacts (VILLA, BORTOLI, and VASCONCELLOS, 2023).

Thus, this article investigates the relationships between climate and the design of SH in use and the thermal comfort of its users. To facilitate this investigation, the IQ and a "supplementary impact questionnaire," referred to as SIQ, were designed and applied to residents in a case study comprising two units of analysis (YIN, 2005), the horizontal SH developments referred to as RSB and 2A4, located in the city of Uberlândia (MG), Bioclimatic Zone 4 (BZ 4), Brazil. Additionally, an analysis of the bioclimatic potential of Uberlândia in relation to the construction strategies practiced in the case study was conducted, enabling discussions.

The results provide evidence of the existence and magnitude of disturbances caused by climate in the case study, examining the relationship between the physical aspects of the housing and thermal discomfort, natural ventilation, and the emergence of health problems related to thermal stress. They contribute to the expansion of knowledge in the field, underpinning the provision of technical assistance for social housing aligned with the priorities of SH residents. This supports subsequent research stages aimed at promoting more effective climate resilience in horizontal SH of the PMCMV.

The article presents partial results of the doctoral thesis of one of the authors (BORTOLI, 2023)[3], developed within the scope of the [CASA RESILIENTE] research, linked to the Post-Graduate Program in Geography at the Federal University of Uberlândia (PPGEO/UFU).

CLIMATE, HEALTH AND THERMAL COMFORT IN HORIZONTAL SH OF THE PMCMV

The 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) warned that the world is expected to reach a temperature 1.5°C higher than pre-industrial levels within the next two decades, with urban areas being the most affected by the projected increase in global temperature averages.

Research Productivity Scholarship (PQ) number 311624/2021-9. See more at: https://morahabitacao.com/pesquisas-em-andamento-2/casa-resiliente-estrategias-projetuais-para-a-promocao-da-resiliencia-em-habitacao-social-a-partir-de-metodos-de-avaliacao-pos-ocupacao/

3 Titled: "Resilience and thermal comfort in horizontal social housing in Uberlândia (MG): evaluation for renovation guidance." See at: https://repositorio.ufu.br/handle/123456789/39335

Among the consequences for sectors such as agriculture, energy, transportation, infrastructure, among others, the anticipated impacts on human health and well-being due to climate changes in cities are particularly noteworthy.

Climate directly influences human thermal comfort, and its variations can contribute to the onset or exacerbation of illnesses. Chronic thermal discomfort can lead to the development or worsening of cardiovascular and circulatory diseases in heat, and respiratory and rheumatic diseases in cold conditions, for example (BARROS, 2021; PASCOALINO, 2013; KOVATS & HAJAT, 2008; SARTORI, 2000). At this point, the environmental quality of human habitats emerges as a social determinant of health, as their physical and material constitution can either contribute to or detract from human protection against the rigors of climate and its elements (MENDONÇA, 2021; AYOADE, 2013). Dwellings stand out as spaces where humans spend most of their time, being directly influenced by their attributes (BOTTON, 2007).

Achieving thermally comfortable homes fundamentally depends on providing qualities that enable them to positively cope with climate characteristics, without losing their essence, functionality, or demanding excessive energy, thus demonstrating resilience (GARCIA & VALE, 2017; STOCKHOLM RESILIENCE CENTRE, 2014; PICKETT *et al*., 2014; HASSLER & KOHLER, 2014; WALKER *et al*., 2004). In Brazilian SH projects, these issues are particularly relevant given the vulnerability of their beneficiaries and the fact that they are naturally conditioned structures (BUONOCORE, 2023; KHOSLA *et al*., 2020).

Housing units offered by the Brazilian governmental program *"Minha Casa, Minha Vida"* (PMCMV) have been found to neglect these issues. Recent research has shown that standard project designs and construction specifications for PMCMV housing in various Brazilian climatic regions often lead to thermal discomfort and increased energy consumption during the occupancy and operational phases, exacerbated by self-built renovations (SIMÕES & LEDER, 2022; GARREFA *et al*., 2021; SIMÕES, LEDER & LABAKI, 2021; BORTOLI & VILLA, 2020; MORENO, MORAIS & SOUZA, 2017, among others).

Simões and Leder's (2022) study correlates actual energy consumption data with spatial modifications in Brazilian SH, their internal thermal conditions, and resident behavior. The authors demonstrate that despite the social vulnerability of social housing residents, energy consumption in these buildings has increased due to climate change and the low quality of constructions, further compromising the energy security of these dwellings. Villa *et al*. (2021) analyzed the impacts of the pandemic on the satisfaction of residents in single-story houses and apartments (including SH) regarding environmental quality, family and neighbor interactions, and other residence attributes. The results indicated worsened pre-pandemic problems, notably with 16,2% expressing dissatisfaction with thermal comfort and 6.4% experiencing exacerbated discomfort during the pandemic; 12,3% were dissatisfied with natural ventilation, with a worsening perception for 3,7%.

Simões, Leder, and Labaki (2021) discussed the negative effects of self-built expansions without appropriate technical guidance on thermal comfort, exacerbated by observed trends of full lot densification. In a case study in Uberlândia (MG), Bortoli and Villa (2020) observed embryo projects and their expansions combining construction materials incompatible with the local climate (high coefficients of absorptance and thermal transmittance), such as solid concrete for walls and fiber cement without ceiling/floor for roofs. In this scenario, more than half of the residents interviewed by the authors rated their homes as hot during the spring-summer period, with 70% of participating households using fans, humidifiers, and/or air conditioners.

Meanwhile, Moreno, Morais, and Souza (2017), in a study covering the primary materials used in PMCMV housing developments across the country, found that solid concrete walls failed to meet approval under any Brazilian thermal performance evaluation standards in any

Brazilian Bioclimatic Zone (BZ), whereas concrete tile roofs with PVC ceilings were approved only for BZ 1, where the climate is predominantly cold. Concurrently, ceramic block walls with internal and external plaster were approved in BZs 1, 2, 3, 5, and 8, and ceramic tile roofing with PVC ceilings was approved only in BZ 8.

For instance, horizontal SH projects offered by PMCMV favor vulnerability to climate conditions from the outset. The delivered buildings also hinder renovation efforts due to their floor plan characteristics, lot placement, room sectorization, and load-bearing masonry structure. Compounding this issue, residents have limited access to architecture and urbanis planning information and services for renovation guidance, worsening the environmental quality of occupied housing, especially post-transformation.

In-use horizontal SH units, conceived and spontaneously transformed without consideration for climate characteristics and the needs and priorities of local populations, can lead to thermally uncomfortable environments for their users. These environments interact unintentionally and often unfavorably with external atmospheric elements, notably solar radiation and natural ventilation. The resulting discomfort not only increases energy consumption to rectify thermal conditions but also contributes to health problems associated with habitual exposure to extreme temperatures, reducing the resilience of both homes and people to climatic challenges.

Since 2008, the "ATHIS" Law[4] (Number 11.888) has ensured low-income families' right to free technical assistance for building or renovating SH. However, its effective implementation remains limited. Given this scenario, there is a need to expand knowledge on the relationships between climate and structural characteristics of in-use horizontal social housing, aiming to substantiate the provision of effective technical assistance, prioritizing resilience achievement.

MATHERIALS AND METHODS

Uberlândia is located in the mesoregion of Triângulo Mineiro and Alto Paranaíba, State of Minas Gerais, Southeast Region of Brazil, recognized nationally as an important wholesale hub. Positioned geographically at coordinates 18° 55' South and 48° 17' West, the city experiences a moderate temperature range due to its altitude of approximately 865 meters. The average annual temperature from 2010 to 2020 was around 23,4°C. Over the past forty years, recorded maximum and minimum temperatures were 38,5°C in 2020 and 1,0°C in 1981, respectively (SEPLAN, 2021). According to the Köppen classification, universally adopted and adapted for Brazil, the municipality falls under the "Aw" climate classification: A - Mesothermal (hot year-round, with average temperature of the coldest month above 18°C); w - Summer rainfall (KOTTEK *et al*., 2006).

Bioclimatic potential of Uberlândia (MG)

Applying Guarda's methodology (2019) for processing climatic data, it was possible to obtain the bioclimatic diagram of Uberlândia city[5], as depicted in Figure 1, and its subsequent reports.

The data obtained indicate that Uberlândia (MG) is thermally comfortable for the majority of the year (59,1% of the time), with heat discomfort prevailing 29,4% of the time. Natural ventilation emerges as the primary recommended passive cooling strategy during these discomfort periods, applicable 28,2% of the time. Thermal inertia is another crucial strategy,

4 The acronym “ATHIS”, in Portuguese, translates to "Technical Assistance for Social Interest Housing."

5 The diagram was produced using the Analysis BIO software from LabEEE/UFSC, based on Guarda's methodology (2019) and the file "BRA_MG_Uberlandia-Bombonato.AP.835250_TMYx. 2007-20211", obtained from https://climate.onebuilding.org/. Accessed in February 2022.

utilized for both cooling (10,1%) and heating (10,9%), leveraging the thermal capacity of building materials[6]. Especially during the hottest and driest periods of the year, daytime ventilation can inadvertently introduce thermal gains, underscoring the significant role of thermal inertia as a heat barrier. Evaporative cooling (10,1%), facilitated by vegetation and urban waters among other building features, is frequently recommended during heat conditions for integration at the site scale.

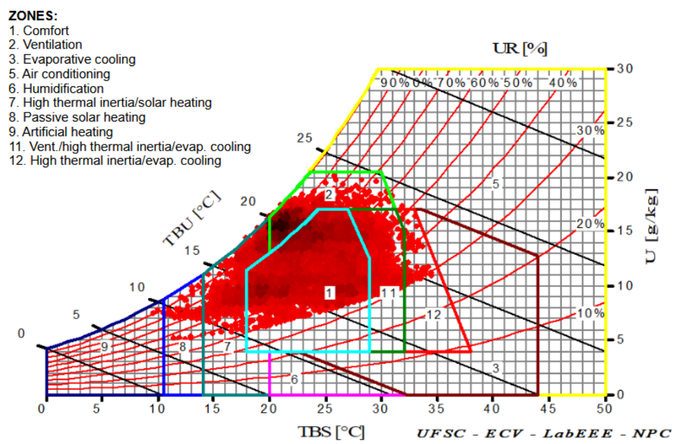


Figure 1. Givoni's bioclimatic chart for Uberlândia (MG) .

Source: Authors, adapted from *Software* Analysis BIO (LabEEE/UFSC) and Guarda (2019).

- Overall comfort/discomfort analysis:
  >> Comfort: 59%
  >> Discomfort: 41%
  -Heat: 29,4%
  -Cold: 11,6%

- Recommended bioclimatic strategies for heat:
  >> Ventilation: 28,2%
  >> High thermal inertia for cooling: 10,1%
  >> Evaporative cooling: 10,1%
  >> Air conditioning: 0,0228%

- Recommended bioclimatic strategies for cold:
  >> High thermal inertia/solar heating: 10,9%
  >> Passive solar heating: 0,685%
  >> Artificial heating: 0,0228%
  >> Humidification: 0%

The NBR 15220-3 (ASSOCIAAÇÃO..., 2005) recommends compatible construction guidelines for locations in Bioclimatic Zone 4 (BZ 4): medium ventilation openings (15% to 25% of floor area); shaded openings; heavy walls (U ≤ 2.20; φ ≥ 6.5; FSo ≤ 3.5); light and insulated roofs (U ≤ 2.00; φ ≥ 3.3; FSo ≤ 6.5); in summer, evaporative cooling, thermal inertia for cooling, and selective ventilation (during hot periods when indoor temperatures exceed outdoor temperatures); in winter, solar heating of the building and heavy internal seals (thermal inertia). For ZB 4, NBR 15575 (ASSOCIAÇÃO..., 2021) recommends TC ≥ 130 kJ/m².K. This highlights the importance of solar protection for openings, selective admission of natural ventilation, thermal and optical properties of building materials, and urban vegetation in achieving passive thermal comfort in buildings located in Uberlândia (MG), ZB 4.

Design aspects of the case study

The city of Uberlândia exhibits a pattern of dispersed growth, resulting in neighborhoods that are difficult to access for low-income populations, such as Shopping Park (in the southern extreme) and Pequis (in the southwest extreme), where access by private vehicle can take up

6 The thermal property associated with thermal inertia is thermal capacity (TC), which refers to the amount of heat required to change the temperature of a system by one unit, measured in kJ/m².K. Components with high thermal capacity have greater thermal inertia, making them suitable for the use of thermal inertia for cooling (ASSOCIAÇÃO..., 2005).

to 36 minutes from the city center (MELO and SAMPAIO, 2014; SANTOS, 2019).

These areas host the Residential Sucesso Brasil (RSB) and the residential 2A4, respectively, both SH developments selected as units of analysis under the PMCMV (SAMPAIO, SABADINI, and KOLLER, 2022; YIN, 2005).

The RSB and 2A4 represent different phases of the PMCMV in Uberlândia, with one delivered between 2010/2011 and the other between 2016/2017, respectively. They are similar in that they are both horizontal developments aimed at the former income bracket 1 (0 to 3 minimum wages[7]). Based on project documentation provided by the Municipality to the research group, it was possible to analyze the design aspects of the housing units. According to Weber *et al*. (2017), Dornelles (2008), Dornelles (2021), and Associação... (2005), it was analytically verified that the vertical sealing systems exhibit differences among them, namely:

2A4	**RSB**
Cast-in-place concrete 10 cm, without mortar, absorptance 0.411, TC = 240 kJ/(m^2.K), and U = 4.4 W/(m^2.K)	Ceramic block 19 cm - brick 12x19x19 + internal and external mortar (absorptance 0.11 to 0.29), TC = 153 kJ/(m^2.K) and U = 2.37 W/(m^2.K)

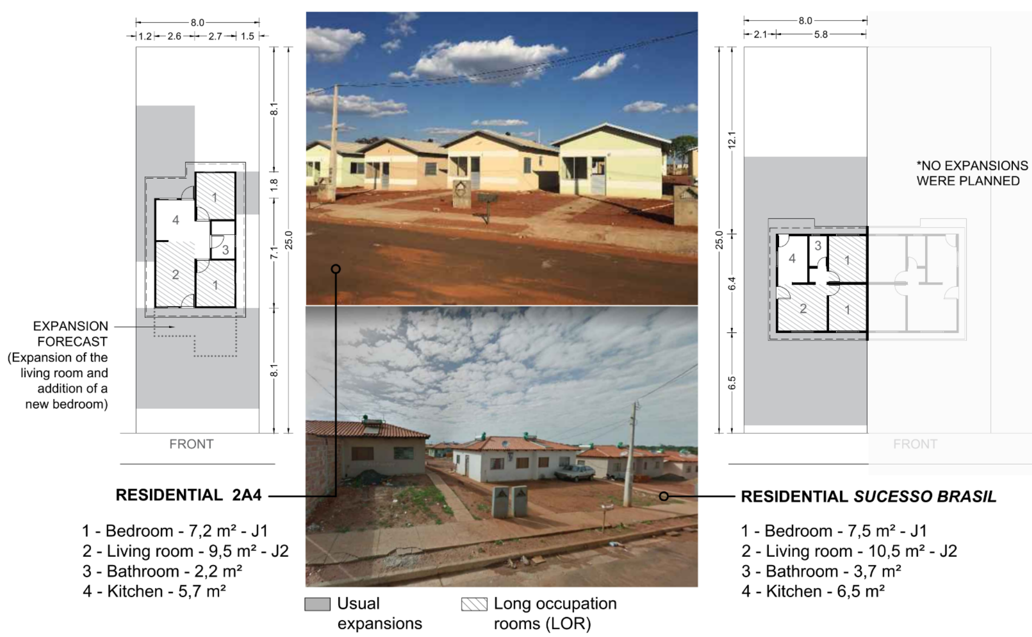


Figure 2. General characteristics of the SH units under analysis.

Source: Authors.

The roofing systems also differ, with ceramic tiles and PVC lining in RSB (U = 1.75 W/(m^2.K)) and concrete tiles with PVC lining in 2A4 (U = 1.75 W/(m^2.K)). Additionally, the layout strategy in the former consists of semi-detached houses, while in the latter, houses are detached within the plot (Figure 2). It is noted that neither meets the thermal transmittance limit for walls (U ≤ 2.20 W/(m^2.K)) (ASSOCIAÇÃO..., 2005). The thermal capacity of both systems meets the recommended threshold (≥ 130 kJ/m^2.K), with significantly higher capacity in 2A4, enhancing the thermal inertia of its housing units compared to RSB.

Based on on-site photographs and Annex II of RTQ-R (INMETRO, 2012), as well as Telles (2016), the effective ventilation areas for the window models used in long occupancy areas (LOR), namely bedrooms and living rooms, were also identified (Figure 3).

7 The minimum wage in Brazil in 2010 was R$ 510,00. In 2016, it was R$ 880,00.

Figure 3. Windows characteristics

Source: Authors.

It is observed that in both developments, the percentage of openings for ventilation recommended by NBR 15220-3 is not achieved, although in 2A4 these percentages are higher compared to RSB. Furthermore, it is noted that shading of openings is not a design strategy, further exposing these dwellings and their occupants to the rigors of the climate.

POE Instruments

An impact assessment was conducted on both units of analysis, identifying their thermal comfort issues stemming from the interplay between climate and design. This evaluation includes POE instruments that gather contextual information at the community, dwelling/plot, and resident opinion levels, denoting and measuring the impacts of climate on the housing system: IQ (Impact questionnaire) and SIQ (Supplementary impact questionnaire). Figure 4 illustrates the aspects assessed by IQ.

The IQ was structured around major causes of impacts, threats, and their related negative effects. The primary cause of impact addressed here is the climate and its elements (thermal radiation, ventilation, humidity, rainfall). The threats associated with this major cause include intense rainfall, prolonged drought/dry periods, heatwaves, cold waves, gusts of wind, disruptions in water and energy supply. The negative effects on homes and families range from leaks and infiltrations to discomfort due to heat and cold indoors, leading to health problems and increased energy bills as a result of thermal discomfort (VILLA *et al*., 2022).

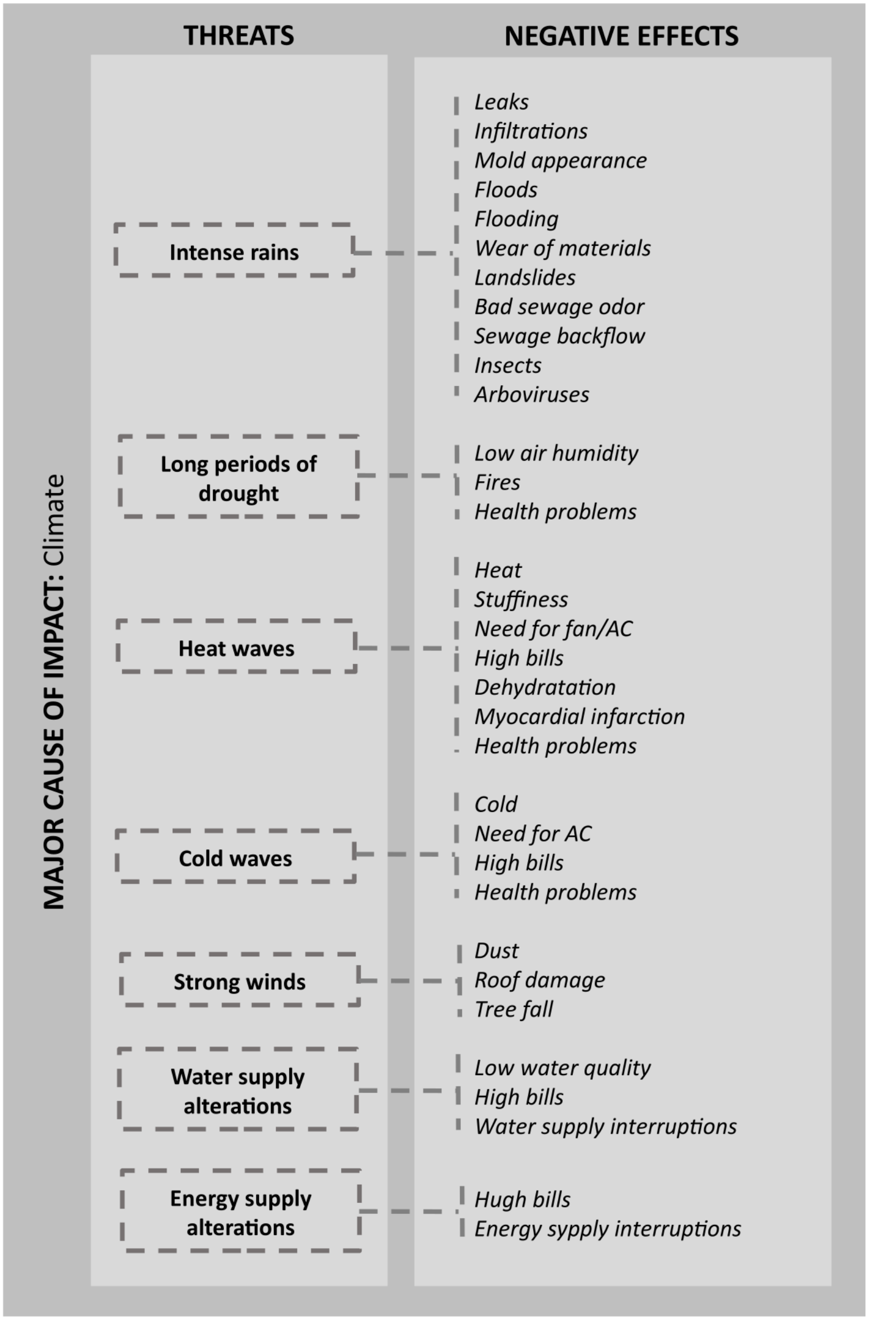


Figure 4. Aspects evaluated by IQ.

Source: Authors.

The SIQ complements the IQ assessment by measuring residents' perceptions regarding temperature and ventilation sensations and satisfaction, which characterize the thermal environment within homes. Additionally, it enables a comprehensive survey of expansions and their types. Its main references include perception questionnaires regarding satisfaction and thermal sensation used in Standard 55 (ASHRAE, 2014), as recommended by Lamberts *et al*. (2013) for evaluating comfort in existing buildings. The SIQ assesses the presence of health problems caused by cold and heat and existing illnesses, based on the terminologies adopted by the notification forms of the Brazilian Information System for Notifiable Diseases (SINAN, 2016). It also surveys general construction characteristics of homes and their expansions. Frame 1 provides further details on the impact assessment instruments.

Instruments	Informations
Impact questionnaire (IQ)	**Objective:** Evaluate residents' perception of disturbance caused by climate impacts interacting with housing design, manifested in terms of negative effects on both the house and people's health. Standardized indices first assess the perception of negative effects (if "yes" or "no"), and subsequently, the level of disturbance they cause (such as "little", "much", or "none"). **Aspects evaluated:** Negative effects caused by heat waves and cold waves, intense rains and droughts, wind gusts, impacts on health and utilities, and costs of water and energy. **Number of questions:** 37
Supplementary impact questionnaire (SIQ)	**Objective:** Evaluate residents' perception regarding thermal environment quality, health conditions, and housing construction characteristics. It uses a 7-point scale to assess thermal sensation and simplified indices to measure satisfaction with ventilation (such as "little", "sufficient", or "much") and overall satisfaction (such as "satisfied" or "unsatisfied") for both aspects evaluated. Indices vary for health assessment and housing construction characteristics. **Aspects evaluated:** sensation and satisfaction with temperature and airflow, climate effects on health and pre-existing health conditions, and housing expansion patterns. **Number of questions:** 12
For both	**Approach:** Quantitative (closed-ended questions). **Sample universe:** 383 lots (RSB – 175, 2A4 – 208). **Sampling[8]:** 106 houses (53 in each development) – 27.7% of the universe, sampling error of 8.15%. **Selection criteria:** Expanded and non-expanded houses with varied solar orientations – convenience random sampling. **Data collection method:** Printed paper questionnaires. **Application period:** February – May 2022.

Frame 1. Detailing of information about instruments

Source: Authors.

Both questionnaires together advance the understanding of the consequences resulting from environmental exposure and the vulnerability of individuals to climate impacts. They were duly reviewed and approved by the Research Ethics Committee involving human subjects (CEP/CONEP/UFU), under protocol number CAAE 56151522.3.0000.5152, following a pilot test involving 20 participants in December 2021.

Inferential analyses were conducted by cross-referencing results from the IQ and SIQ instruments, associating residents' perceptions regarding temperature, health issues, and the implementation of expansions. The Shapiro-Wilk test was used to assess normality, and for variables with normal distribution, the t-Student test was applied to compare groups; otherwise, the Mann-Whitney test was used (ZAR, 1999).

RESULTS AND DISCUSSION

In 2A4, the climate-related threats most perceived by residents are prolonged periods of drought (with 69,9% of respondents perceiving their negative effects), intense rains (69%), and heatwaves (62,8%). In RSB, drought is also the most perceived threat (with 62,5% responses), followed by cold waves (62,2%) and intense rains (59,6%). In both developments, other threats are perceived by the majority of respondents but at a lower frequency than those listed above (Frame 2).

8 Defined by Prof. Dr. Lúcio Borges de Araújo, faculty member at the Faculty of Mathematics (FAMAT) of the Federal University of Uberlândia (UFU).

Cause (major event): CLIMATE									
Threats	Negative effects on the house and family	Perceives the effect		Level of disturbance					
		2A4	RSB	2A4			RSB		
		Yes (%)		Little	Much	None	Little	Much	None
Intense rains	Leaks	87,8	85,2	14,0	69,8	16,3	10,9	82,6	6,5
	Infiltrations	73,5	72,2	11,1	52,8	36,1	7,7	71,8	20,5
	Mold appearance	65,3	70,4	6,3	37,5	56,3	18,4	57,9	23,7
	Floods	59,2	48,2	6,9	24,1	69,0	19,2	34,6	46,2
	Flooding/water accumulation on the lot (including the sidewalk)	73,5	55,6	8,3	41,7	50,0	10,0	60,0	30,0
	Wear of materials (roof tiles, ceilings, walls, coverings, floors/paving – on the lot and sidewalks)	71,4	59,3	11,4	42,9	45,7	21,9	53,1	25,0
	Landslides	49,0	29,6	0,0	4,2	95,8	0,0	12,5	87,5
	Bad odor coming from the sewage system and or storm/drainage	63,3	61,1	12,9	41,9	45,2	9,1	66,7	24,2
	Sewage backflow into the sanitary system	63,3	51,9	9,7	32,3	58,1	3,6	39,3	57,2
	Insects appearance	87,8	75,9	30,2	53,5	16,3	19,5	73,2	7,3
	Occurrence of arboviruses (dengue, Zika virus, chikungunya, etc)	65,3	46,3	9,4	28,1	62,5	24,0	32,0	44,0
	Average	**69,0**	**59,6**	**10,9**	**39,0**	**50,1**	**13,1**	**53,1**	**33,8**
Long periods of drought	Low air humidity ("dryness")	67,4	69,2	21,2	48,5	30,3	30,6	50,0	19,5
	Fires	75,5	67,3	13,5	67,6	18,9	11,4	74,3	14,3
	Health problems due to air "dryness"	69,4	59,6	11,8	44,1	44,1	19,4	67,7	12,9
	Worsening/emergence of respiratory problems	67,4	53,9	42,4	15,2	42,4	10,7	60,7	28,6
	Average	**69,9**	**62,5**	**22,2**	**43,8**	**33,9**	**18,0**	**63,2**	**18,8**
Heat waves	Heat inside the house	75,5	71,2	10,8	73,0	16,2	16,2	62,2	21,6
	Stuffiness in rooms (heat + humidity)	73,5	61,5	8,3	58,3	33,3	15,6	56,3	28,1
	Need for fan or humidifier	79,6	75,0	30,8	43,6	25,6	18,0	64,1	18,0
	Need for aird conditioning	57,1	44,2	0,0	25,0	75,0	13,1	30,4	56,5
	High water/electricity bills	67,4	75,0	12,1	75,8	12,1	7,7	84,6	7,7
	Occurrence of dehydratation	49,0	42,3	8,3	8,3	83,3	9,1	13,6	77,3
	Occurrence of myocardial infarction	49,0	40,4	0,0	0,0	100,0	19,1	4,8	76,2
	Occurrence of other health problemsdue to heat	51,0	42,3	4,0	8,0	88,0	4,6	31,8	63,6
	Average	**62,8**	**56,5**	**9,3**	**36,5**	**54,2**	**12,9**	**43,5**	**43,6**
Cold waves	Cold inside the house	61,2	67,3	20,0	13,3	66,7	31,4	51,4	17,2
	Need for heater	51,0	46,2	4,0	0,0	96,0	8,3	25,0	66,7
	Need to use electric shower in winter mode	61,2	75,0	13,3	26,7	60,0	23,1	43,6	33,3
	High water/electricity bills	63,3	73,1	19,4	74,2	6,5	15,8	79,0	5,3
	Increase in body pains	61,2	63,5	13,3	30,0	56,7	3,0	63,6	33,3
	Occurrence of other health problems due to cold	59,2	48,1	6,9	17,2	75,9	8,0	32,0	60,0
	Average	**59,5**	**62,2**	**12,8**	**26,9**	**60,3**	**14,9**	**49,1**	**36,0**
Wind gusts (strong winds)	Dust / soot / particulate matter inside the house (dirt)	87,8	69,2	9,3	60,5	30,2	8,3	77,8	13,9
	Roof damage / ceiling collapse	49,0	57,7	0,0	12,5	87,5	6,7	66,7	26,7
	Tree fall	49,0	36,5	0,0	0,0	100,0	10,5	0,0	89,6
	Average	**61,9**	**54,5**	**3,1**	**24,3**	**72,6**	**8,5**	**48,2**	**43,4**
Water supply alterations	Low water quality at the tap	55,1	40,4	11,1	11,1	77,8	9,5	19,1	71,4
	Increase in water bill costs	57,1	76,9	14,3	46,4	39,3	15,0	67,5	17,5
	Water supply interruptions	69,4	46,2	14,7	32,4	52,9	16,7	33,3	50,0
	Average	**60,5**	**54,5**	**13,4**	**30,0**	**56,7**	**13,7**	**40,0**	**46,3**
Energy supply alterations	Increase in energy bill costs	65,3	69,2	9,4	75,0	15,6	8,3	83,3	8,3
	Energy sypply interruptions	65,3	63,5	9,4	25,0	65,6	24,3	57,6	18,2
	Average	**62,1**	**58,4**	**12,0**	**36,6**	**51,3**	**14,6**	**50,1**	**35,3**

Frame 2. Perception of disturbance according to incident threats and their negative effects.

Source: Authors.

In 2A4, among those who perceive the threats (response to perception "yes"), it is observed that many are not bothered (response to disturbance "none"). On the other hand, among those who are bothered, extreme responses prevail (response to disturbance "very"), with 43,8% highly bothered by prolonged droughts, 39% by intense rains, and 36,5% by heatwaves. In RSB, the proportion of people perceiving the effects but reporting no disturbance is lower compared to 2A4 (on average 36,7% vs. 54,2% in 2A4). Conversely, the number of extreme responses is higher (on average 49,6% responding "very" in RSB vs. 33,9% in 2A4). Prolonged periods of drought are the most extreme disturbance-inducing effect in RSB, with 63,2%, followed by intense rains at 53,1% and cold waves at 49,1% highly bothered.

On average, a higher percentage of people perceive the existence of negative effects in residential 2A4, at 63,7% compared to 58,3% in RSB. However, in 2A4, the average number of people who are not disturbed is considerably higher than in RSB (54,2% vs. 36,7% in RSB). This may be due to the fact that residential 2A4 was delivered more recently than RSB (between 2016 and 2017), which may contribute, on one hand, to the perceived severity of problems being lower (due to them being still "recent"). Additionally, the exposure time and recurrence of problems tend to be shorter in 2A4, whereas in RSB, people have been living with issues for over a decade (houses delivered between 2010 and 2011), which may intensify their perception of disturbance in general.

Regarding thermal comfort (focus of the study), there is an interesting difference between the two developments. While in 2A4 the perception of heatwaves is more frequent (with an average of 62,8% of respondents perceiving their negative effects), in RSB it is cold waves that are most perceived (by 62,2%). Specifically, disturbance due to heat indoors reaches 83,78% in 2A4, compared to 78,4% in RSB (combining perceptions as much and little). Conversely, the sensation of cold indoors bothers 33,3% in 2A4 and 82,8% in RSB.

In summary, it is observed that in 2A4, more people are impacted by the investigated negative effects of the climate, although among these, fewer feel bothered by them. In RSB, the number of people perceiving negative effects is slightly lower compared to 2A4, but among these, those who feel bothered (much or little) predominate, in a greater frequency than observed in 2A4. The fact is that in both neighborhoods, the majority of residents perceive the existence of the investigated negative effects (on average 63,7% in 2A4 and 58,3% in RSB), and a considerable number feel bothered (either much or little) by them (on average 45,8% in 2A4 and 63,3% in RSB), indicating the existence of exposure and vulnerabilities, whether physical or personal, which tend to make the built environment of these SH less resilient to dealing with climate in cities.

From the supplementaru impact questionnaire, knowledge about thermal comfort in the case study was deepened. It was found that in both neighborhoods, the sensation regarding ventilation in the LORs is similar, with most residents finding it sufficient (2A4 – 47,8% and RSB – 48,4%, on average). However, the number of people who evaluated ventilation as insufficient in the LORs is also considerable, totaling 42,1% in 2A4 and 44,0% in RSB. Additionally, a smaller number of people think ventilation is excessive - a total of 10,1% in 2A4 and 7,5% in RSB (Frame 3).

Although in RSB the number of people who find ventilation sufficient in the LORs is slightly higher than in 2A4 (RSB – 48,4% and 2A4 – 47,8%, on average), it is observed in Frame 4 that in RSB the number of people dissatisfied with ventilation is considerably higher (RSB – 36,48% and 2A4 – 28,3%, on average). In both neighborhoods, dissatisfaction with ventilation is higher in bedrooms (Frame 4). Overall, satisfaction with ventilation in both sets is higher than dissatisfaction. This shows that, although the effective ventilation areas of the window models offered in both developments are below what is recommended by NBR15220-3 (Figure 3), this is not yet a priority issue in the case study.

	2A4 (%)			RSB (%)		
Feeling with ventilation:	Little	Sufficient	Much	Little	Sufficient	Much
In the living room	43,40	47,17	9,43	37,74	49,06	13,21
In the front bedroom	45,28	45,28	9,45	47,17	47,17	5,66
In the back bedroom	37,74	50,94	11,32	47,17	49,06	3,77
Average	42,14	47,80	10,07	44,03	48,43	7,55

	2A4 (%)		RSB (%)	
Satisfaction with ventilation:	Dissatis.	Satisf.	Dissatis.	Satisf.
In the living room	24,53	75,47	30,19	69,81
In the front bedroom	30,19	69,81	37,74	62,26
In the back bedroom	30,19	69,81	41,51	58,49
Average	28,30	71,70	36,48	63,52

Frame 3. Perception of ventilation (above).

Frame 4. Satisfaction with ventilation (below).

Source: Authors.

In Frames 5 and 6, it is observed that thermal sensation during summer in the living spaces (LORs) of houses, for both developments, is predominantly perceived as warm (averaging responses for slightly warm, hot, and very hot, yields 2A4 – 88,0% and RSB – 92%). Among those who feel warmth, the majority perceive it as very hot in both developments (2A4 – 55,3% and RSB – 59,3%, on average). In winter, the situation differs slightly, with residents of RSB feeling cold 69.2% of the time, among whom "very cold" responses were given 39% of the time, on average for the LORs. Thermal neutrality occurs with 28,9% of residents during winter in RSB. In contrast, in 2A4, there is a feeling of cold for only 30,18% of respondents, on average, with a predominance of neutral thermal sensation in the LORs, accounting for 61,6% of responses. In both developments, there were also responses indicating a slight feeling of warmth during winter, 6,3% of responses in 2A4 and 2% in RSB, on average.

	2A4 (%)						
Temperature Sensation (Summer):	Extremely cold	Cold	Slightly cold	Neutral	Slightly warm	Hot	Extremely hot
In the living room	0,00	0,00	0,00	15,09	16,98	15,09	52,83
In the front bedroom	0,00	0,00	0,00	11,32	16,98	16,98	54,72
In the back bedroom	0,00	0,00	0,00	9,43	16,98	15,09	58,49
Average	0,00	0,00	0,00	11,95	16,98	15,72	55,35
Temperature Sensation (Winter):	Extremely cold	Cold	Slightly cold	Neutral	Slightly warm	Hot	Extremely hot
In the living room	15,09	3,77	11,32	62,26	5,66	0,00	1,89
In the front bedroom	15,09	3,77	11,32	62,26	5,66	0,00	1,89
In the back bedroom	15,09	3,77	11,32	60,38	7,55	0,00	1,89
Average	15,09	3,77	11,32	61,63	6,29	0,00	1,89

Frame 5. Thermal sensation in summer and winter – 2A4.

Source: Authors.

	RSB (%)						
Temperature Sensation (Summer):	Extremely cold	Cold	Slightly cold	Neutral	Slightly warm	Hot	Extremely hot
In the living room	0,00	0,00	1,89	5,66	15,09	20,75	56,60
In the front bedroom	0,00	0,00	0,00	5,66	13,21	18,87	62,26
In the back bedroom	0,00	0,00	1,89	9,43	13,21	16,98	58,98
Average	0,00	0,00	1,26	6,92	13,84	18,87	59,28
Temperature Sensation (Winter):	Extremely cold	Cold	Slightly cold	Neutral	Slightly warm	Hot	Extremely hot
In the living room	39,62	16,98	11,32	30,18	1,88	0,00	0,00
In the front bedroom	37,73	13,20	16,98	30,18	1,88	0,00	0,00
In the back bedroom	39,62	15,10	16,98	26,41	1,88	0,00	0,00
Average	38,99	15,09	15,09	28,92	1,88	0,00	0,00

Frame 6. Thermal sensation in summer and winter - RSB.

Source: Authors.

In summary, the results suggest that in RSB, households are more susceptible to temperature variations, possibly due to self-shading provided by the semi-detaching of bedrooms which reduces the contribution of solar radiation to heating the house as a whole during winter. Nevertheless, thermal neutrality is observed for a considerable number of respondents in RSB (28,9% on average).

	2A4 (%)	RSB (%)
Health issues caused by heat/type:	85,87	70,73
Skin allergy	2,17	3,66
Respiratory allergy	8,70	7,32
Asthma	2,17	0,00
Difficulty breathing	5,43	2,44
Extreme tiredness	11,96	4,88
Flu/colds	3,26	2,22
Lethargy	17,39	13,41
Discomfort	22,83	19,51
Increased blood pressure	1,09	1,22
None	14,13	29,27
Health issues caused by cold/type:	53,62	56,25
Increased blood pressure	18,52	19,30
Body aches	7,25	7,81
Respiratory allergy	15,94	9,38
Flu/colds	10,14	15,63
Lethargy	2,90	9,38
Discomfort	7,25	4,69
None	46,38	43,75

Frame 7. Occurrence of health problems caused by heat/cold.

Source: Authors.

	2A4 (%)	RSB (%)
Pre-existing health issues:	42,59	49,12
Diabetes	5,6	3,5
Heart diseases	18,5	19,3
Joint diseases	0,0	3,5
Autoimmune diseases	0,0	1,8
Respiratory diseases	11,1	8,8
Other	7,4	12,3
None	57,4	50,9

Frame 8. Previous health problems.

Source: Authors.

	2A4 (%)	RSB (%)
Units that undewent expansion/type:	63,8	94,4
Covered front area	26,4	1,1
Covered back area	35,8	40,9
Covered side area	0,0	21,5
New room at the front	9,4	6,5
New room at the back	24,5	24,7

Frame 9. Types of expansions.

Source: Authors.

In 2A4, the results indicate that houses respond better to cold than in RSB, due to their high thermal capacity and thus greater inertia (see case study section for details). This characteristic is less advantageous in summer for ZB 4, given the high number of people who perceive the heat as very intense in this development during this period (55,3%). Additionally, in 2A4, higher percentages of open areas for ventilation in the LORs contribute, on one hand, to greater satisfaction with ventilation and thus a greater potential for natural cooling. On the other hand, the increased ventilation availability, combined with high thermal capacity of walls, contributes to heat sensation being nearly as frequent in 2A4 as it is in RSB, where the windows open areas are smaller. These findings provide clues about the complexity of interactions between thermal properties, building geometry (design), and climate in promoting thermal comfort, issues that go beyond the scope of this study.

Concerningly, a significant number of people reported health problems in both developments due to heat sensation, being 85,9% in 2A4 and 70,7% in RSB (Frame 7). Cold also leads to undesirable health situations, albeit temporary, affecting 46,38% of respondents in 2A4 and 43,7% in RSB. The main heat-related problems in both developments are malaise (2A4 – 22,8% and RSB – 19,5%) and lethargy (2A4 – 17,4% and RSB – 13,4%), while during cold, increased blood pressure (2A4 – 18,5% and RSB – 19,3%), respiratory allergies (2A4 – 15,9% and RSB – 9,4%), and flu/colds (2A4 – 10,1% and RSB – 15,6%) are prominent. Analyzing pre-existing diseases (Frame 8), it was observed that in both developments, a significant number of people have heart diseases (2A4 – 18,5% and RSB – 19,3%) and respiratory diseases (2A4 – 11,1% and RSB – 8,8%).

The supplementary impact questionnaire also conducted an initial assessment of the extent of expansions in the complexes (Frame 9). It was found that in 2A4, 63,8% underwent expansion, whereas in RSB, this number is considerably higher (reaching 94,4%). Thus, there is a trend towards expansions in the houses, consistent with the time elapsed since the delivery of the development to users (RSB between 2010/11 and 2A4 between 2016/17). It is observed that the higher density of lots in RSB, coupled with the semi-detached embryo characteristic, reduces the house's porosity to ventilation, favoring situations of extreme heat (Figures 5 and 6).

Figures 5 e 6. Example of SH in RSB, where there was high lot density combined with the pairing of the embryo (front and back, respectively).

Source: Authors.

Figures 7 e 8. Example of SH in 2A4, where it is possible to observe the use of concrete tiles and the isolated implantation of the embryo in the lot (front and back, respectively).

Source: Authors.

In 2A4, despite lower density and a more favorable detached typology for lot ventilation, the use of solid concrete in walls and concrete tiles + PVC ceiling (Figures 7 and 8) contribute to the embryos being perceived as very hot. During technical analysis visits and questionnaire performance, attention was also drawn to the high degree of land impermeabilization, simultaneous with the suppression of permeable areas and vegetation. Consequently, these transformations impair the environmental quality of the surroundings, leading to negative repercussions on human thermal comfort.

Through inferential analyses, it was observed that in non-expanded houses, the proportion of individuals bothered by heat averages 51,9% across both developments, compared to 57,1% in expanded houses (p = 0,49 to 0,50). Similarly, discomfort due to cold in non-expanded houses averages 25,45%, compared to 41,7% in expanded houses (p = 0,39 to 0,56).

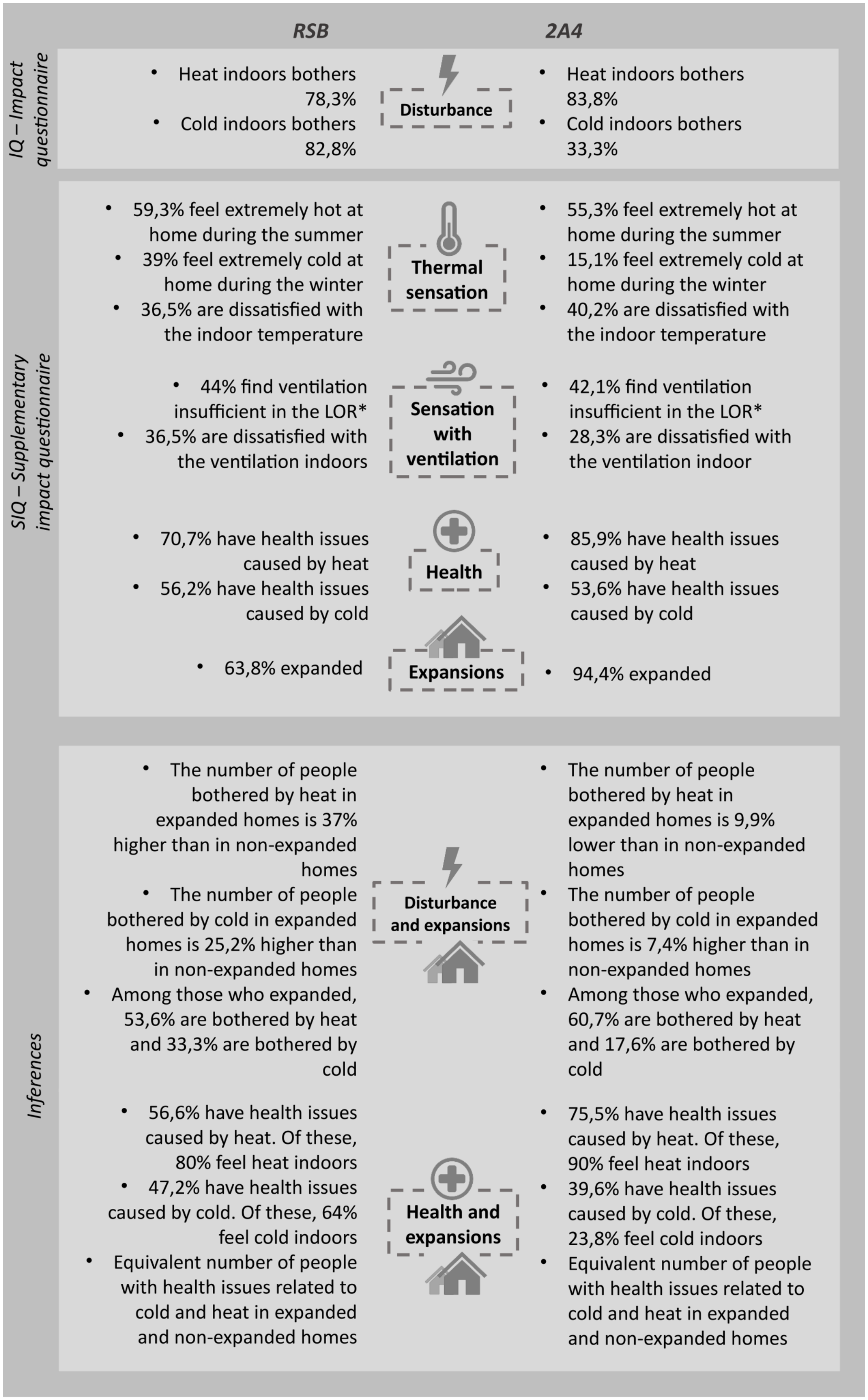
Regarding the relationships between thermal sensation, health, and expansions, among those experiencing heat indoors (average 83,9% in both developments), an average of 67,2% reported experiencing heat-related health problems (p = 0,08 to 0,49). Concerning cold sensation, among those experiencing it (48,1% on average), 38,5% reported cold-related health issues (p = 0,41 to 0,77). In both developments, the occurrence of health problems related to heat and cold does not show a significant relationship with the implementation of expansions, as the proportion of people who have and have not expanded their houses is equivalent among those experiencing health issues and those who are not.

These results indicate that trends of improvement in thermal sensation and occurrence of health problems in expanded houses cannot be conclusively affirmed—often, there is a worsening instead. This reveals an underutilization of resources when interventions without technical assistance are carried out, which should ideally aim for significant improvements in various aspects of housing quality, including thermal comfort and environmental health, especially critical in the context of SH where resources are limited and users are more vulnerable (SIMÕES, LEDER, & LABAKI, 2021).

Therefore, the thermal comfort situation of these residents in their housing context does not support the management of pre-existing health conditions, given the observed association between habitual experiences of excessive heat and cold and the emergence of respiratory and cardiovascular problems (BARROS, 2021; PASCOALINO, 2013; KOVATS & HAJAT, 2008; SARTORI, 2000). Hence, although many of the health issues observed may be transient, they remain concerning as they can trigger more significant health issues (MENDONÇA, 2021; AYOADE, 2013).

Thus, attention to thermal comfort as a resilience attribute in new projects and renovations in SH is crucial, involving technical specifications appropriate to the local climate (ASSOCIAÇÃO…, 2003; MORENO, MORAIS, & SOUZA, 2017). This is a public health issue with social costs affecting society as a whole. Additionally, there are environmental costs associated with the trend towards mechanized solutions for thermal environment correction (SIMÕES & LEDER, 2022; ELIAS-TROSTMANN *et al*., 2018).

Finally, Figure 9 summarizes the findings, providing evidence regarding the relationships between climate, design characteristics of SH developments in the case study, and their implications for user health and thermal comfort.



*LOR – Long occupied rooms

Figure 9. Synthesis of findings.

Source: Authors.

CONCLUSION

Based on the results obtained, it was found that thermal discomfort is a significant issue perceived in the case study, with considerable disturbance related to both heat and cold in the two analyzed areas. Additionally, a high frequency of health issues caused by heat and cold was observed, reinforcing the perception that the housing units in use have fostered situations of thermal stress and imposed high social costs on their beneficiaries.

Aspects related to the materiality and geometry of the houses were inferred to contribute to the low quality of the thermal environment experienced in both units of analysis, emphasizing issues such as the choice of construction materials and lot occupation strategies (for both the original unit and subsequent expansions) designed in accordance with climate characteristics to achieve thermal comfort.

It was noted that the relationship between climate and thermal comfort is worse in the 2A4 due to technical specifications of the housing units, notably the use of *in situ* molded solid concrete walls with a thermal transmittance of U = 4,4 W/(m^2.K), whereas the recommended value for Zone 4 would be U ≤ 2,00 W/(m^2.K). This characteristic, coupled with the high thermal capacity of walls (240 kJ/(m^2.K)) and larger effective ventilation area compared to the RSB, favors greater thermal gains through radiation and convection, justifying the high level of discomfort due to heat observed in this complex - 89,2% compared to 83,8% in the RSB. During the research, the high degree of soil sealing and the absence of shading devices on openings also drew attention in both complexes.

On the other hand, the expansion of houses did not have a positive impact on thermal comfort and the occurrence of health problems, indicating that interventions carried out spontaneously by residents, without proper technical assistance, lead to suboptimal use of limited resources. Ultimately, the findings explored relationships between thermal comfort and the design of horizontal SH under the PMCMV in use in Uberlândia (MG), highlighting the magnitude of impacts resulting from projects designed without considering climate and indicating priorities for interventions in the case study, such as: specifying materials and window models and dimensions suitable for the climate, shading strategies for openings, and increasing soil permeability simultaneous with increased tree planting. This expanded knowledge in the field, providing insights for more informed guidance of interventions, with technical assistance, and aiming to enhance the resilience of SH against climate impacts.

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