More space, please: spatial adaptations (modifications) and their impact on the habitability of Social Houses

Mais espaço, por favor: adaptações espaciais (reformas) e o impacto na habitabilidade de Habitações Sociais

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Abstract

Social House (SH) residents usually make spatial adaptations. With no technical guidance, these modifications often compromise building performance. This article investigates the dynamics of modifications made to low-income houses and their consequences for habitability conditions. The data were obtained through on-site spatial mapping and a semi-structured interview. The study found modifications that expand the built area and a tendency to occupy the total area of the lot. The type of expansion with the greatest impact on the environmental quality of a house was predominant in the row houses (89.2%). The need for more space is confirmed by houses that have grown more than 30.0% up to over 70.0%. The study also identified a large number of removed windows, and expansions that confined rooms. Besides thermal discomfort, many rooms bear signs of unhealthiness, such as mold, lack of ventilation and sunlight, which have a negative impact on residents' health. Extreme cases were found (G=12.1%), in which the access gate to the house is the only way of contact with the outside. Spatial adaptations in SH are recurrent and cannot be disregarded as they significantly compromise the health conditions in the houses under study.

Keywords: Social Housing. Performance evaluation. Habitability. User health.

Resumo

Usuários de habitação social (HS) comumente realizam adaptações espaciais. Sem orientação técnica, essas modificações geralmente comprometem o desempenho da edificação. Esse artigo investiga a dinâmica das modificações feitas em casas populares e suas consequências para as condições de habitabilidade. Os dados foram obtidos através de mapeamento espacial em campo e entrevista semiestruturada. O estudo encontrou modificações que ampliam a área construída e uma tendência de ocupação da área total do lote. O tipo de ampliação com maior impacto na qualidade ambiental de uma casa foi predominante nas casas geminadas (89,2%). A necessidade por mais espaço é confirmada pelas casas que cresceram mais de 30,0% até mais de 70,0%. O estudo também constatou um elevado número de retirada de esquadrias, e ampliações que confinaram ambientes. Além do desconforto térmico, muitos ambientes apresentam sinais de insalubridade como: mofo, ausência de ventilação e iluminação natural, impactando negativamente na saúde dos moradores. Casos extremos foram registrados (G=12,1%), em que o portão de acesso da moradia é a única forma de contato com o meio externo. As adaptações espaciais nas HS são recorrentes e não podem ser desconsideradas, pois comprometem significativamente as condições de saúde das habitações em estudo.

***Palavras-chave**: Habitação Social. Avaliação de desempenho. Habitabilidade. Saúde dos usuários.*

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Recebido em 26/11/21
Aceito em 21/02/22

Introduction

The mass production of Social House (SH) projects, in many cases, results in houses that do not meet the needs of residents (AZUMA, 2016; TAUBE; HIROTA, 2017; THÉRY, 2017). The production of housing units for low-income populations in Brazil uses standardized projects, which results in a monotonous sight with poor innovation, and low-quality constructions that are inappropriate for the local context, such as climate (MENDES, 2014; TUBELO *et al*., 2018).

Two principles should guide social architecture projects: flexibility and habitability. Flexibility refers to the idea of multifunctionality, the degree of freedom of interior space, and the ability to accommodate modifications over time (PARIS; LOPES, 2018), while habitability is associated with the minimum characteristics of the built environment to provide quality of life, well-being and health to the communities (SARKARB; BARDHANA, 2020). Thus, it is important to suit the several family profiles, with the minimum criteria of comfort and privacy (GIVISIEZ; OLIVEIRA, 2013).

Vecchia and Kolarevic (2020) affirm that investing in flexibility may be a way of allowing families to best suit their needs after occupancy. However, Mendes (2014) believes that the quality of Social Interest Housing enterprises is a long way from incorporating flexibility as well as the concepts of customization and sustainability, because design solutions are still set on increasing production by replicating standards, from projects to elements.

The housing issue has led to lowered standards of popular houses, and reduced size is an important reason for user dissatisfaction (MONTEIRO; MIRON, 2018). European regulations for SH recommend from 15 to 18 m^2 as the minimum residential area per family member (PETKOVIĆ-GROZDANOVIĆ *et al*., 2017). In Brazil, the standard social house has approximately 35 m , which, for a family of 4, corresponds to less than 10 m per person. The need for more space is appointed as a factor of house inadequacy, however, the architectural type may make it impossible to expand, and the financial situation may also be an issue (BONATTO; MIRON; FORMOSO, 2011).

When the house is not adequate, users choose to modify it or move away (ELKADY; FIKRY; ELSAYAD, 2018). Spatial adaptations are necessary for the house to suit all family groups, and to better adapt the built environment to the real needs of the families. In the current scenario of social house modifications, in the vast majority of the residential units, some built area has been added but such expansions may compromise the pre-existing rooms by confining them – the original openings are removed (closed with masonry) or simply become a communication between the original rooms and the newly created space (SIMÕES, 2018; SIMÕES; LEDER; LABAKI, 2021). A closed mesh is created by the many expansions to the plot land boundaries (SIMÕES; LEDER; LABAKI, 2021).

In this context, the mass customization of houses may cater to the individual needs of the families at costs similar to the mass-produced items; such an approach includes spatial aspects with a greater potential to prevent demolitions and unnecessary renovations (VECCHIA; KOLAREVIC, 2020).

There is scarce empirical research on the effects of modifications made in vulnerable populations' houses. Given the above, this study aims to investigate the dynamics of modifications made to low-income houses and their consequences for habitability conditions. This article describes the implications of such modifications, the pattern of use of social houses, and it identifies the users' relationship with the architectural project.

The study also opens an interesting debate on the role of users in the maintenance and in the environmental quality of their homes; even if the original design of the house aimed to provide residents with comfort in a warm climate, their modifications, which mainly seek to obtain an extra usable surface to the detriment of the indoor quality, can make these houses uninhabitable. This paper is divided as follows: Literature review (Spatial adaptations in SH, Habitability and user adaptation), Methods (Characteristics of the object of study, On-site surveying, Data analysis), Results (Spatial modifications in the houses, Impact on habitability, Hypotheses testing), Discussion, and Conclusions.

Literature review

Spatial adaptations in SH

Given the growth of cities and land speculation, Bergan (2005) affirms that the low-income population has been the one that suffered the most with the spaces they are offered, due to excessively small houses and a large number of residents. In the studies of Mohit, Ibrahim and Rashid (2010), dissatisfaction with houses was associated with their size, especially large families with high bedroom occupancy. Addo (2015) associates low-income house overcrowding as a point of conflict, however, there is scarce space to expand and accommodate different family generations living in one single house.

Such a reduction in house size drives families to make big geometrical modifications in their houses, such as a significant expansion of the house area (SZUCS, 2002; CONCEIÇÃO; IMAI; URBANO, 2015; VECCHIA; KOLAREVIC, 2020). In Brazil, several studies have underscored the significant number of SH whose initial characteristics were modified over time (FISCHER, 2003; MARROQUIM, 2007; BRANDÃO, 2011; LOGSDON; AFONSO; OLIVEIRA, 2011; IMAI, 2013; ONO *et al*., 2017; LUZ; RODRIGUES; SILVEIRA JUNIOR, 2018; MONTEIRO; MIRON, 2018; SIMÕES; LEDER; LABAKI, 2021). House modifications are not limited to expansions of the built area, some reveal radical transformations, with large areas demolished and restructured (SZUCS, 2013).

Spatial adaptations are more limited in multi-story SH. Bergan (2005) identified an increase in the usable area of apartments in Brazil, which changed their architectural characteristics, because residents do not follow a formal or aesthetical criterion to make modifications. In another Brazilian study, the following modifications were identified:

(a) ground-floor expansions;

(b) installation of roofs/covers over parking spaces; and

(c) installation of protection bars and awnings/eaves at windows (LUZ; RODRIGUES; SILVEIRA JUNIOR, 2018).

Another point is that there exists a significant number of SH with inadequate adaptations, with particular damage to the habitability of the building (LARCHER, 2005), as well as loss in the functionality of the spaces (LUDOVICO; BRANDÃO, 2018). In some cases, the house is changed so much that it becomes impossible to identify the original project (BRANDÃO, 2011; IMAI, 2013; MOREIRA; SILVA, 2017).

Inadequate adaptations can also compromise the quality of public areas and adjacent buildings (SIMÕES, 2018; SIMÕES; LEDER; LABAKI, 2021). Setbacks are completely occupied, and sidewalks and green areas are misappropriated resulting in both reduced privacy and natural ventilation (SIMÕES, 2018). Despite the importance of environmental comfort, it is not considered in such modifications (SILVA, 2015; SIMÕES; LEDER; LABAKI, 2021).

In this scenario, the concept of flexibility is considered a significant contributor to developing solutions that may be applied to low-income houses, thus improving house quality. Involving design flexibility makes the units more adequate to the individuals, thus allowing internal diversification and redesign as well as more functionality and versatility (ELKADY; FIKRY; ELSAYAD, 2018; PARIS; LOPES, 2018). Flexibility is essential for residents to adapt their houses to their tastes and needs without major works or financial investments, because the easier and less expensive the adaptation and expansion process is, the better quality the house will have (DIGIÁCOMO, 2004).

Construction flexibility will depend on the designed shape and the geometrical layout of the spaces to generate a shape that enables the house to evolve (LUDOVICO; BRANDÃO, 2018). According to Griz *et al*. (2016), a high level of flexibility facilitates the inevitable process of personalization[1]. However, the way the SH are currently produced, the layouts are not flexible, and expansions are unfeasible, except through large and uneconomical modifications (BRANDÃO; ABREU, 2010).

Based on such findings, mass customization in construction may enable house flexibility and prevent several design problems such as the need to modify the house and increase user satisfaction. Mass customization emerged as a production strategy opposed to mass production, and it focuses on producing distinctive goods with high added value (AZUMA, 2016).

Considering the differences between the concepts of customization and personalization, Schoenwitz, Naim and Potter (2012) define personalization as the possibility to build, change or fit a product or service according to individual specifications, while mass customization is the capacity to do the same, but with the efficiency of mass production. Noguchi (2004) complements that these two concepts occur at different

[1]The term used by the authors was customization but we believe they mistook it for personalization.

moments, in that customization occurs up to the moment the product is delivered whereas personalization is made by the client after product delivery.

Mass customization is being adopted in many housing contexts around the world to provide families with houses that meet their individual needs (VECCHIA; KOLAREVIC, 2020). However, adopting mass customization in the Brazilian social housing programs faces the challenge of not involving the clients in the process of choosing their own house options (LEITE, 2019).

Habitability and user adaptation

Habitability is one of the aspects often criticized in SH in Brazil. It is certainly associated with the low quality of SH and with low standards of environmental comfort (KOWALTOWSKI *et al*., 2005; TUBELO *et al*., 2018). Habitability affects the most vulnerable population and generates environmental (in)justice as poor-quality houses cause health inequalities (ADDO, 2015). That author adds that living in concentrated poverty increases inequalities and produces worse health outcomes: worse mental and social health, as well as poor ventilation, exposure to noise and air pollution, and lack of sunlight.

Similar considerations were made in studies conducted by Sarkarb and Bardhana (2020) when they reinforce the importance of exploring the effect of the built environment on physical habitability indicators such as air quality, ventilation and thermal comfort, as it directly affects – and is vital to – the occupants' health.

Original houses often present thermal and luminous performance issues, notably with regard to natural ventilation and sunlight (SIMÕES, 2018). Moreover, physical adaptations can further compromise the performance of the building. The expansions change and compromise the initial habitability conditions of the house (ABIKO; ORNSTEIN, 2002; FISCHER, 2003; ROMERO; ORNSTEIN, 2003), especially functionality and air flows, thus creating conditions that put the health of residents at risk (DIGIÁCOMO, 2004; OLIVEIRA, 2009). In Brazil, a field survey on SH found that thermal discomfort was an unexpected consequence of the expansion for residents; however, it does not change their decision to further expand the house (SIMÕES; LEDER; LABAKI, 2021).

The low performance of the building results in increased energy consumption, with more demand for artificial systems such as air conditioning, ventilation and lighting (MORENO; MORAIS; SOUZA, 2017; TUBELO *et al*., 2018; ELKADY; FIKRY; ELSAYAD, 2018). Individuals, in general, have a natural tendency to seek a form of adapting to the environment when they are subjected to discomfort (NICOL; HUMPHREYS, 2002; TABLADA *et al*., 2009). Thus, residents are satisfied with a house when it is possible to interact with the building to promote comfort (DE DEAR *et al*., 2013).

Occupants have the capacity to modify thermally uncomfortable spaces by employing the following solutions: opening or closing doors and windows, operating building elements such as curtains and awnings/eaves, using appliances such as fans and air conditioners, or even adopting individual strategies such as changing clothes, eating hot/cold food or drinking hot/cold drinks (FERIADI; WONG, 2004; DE VECCHI; CÂNDIDO; LAMBERTS, 2016; COLEY *et al*., 2017; BALVEDI *et al*., 2018).

The occupants modulate their habits and their attitudes to neutralize the discomfort in their physical, social, behavioral and psychological system (DEBNATH; BARDHAN; SUNIKKA-BLANK, 2019a). In a study on SH in Mumbai, India, the absence of natural ventilation for air renewal in homes resulted in the frequent use of fans throughout the day (6 to 10 hours) (DEBNATH; BARDHAN; SUNIKKA-BLANK, 2019b). Those users reported that, with the need to use appliances for comfort, the energy bill increased by 40.0% when compared to their previous house.

Methods

The method used in this research was the case study in two housing estates, namely Gadanho (G) and Timbó (T), in the city of João Pessoa, state of Paraíba, Brazil. They are considered a case study because they represent architectural types which were replicated in 6 other locations in the city. Gadanho is considered a new model of social housing, designed by the city's Municipal Housing Secretariat.

The information presented in this paper corresponds to partial results of a broader research for producing a Ph.D. thesis. The data presented comprises four large groups of housing assessment:

(a) internal thermal comfort (SIMÕES; LEDER; LABAKI, 2021; DEBNATH *et al*., 2020);

(b) spatial adaptation (modifications);

(c) energy consumption (energy poverty); and

(d) individual behavioral adaptations.

This article focuses on the in-depth analysis of the 2nd large group – spatial adaptation, and highlights the importance of associating the other groups to understand the general background.

Characteristics of the object of study

The two communities contain 181 housing units, 45 of which are in Gadanho and 136 in Timbó. The housing compounds were completed in 2013, built by the PSH program (Social Interest Housing Subsidy Program; Programa de Subsídio à Habitação de Interesse Social, in Portuguese) and the City Administration, to serve a low-income population residing in a risk – mudslides and river floods – area. The houses have similar programs: living/dining room (G=12.2 m , T=9.4 m), two bedrooms (G=7.0 m each, T=6.7 m each), kitchen (G=4.0 m , T=5.6 m), bathroom (G=2.1 m , T=2.0 m) and laundry with no roof/cover (Figure 1).

On-site surveying

This phase consisted in interviewing users as well as conducting a physical and photographic survey of the houses for a later diagnosis of the spatial adaptation. Due to the great difficulty of access to the interior of the houses, the non-probabilistic convenience sampling technique was used, that is, as much on-site information as possible was collected. The survey was conducted in the summer, from 1 to 5 o'clock in the afternoon, and in four steps:

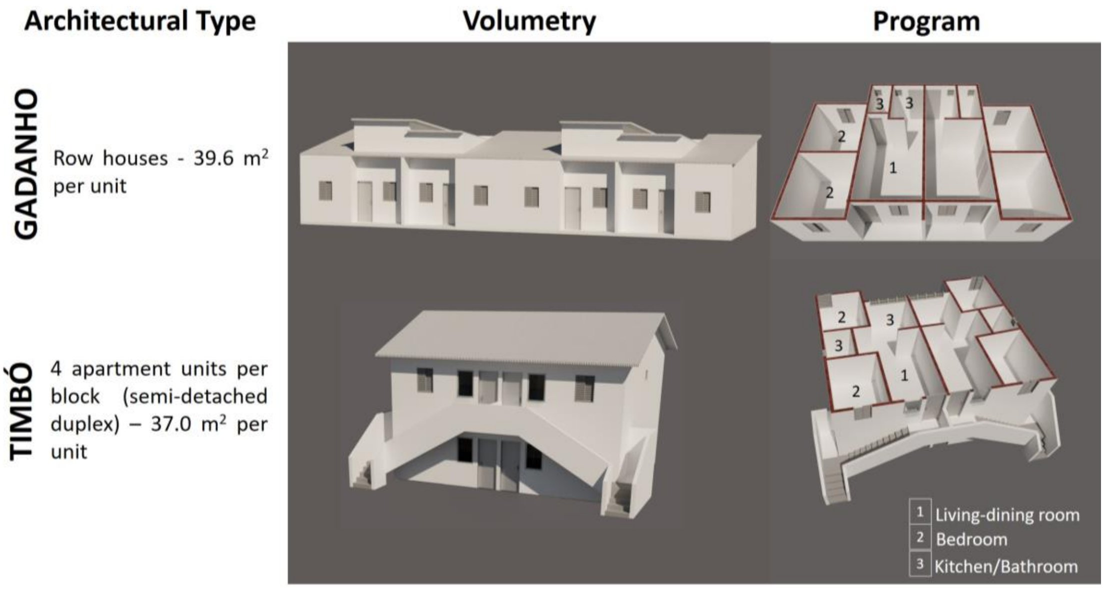
(a) the researchers approached the residents and explained the objectives of the research and the strictly academic nature of the study, to prevent residents from expecting free house modifications or some financial gain. Consent was given verbally (in person). All units were approached; however, several residents refused consent, therefore, not all houses were surveyed. Interviewees were promised that their names would not be revealed;

(b) residents accepted to participate in the study;

(c) questionnaires were applied: one resident per housing unit was submitted to a semi-structured interview; and

(d) physical and photographic surveying inside the housing units.

Figure 1 - **SH architectural types studied**



Based on models found in the literature (FISCHER, 2003; LYRA, 2007; BRANDÃO, 2011), the questionnaire was designed to obtain the data and understand the users' perception. One resident from each house was invited to answer 25 questions that covered the following, among other issues: profile of the resident, the modifications made to the house, the elements that motivated the adaptations, and residents' greatest wishes and needs for modifications.

As a preliminary strategy, the field work was planned, and a pilot study was conducted with 11 houses to check the need to fix the questionnaire to make it clearer and to avoid misinterpretation. Inside the houses, the photo survey of all rooms was done while the semi-structured interview was conducted in the living room.

Data were collected in two different moments:

(a) 1st (February-April 2017) – surveying the spatial adaptations of all houses (no. = 181) + detailed study inside the sample houses (no. = 99) and interview with one resident per house (no. = 99); and

(b) 2nd (October 2020) – surveying the spatial adaptations of all houses (no. = 181) to understand the evolution of the modifications after about four years.

For the houses outside the sample, the on-site surveying collected the spontaneous modifications made by house residents from 2013 to 2020, by observing the facades and setbacks.

Data analysis

The data analysis focused on the spatial adaptations of the sample, by relating the original design of each housing unit to its subsequent modifications. The aspects of habitability were evaluated based on the house expansions and window modifications after residents moved in.

The modifications identified in the field survey were modelled in Revit software to obtain a 3D model to be analyzed. The evolution of modifications over the years, object of the 2nd on-site survey, was analyzed in three different moments:

(a) 2013, the year the residential units were delivered;

(b) 2017, the first field survey on modifications; and

(c) 2020, the second survey.

Through spatial mapping, the modifications were characterized as to their level of change and type of expansion. To evaluate the change, three levels were defined:

(a) (L1) original;

(b) (L2) small modifications, such as opening modification – exchange and/or withdrawal; and

(c) (L3) architectural expansion, which might include level 2 modifications (Figure 2).

The type of expansion was identified based on the following expansion categories (Figure 3):

(a) open expansion;

(b) semi-open expansion; and

(c) closed expansion.

The expansions were categorized according to the degree of connection with the exterior, from simply installing a cover/roof to building a closed room (with or without windows).

Finally, the RStudio software was used in the descriptive analyses (considering the calculation of descriptive measurements such as medians and quartiles) and inference by the Mann-Whitney e de Kruskal Wallis tests. The descriptive analysis also used frequency distribution graphs (Excel). Regarding the general hypothesis outlined, the study sought to investigate whether the physical modifications in the communities under study present a relationship of dependence on the change of users' thermal/wind sensation and preference. In this research, one question was asked: "Does each and every type of expansion generate different wind sensations votes?". At the end of the results, the statistical hypotheses test will be presented.

Results

The sample of respondents comprised 99 houses surveyed, 33 in Gadanho and 66 in Timbó (Figure 4).

Figure 2 - **Levels of modification made to the housing unit**

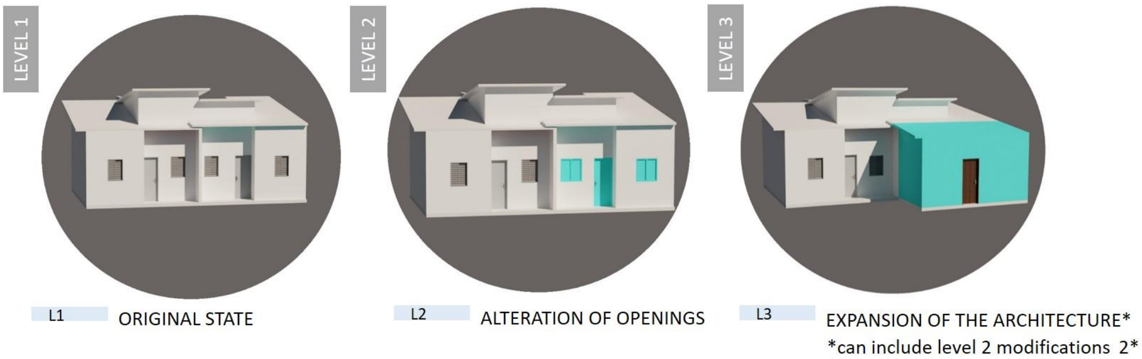


Figure 3 - **Types of expansion of the housing unit**

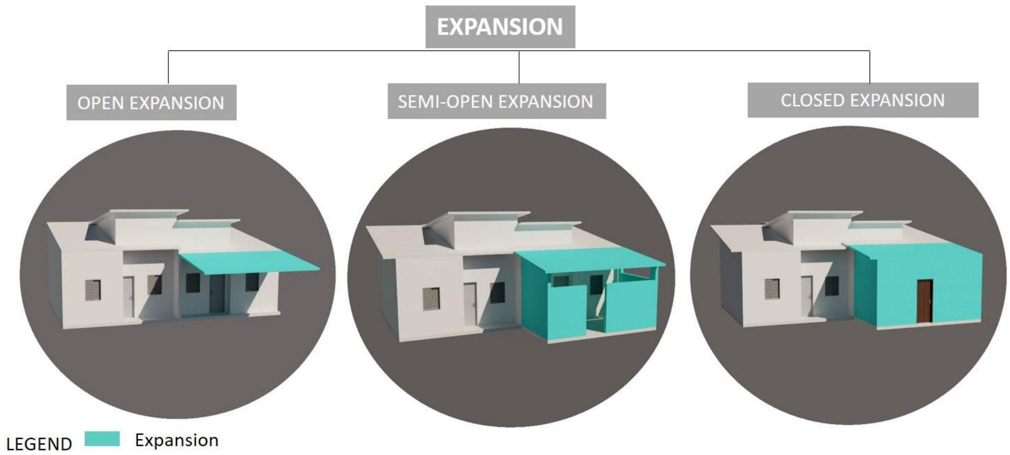


Figure 4 - **Interviewed units' outline**

The application of the questionnaire resulted in 99 full questionnaires (this paper used the answers to 13 questions that cover the interviewees' profile and house modifications). Most respondents were female aged from 31 to 40 years, had a low education level (incomplete elementary school), and were either self-employed or unemployed. The number of residents in each house varied; in most cases there were 3 to 4 residents per unit who lived in the house since the units were delivered.

Spatial modifications in the houses

Based on the survey of the constant expansions over the years (2013 – 2020), the analysis of the evolution of the modifications is presented (Figures 5 and 6). Different colors were used for regular expansions (orange for expansions made by ground floor residents, pink for expansions by upper floor residents [specifically for the duplex architectural type in Timbó]) and irregular expansions (orange – misappropriated sidewalk, street, communal green area, parking lot) (Figures 5 and 6). In both scenarios, modifications increased over the years, and they were made disorderly with a tendency to occupy the lot completely. These modifications were conducted without the participation of construction professionals, therefore, without technical instruction.

The analysis of the evolution of modifications confirms the critical scenario of the increasing number of expansions (Figures 5 and 6). Such a dense built mass cannot be disregarded because it will eventually compromise the thermal comfort of the interior of the houses and, consequently, the satisfaction and health of the residents.

There were few cases of vertical expansion, that is, building a new upper floor, in both architectural types. When the houses outside the sample are included in the calculation, in 2020 the row architectural type [G] was verticalized by only 13.0% while the duplex type [T] was verticalized by as little as 8.0% (Figures 5 and 6).

Although obviously illegal, many irregular expansions were observed, that is, they occupy public areas such as green areas, sidewalks and streets (2020: G:470.0 m , T:670.0m) (orange color – Figures 5 and 6). It is evident that residents misappropriate non-private areas because governmental institutions do not supervise low-income communities to control their constructions.

A striking feature observed was the large number of expansions. Only 5 units in the Timbó community (7.6% – 2020) remain in their original state (L1 – Figure 7). In Gadanho, all units underwent some type of modification. According to the interviewees, keeping the houses in their original state cannot be understood as a sign of satisfaction; rather, it is due to financial constraints.

The analysis over the years shows a reduction in the number of houses in their original state and houses that only had their openings modified; on the other hand, it shows an increase in the number of houses with expansions (Figure 7). Of the types of modification, the expansion of the built area prevailed, with no. = 28 (84.8%) in Gadanho and no. = 57 (86.3%) in Timbó in 2020 (L3 – Figure 7). A large number of opening modifications (replacement and/or withdrawal) occurs concomitantly with house expansions (L3 – Figure 7). Level 2 – only opening alterations accounted for no. = 5 (15.1%) in the Gadanho Community and no. = 4 (6.0%) in the Timbó Community (L2 – 2020, Figure 7). The original iron doors and windows are gradually replaced with wood or aluminum with glass (windows).

Expansions are more recurrent in the ground floor units (Figure 8), in both communities studied. On the other hand, upper floor expansions were infrequent, because they require a greater investment in structural elements. The ground floor areas are disputed by the residents; therefore, 60.0% of the upper floor units expanded on the ground floor (b – Figure 8, pink color – Figure 6). This contributes to an increased built mass on the ground floor, when added to the expansions of ground floor houses. When investigating the types of expansion of the built area (L3 – Figure 7), the "Closed" category, the one with the greatest impact on the environmental quality of house, was found to be predominant in the row type (G), totaling 89.2% (T=40.3%) (Figure 8). In contrast, in the duplex type (T), the "Open" expansion prevailed, as high as 82.4% (G=42.8%) (Figure 8). On the upper floors of the duplex units, eaves were added for protecting the front door of the house (from the rain and direct solar radiation) (open expansion – b – Figure 8).

Residents' accounts show great dissatisfaction with row houses because privacy is compromised, and with upper-floor units because they are difficult to expand. When all these elements are considered, it is clear that residents prefer single-story houses – rather than multi-story houses – and those with a side space between the units.

Figure 5 – **Evolution of expansions**

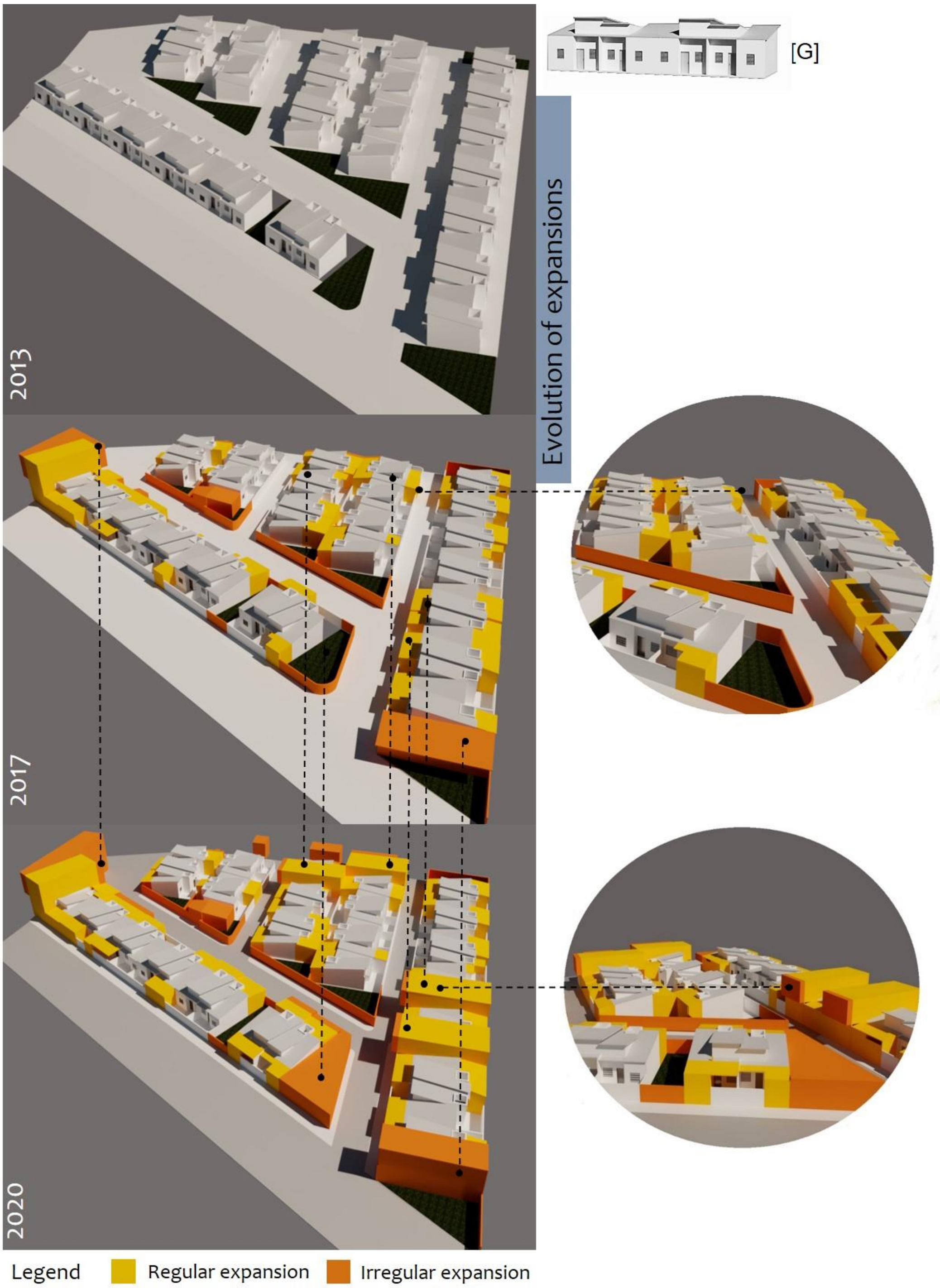


Figure 6 – **Evolution of expansions**

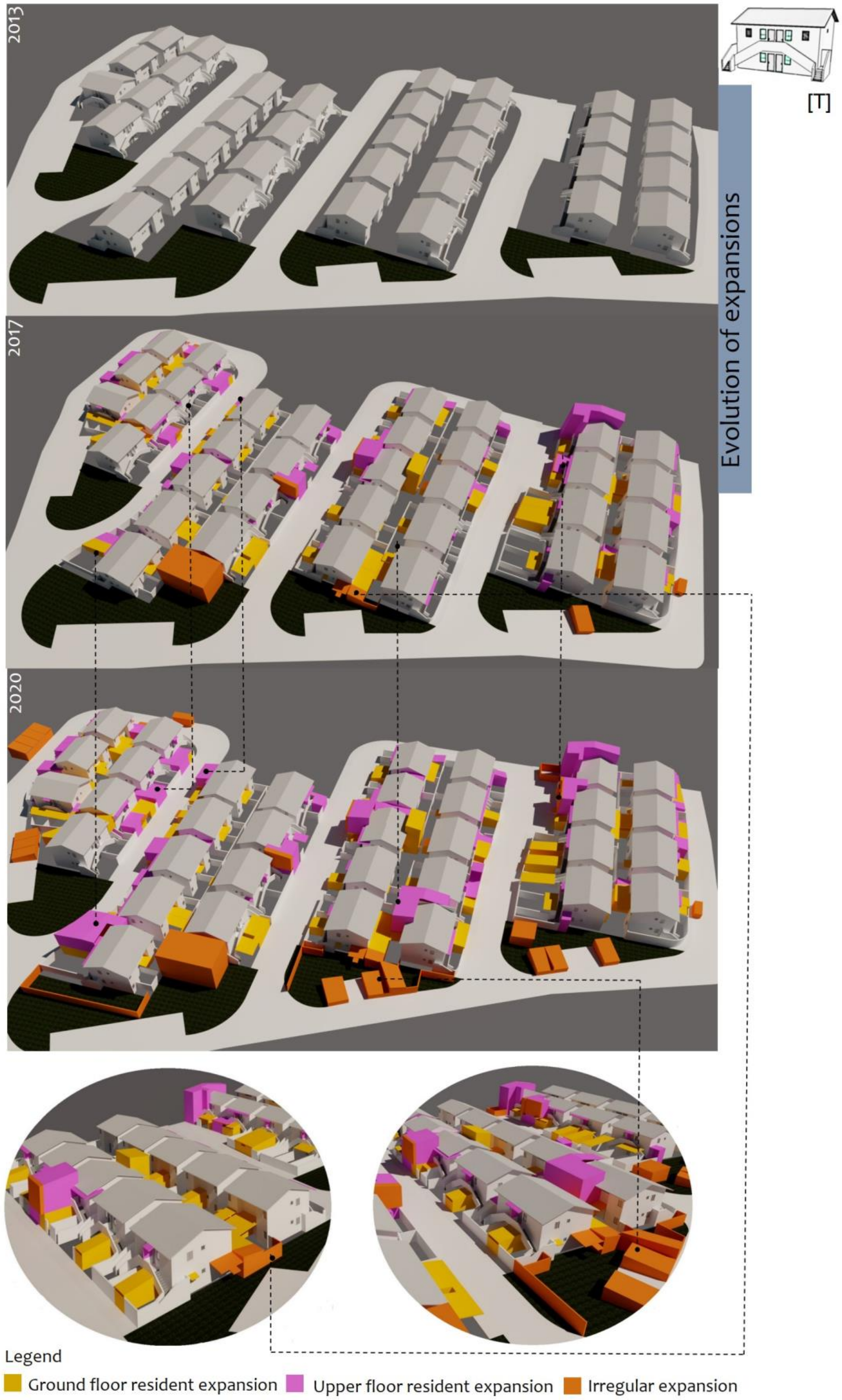


Figure 7 – **Level of modification of the sample units**

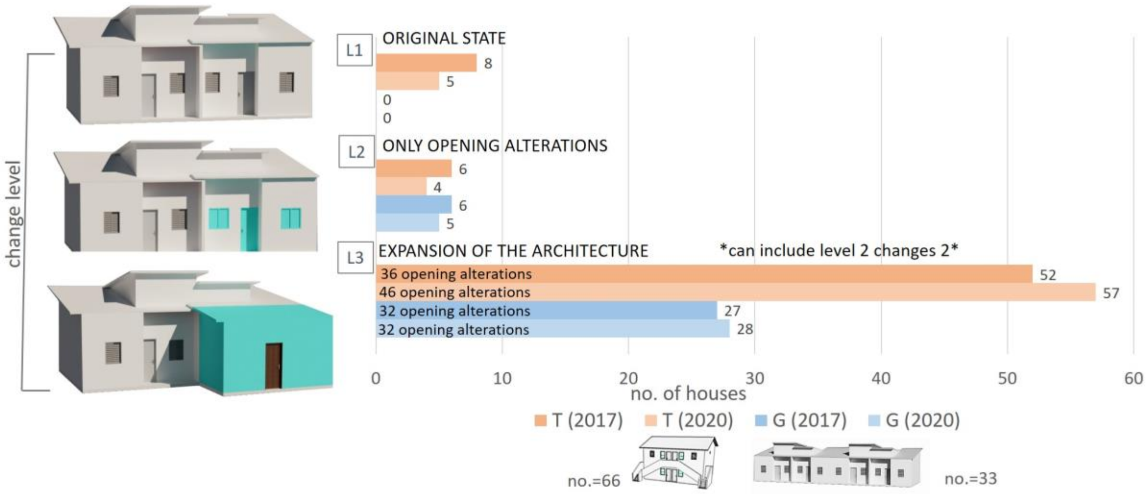
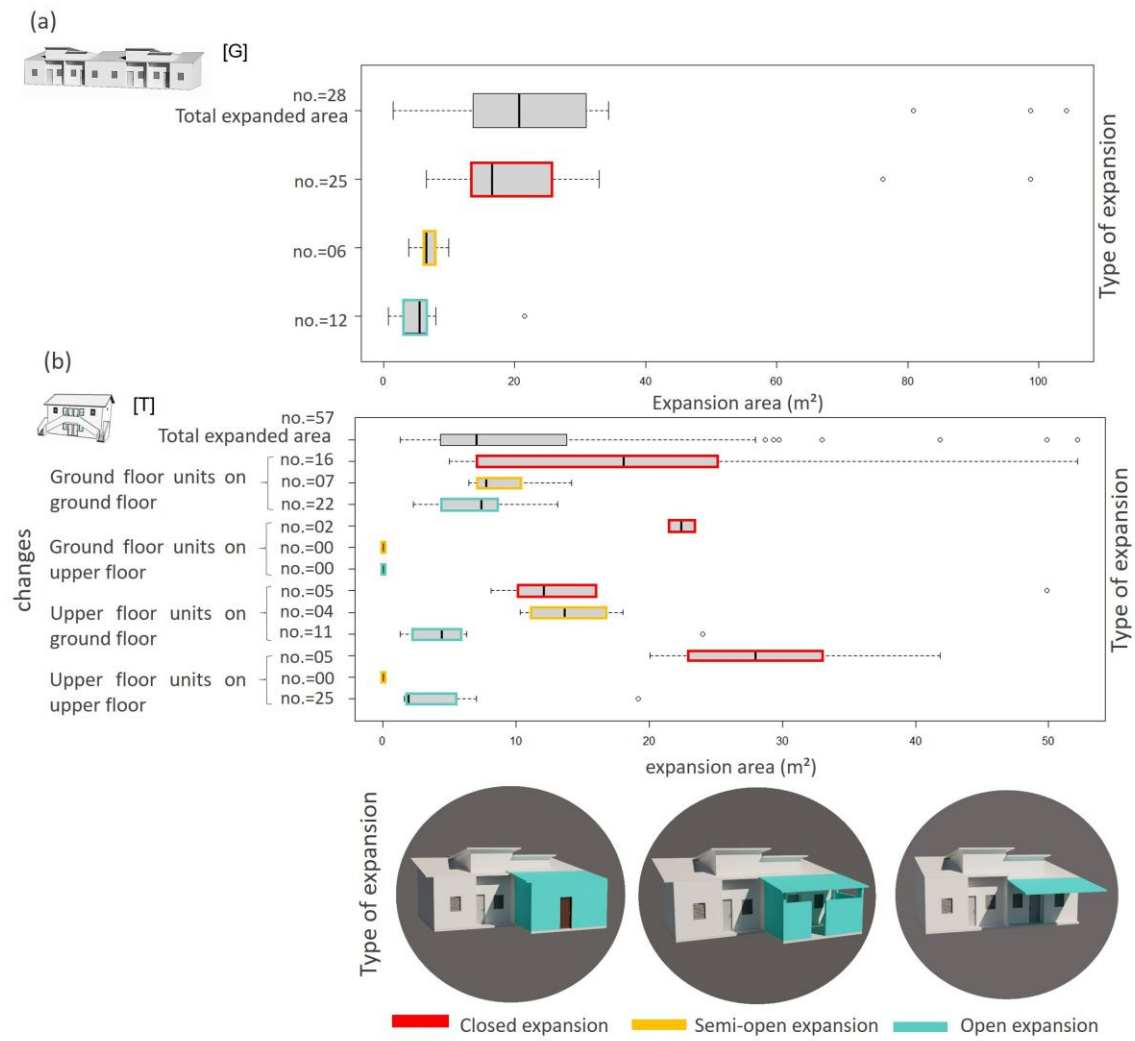


Figure 8 – **Types of expansion (closed, semi-open, open) – 2020**



In both communities, the main motivation for making modifications was increasing the area (G=84.9% and T=44.0%) (Figure 9). In Gadanho, the variables security needs and quality of materials amounted to an equal percentage of 24.2% (Figure 9). Meanwhile, in Timbó, the priority was protecting from the sun/rain (T=37.8%), followed by quality of materials (T=30.3%), security (T=25.7%), and house aesthetics (T=22.7%) (Figure 9).

The need for more space is confirmed when we observe the percentage of area increase relative to the original size of the house (Figure 10) – considering the sum of the closed and semi-open expansion on each floor (not considering the expansions by upper floor residents on the ground floor (discussed in Figure 8 – b). The highest expansion percentages occurred in the row architectural type (G); 24.2% of the sample added more than 70.0% compared to the original area, while 18.0% added 30.0% of area (Figure 10). As to the duplex type, since the expansion of upper-floor units is practically negligible, it is the ground floor units that account for the expansions; the highest percentage of area increase was 20% in 10.6% of sample T (Figure 10).

Figure 9 – **Main motivations for making modifications**

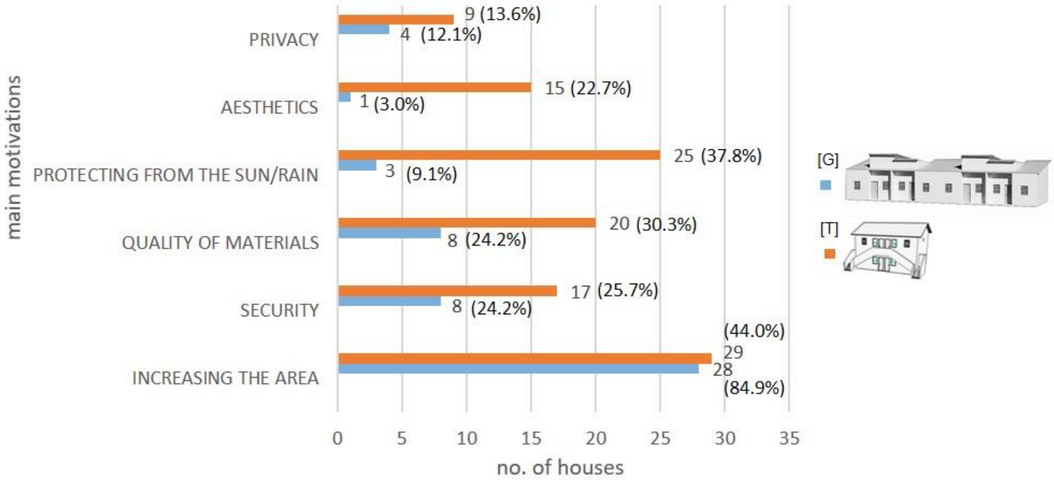


Figure 10 – **Percentage of house growth relative to the original size – 2020**

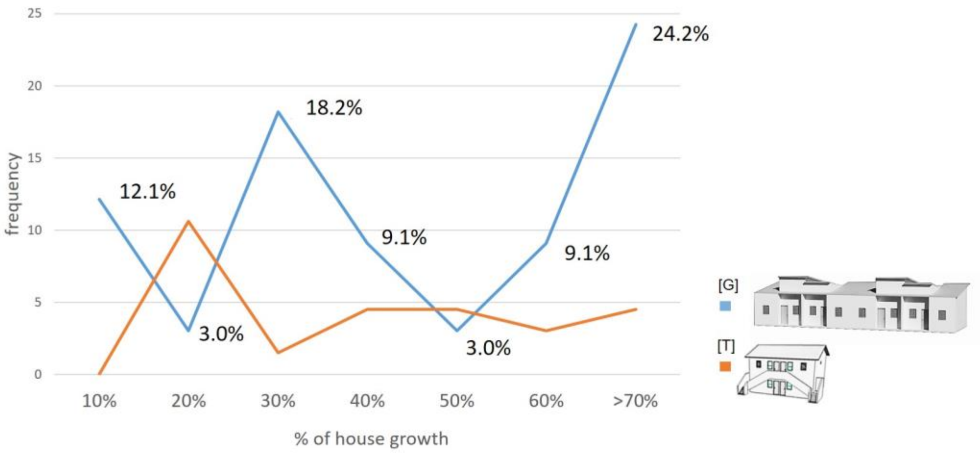
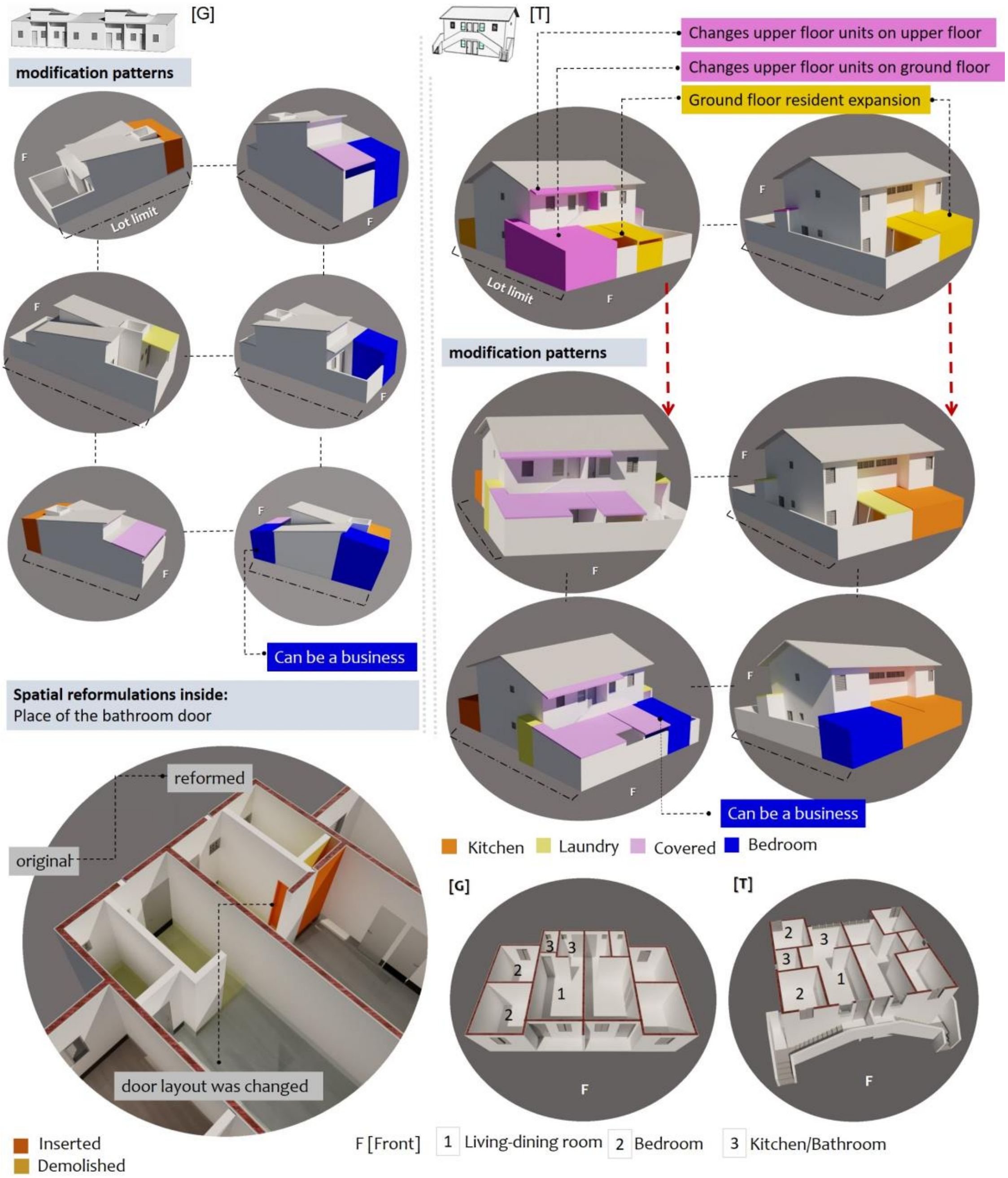


Figure 11 shows the most recurrent modification patterns were expanding the kitchen, covering/sheltering the veranda or laundry, and building bedrooms. The bedroom was the most frequently new room built (G=30.3% and T=10.6%) because the original area was insufficient for the number of house residents. In the kitchen (G=30.3% and T=12.1%), the expanded area was meant for the main cooking activities and family gathering, while the original layout had cabinets installed to make the room more presentable to visitors, or a dining table. In the laundry (G=21.2%, T=18.1%), space was added for installing a washing machine, and a roof/cover was put up for protecting from the rain and the sun. In many cases, when there was no space for a washing machine, the sink was removed to make room for the equipment or it was installed inside the house – mainly in the kitchen (other studies identified problems in the laundry (BERGAN, 2005; PALERMO *et al*., 2022; DAMÉ, 2008; VECCHIA; KOLAREVIC, 2020). There is a relationship between the construction of bedrooms and the number of house occupants; a new bedroom was built mostly when 4 or more people resided in the same unit.

Figure 11 – **Most frequent patterns of expansion**



It is also noteworthy that, although both compounds were intended exclusively for residential use, after they were occupied, land use was diversified; some houses incorporated businesses to sell goods or provide services so that residents could make a living (Figure 11). It is worth mentioning the great occurrence of house expansions and occasional spatial reformulations inside the houses. The most frequent changes are installing ceramic tile flooring, altering the openings, and changing the place of the bathroom door (specific case of the row type – G) (Figure 11). The bathroom door layout was changed in 1/3 of the units justified by the fact that it faced both the living room and the street, which compromises the privacy of the residents. On the other hand, the new location of the bathroom door l becomes unhealthy for the kitchen and reduces the area, which further increases the need for expansion (Figure 11).

Most respondents reported they would like to modify even more (G=100.0% and T=97.0%), see Figure 12. After all the modifications made, many users reported their wish to improve the quality of materials such as flooring, doors and windows, erect a concrete slab, enlarge the kitchen and build another room, among other ideas (Figure 12).

Impact on habitability

Sunlight and natural ventilation are variables with an impact on habitability. Thus, this section addresses the impact of modifications on the natural ventilation and sunlight conditions of the building. The treatment given to the openings stands out. The alteration of the openings, however, does not always favor habitability. The patterns of the modifications that compromise habitability are analyzed schematically (Figure 13).

The increase in the area of the house is related to removing (or disabling) windows and compromising the original rooms and new rooms built over time. Expansions occupying the setback areas lead to partial or total confinement of the house, especially in row house setups. Some extreme cases of alteration were found (G=12.1%), in which the access gate of the house is the only way of contact with the outside.

Invariably, expanding the rooms, besides the impact on the unit itself, also affected the neighboring unit. This is especially due to the increase in the built mass, which blocked the entrance of ventilation and sunlight. The tendency to build in the way of ventilation and sunlight leads to increased energy consumption by using fans (G=45.5%, T=50.1%) and turning on the lights (G=69.7%, T=66.7%) during the day. The highest percentage of fan use occurs at night (G=75.8%; T = 83.3%) to make sleeping a little more comfortable, since, when there still are windows in the rooms, they are closed for both privacy and security. A small part of the sample does not use a fan in the house (G=18.2%, T=9.1%) because residents do not like it or because of allergy issues.

It is important to discuss some findings about unhealthy aspects as well as others that do not favor the use of natural ventilation and sunlight. The most common practice is removing or disabling the external windows as the house is expanded. The contact with the outside is reduced because the windows become mere internal communication between rooms (Figure 13).

Figure 12 – **Respondents expected/desired house changes**

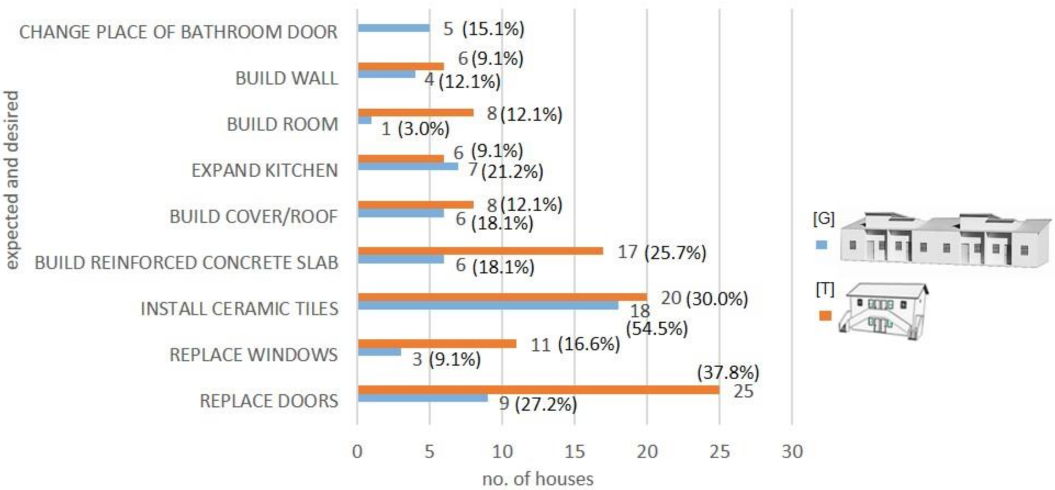
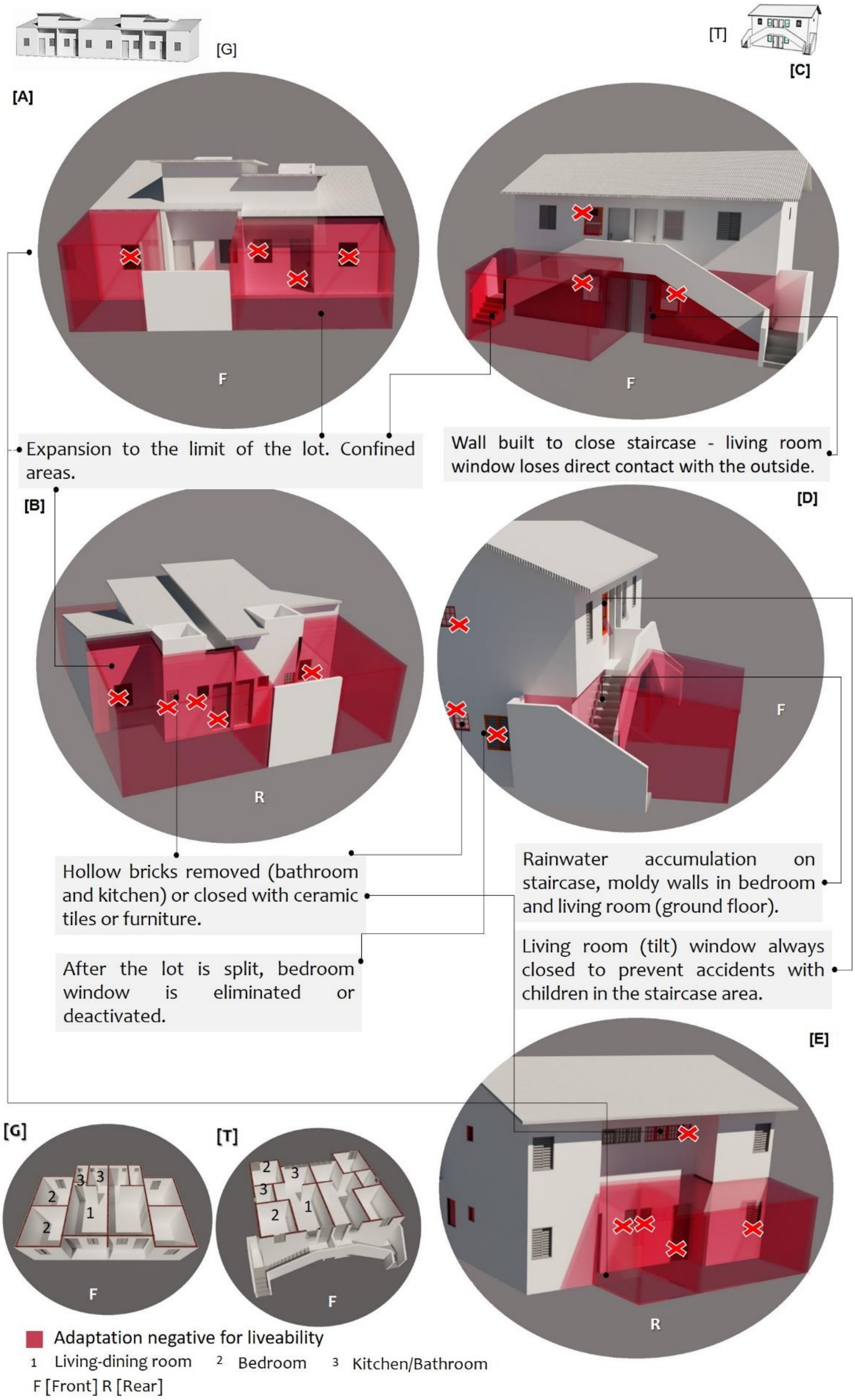


Figure 13 – **Patterns of modifications that compromise habitability**



The hollow bricks in the original design (which play the role of a window in the kitchen and bathroom) are a dispensable item, as they do not contribute to sunlight and natural ventilation (b, d, e – Figure 13). Based on this idea, residents commonly block them definitely, either with mortar or ceramic tiles, or temporarily, with paper, furniture, etc.

In the duplex type, the moldy wall in the front bedroom and living room is caused by accumulated rainwater on the staircase (d – Figure 13). Because eaves are narrow (0.50 m), water accumulates on the stairs and, consequently, moisture attracts fungi and mold, which compromises residents' quality of life. On the upper floor, the rainwater build-up on the entry landing enters the house and wets the furniture.

On the upper floor of the duplex, the living room window loses its function because of the way it is opened – it is a tilt window that opens to the staircase area; it becomes an obstacle and favors accidents with residents (d – Figure 13). By remaining closed, this window will no longer contribute to cross ventilation in the house. On the ground floor, the living room window loses its function as a wall is built to close the staircase area; this way, the window becomes internal and loses contact with the outside (c – Figure 13). Residents say that the construction of the wall follows an aesthetic preference for changing the original facade – it is standardized and done in a series.

In the duplex units, the window of the first bedroom on the ground floor is either removed or disabled because of the division of the lot (d – Figure 13). The upper floor resident who takes over this lateral area on the ground floor demands the removal of the window that faces that area; alternatively, the ground floor resident, due to compromised privacy, will no longer use the window since he/she has no choice to create an opening in another place (the place of the staircase will not allow installing the window on the front wall).

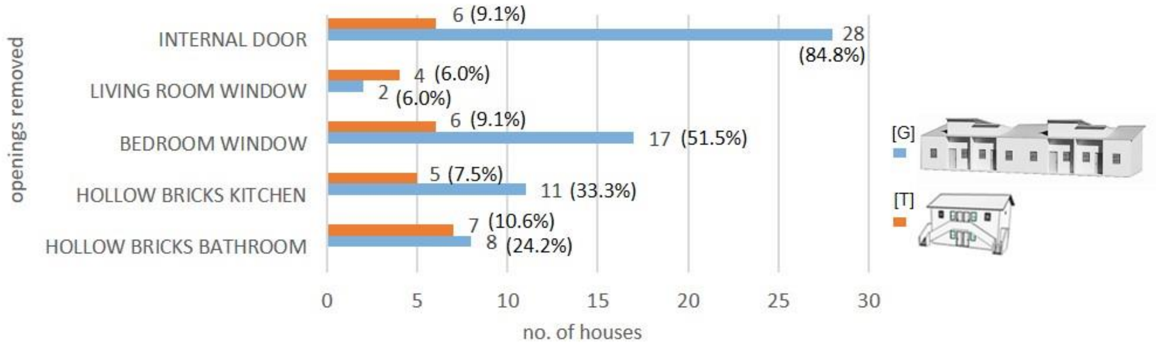
Special attention is paid to the above factors, which, altogether, will make the house lose quality by compromising both thermal and luminous comfort, as well as residents' health and personal satisfaction.

Figure 14 shows the percentages of window removal in the communities: In the row type (G), it occurred more than in the duplex (T) type. In addition, more internal doors were removed in G – because they were broken – followed by hollow brick openings and bedroom windows.

Houses that underwent the most expansions were those that had the most external windows removed. The biggest concern regards the removal of external openings because they are essential to let fresh air and sunlight into the rooms, and when this is lost, unhealthy rooms will depend on mechanical ventilation and artificial lighting throughout the day. Not only the financial aspect should be taken into account, since this is a low-income population, even more serious is the harm done to the health of that population.

As a consequence of expanding the house and confining rooms, some residents reported respiratory problems, especially in children and the elderly. Residents also report their strategies to avoid the heat inside their houses since the thermal conditions indoors are often unbearable: during the day, they stay outside their houses, and when they are indoors, they leave a fan on. Some residents may prefer to sleep in the living room in case of cross ventilation between the kitchen and the living room.

Figure 14 - **Percentage of openings removed**



It is also necessary to analyze the patterns of replacement of doors and windows that have a positive impact on habitability. Replacing an opening is an item of great importance when the units are modified (G=96.9% and T=69.7% – 2020). The motivations indicated by the interviewees were: low quality of the windows/doors in the original project and increasing security. The most common practice was replacing iron doors and windows with wood or aluminum and glass (windows), and replacing hollow bricks with windows.

Replacing windows with others made of better material allows a bigger effective opening area for ventilation and sunlight to come in; the new windows are also easier to operate and contribute to the aesthetics of the house. Replacing windows is more recurrent in the upper floor units in type T, because expanding is a more expensive solution. Hollow brick openings were replaced with glass windows in 9.1% in the Gadanho community and 16.6% in the Timbó community.

Hypotheses testing

The detailed study of the modifications confirms that the internal thermal comfort of the residents is compromised, since the findings show low satisfaction levels (21.2%) and a wish that the place was cooler (68.7%). Then, the next step was to investigate whether these physical modifications had an impact on the change of users' thermal and wind sensation and preference. For the evaluation of the statistical test, the relationship between the explanatory variables was analyzed (level of change, expanded area, and an openings index (OP – Opening, sum of all effective areas of external windows and doors, divided by the total facade areas) and the response variables (thermal and wind sensation and preference).

When the variable wind sensation/preference was associated with the total expanded area, the p-value was lower than the significance level: p-value=0.03406 and p-value=0.03786, respectively (Table 1). As a test conclusion, both hypotheses reject Ho, that is, there is a significant dependence between the change of sensation and preference for natural ventilation. Expanding the houses led users to change their opinion on wind sensation and preference. That also occurred with wind sensation and opening index (OP) (p-value=0.02532) (Table 1). The variables are dependent and the change in OP leads users to change their wind perception votes.

In the Gadanho community, the p-value of variables' occurrence of modification and thermal sensation were lower than the significance level: p = 0.02261 (Table 2). As a test conclusion, the Ho hypothesis is rejected, that is, there is a relationship of dependence between the level of modifications and the thermal sensation votes.

Table 1 – **Comparison between house modifications and user satisfaction**

Variables	Timbó community [T] – Test result (P-value)				
	House Modification (Yes – No)	House expansion area – Ground floor (m²)	House expansion area – 1st Floor (m²)	Total expansion area (m²)	OP (Categories)
Thermal sensation	0.3456	0.5748	0.3224	0.8785	0.512
Wind sensation	0.4631	0.3578	0.5216	0.03406*	0.02532*
Thermal preference	0.09516	0.5049	0.3228	0.9571	0.3572
Wind preference	0.8409	0.4988	0.4594	0.03786*	0.7014

Note: significance level = 0.05 and *P-value < 0.05 – Ho rejected.

Table 2 – **Comparison between house modifications and user satisfaction**

Variables	Gadanho community [G] – Test result (P-value)		
	House Modification (Yes-No)	Total house expansion area (m²)	OP (Categories)
Thermal sensation	0.02261*	0.1213	0.7223
Wind sensation	0.5777	0.7307	0.9365
Thermal preference	0.0633	0.4102	0.3352
Wind preference	0.7408	0.2839	0.6634

Note: significance level = 0.05 and *P-value < 0.05 – Ho rejected.

Discussion

When our results are compared with those of other studies, we find similar conclusions about the need for house modifications over the years. This article identified that only 7.6% of the houses in only one housing complex remain in their original state; predominantly, the built area was expanded, no=28 (84.8%) in Gadanho and no=57 (86.3%) in Timbó. Similar findings are reported by Ono *et al*. (2017), who identified that 48.0% of the residents modified their houses, while Fischer (2003) found that 77.5% of the studied sample expanded their houses while 22.5% transformed some room into another. Also, Szucs (2013) pointed out that only a small part of the evaluated sample went through no change (10 out of 100 units and 2 out of 61 units).

The need for more space was confirmed by analyzing the percentage of added area, for example: 24.2% of the sample added over 70.0% of the original area whereas 18.0% added 30.0% of area. Other studies found that the added area usually equals twice the original area of the house (FISCHER, 2003) or even three times (SZUCS, 2002). In some cases, the increase to the initial project reaches 128% (MOREIRA; SILVA, 2017).

The most recurrent modification patterns identified were: expanding the kitchen, covering the veranda and laundry, and building bedrooms. This finding tends to support the statement of Bergan (2005), who defends that excessive reduction of the kitchen and laundry fosters the need for a bigger home. The most frequently built room was the bedroom because the unit had insufficient area for the number of residents in the house. Similar findings are reported by Conceição, Imai and Urbano (2015), who found that the priority of users is expanding the number of bedrooms to accommodate the whole family; 59.1% of the surveyed population intended to build more bedrooms while 8.6% intended to expand the existing bedrooms.

The main motivations that lead to modifying the house are: the need for more area to suit the house to the number of residents and, mainly, to correspond to the occupants' ideal house and lifestyle; to improve the quality of materials, which is linked to the need to personalize the property, functionality, and to provide more comfort to the family; and security and privacy. House transformations go beyond physical questions; they are also linked to the socio-cultural values of the population. This research corroborates data from other studies that pointed out the following main motivations, among others: improving the standard of finishes and materials; increasing privacy, ensuring more security, personalization the property, and adding a new use to it (FISCHER, 2003; MARROQUIM, 2007; LOGSDON; AFONSO; OLIVEIRA, 2011; SILVA; CARVALHO; RIBERIRO FILHO, 2012; IMAI, 2013; SZUCS, 2013; SILVA, 2015). Finally, due to the need to customize and personalize the house, we underscore the necessity to provide project variations. Besides the basic program, the following customization possibilities might be offered:

(a) an additional bedroom or;

(b) a front area that might also serve as a garage or;

(c) a front room to work in (thus, to generate income) or; and

(d) expanding the kitchen or some other house area.

This may be the focus of future studies.

Conclusions

In this study, a field survey was conducted to investigate the dynamics of modifications made to low-income houses and their consequences for habitability conditions. The most frequent patterns of expansion identified in the two architectural types were: expanding the kitchen and laundry, covering the veranda, and building bedrooms. Financial constraint was reportedly the reason why few houses were kept in their original state. The number of expansions is high and they are more frequent on the ground floor in the two architectural types studied. Expanding the upper units in a duplex presents greater difficulties because it requires a greater investment in structure. Therefore, ground floor areas are disputed by these residents for expansions. Due to the complexity of expanding upper floor units, the study found that residents prefer single-story independent houses. The need for more space is confirmed by analyzing the percentage of area increase in relation to the original size of the house. The highest expansion percentages are associated with the row architectural type (G). Dissatisfaction with the size of the house has a direct relationship with the number of residents and, the wish to make more modifications is inherent in almost all respondents.

It is clear that the row architectural type is the one that most favors expansions, on the other hand, the upper floor units in the duplex type of construction presents more constraints. In turn, the row type favors confining the original rooms, because the alternatives for expanding the house – front and rear – with the tendency of expanding to the limit of the lot does not allow other layouts and moving existing windows to other locations.

Without technical assistance, such modifications compromise the quality of the built environment: excess moisture, moldy walls, dark rooms without air renewal, and confined rooms that do not provide occupants with hygiene and health are frequent outcomes. The large built mass added over the years plus removing windows and confining rooms contribute to understanding the low level of thermal satisfaction of users with the interior of the house.

Fans are needed to alleviate internal thermal discomfort throughout the day (G=45.5%, T=50.1%) and are more frequently used at bedtime (G=75.8%; T=83.3%). However, using appliances for thermal comfort and visual activity results in increased energy consumption, which is an added issue since our study surveyed a low-income population with economic constraints.

Conversely, this research identified interventions in the house that have a positive impact on habitability: when the original window is replaced with either a larger window or one made of better material, it provides a larger effective opening area for ventilation and sunlight to come in, and it may also be easier to operate. Windows were replaced more often on the duplex upper floor because expanding is much more difficult than on the ground floor.

Concerning the statistical tests, results showed that there is a significant dependence between change of sensation and preference for natural ventilation depending on the total expanded area of the duplex (T). That is, expanding the houses led users to change their opinion about wind sensation and preference. In the row type (G), a relationship of dependence was found between the level of modification and the thermal sensation votes.

Modifications are inherent in SH, however, currently, they yield uncomfortable places that are harmful to the health of residents. It is vital to understand the true dynamics of house modifications, the factors associated with such modifications, as well as thermal and health impact on residents. It is crucial to design houses that are closer to what the most vulnerable families want.

Future studies may reapply the method employed in this research to other architectural types to identify patterns of recurrent modifications made to social houses, and present proposals for mass customization. In addition, such studies may further investigate the impact of the problems identified in the health of residents deriving from the modifications that compromised the habitability of the house. We also highlight other issues that need to be investigated, such as: the association between energy consumption and the expansion made to the housing unit, and house transfers to other occupants (rebound). As to one limitation of this study – having full access to all the areas of the housing compound, we suggest using technologies, such as drones, to help in the surveying phase.

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Acknowledgements

The authors would like to thank the CAPES and FAPESQ/PB scholarships and CNPQ funding by Notice MCTIC/CNPq No. 28/2018 – Universal/Band B – Process: 434583/2018; Edevaldo Simões for his great help in collecting the field data; Lilianne Leal for her great help in hypotheses testing.

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Ambiente Construído
Revista da Associação Nacional de Tecnologia do Ambiente Construído
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