Assessment of housing resilience in relation to the impacts of aging

Avaliação da resiliência de moradias em relação aos impactos decorrentes do envelhecimento

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Abstract

The increase in the elderly population can be observed in various countries around the world, including Brazil. Aging involves the individual as a whole, and there are natural structural and functional changes associated with this process. These changes correspond to impacts capable of reducing the independence of the elderly. For each impact, house renovation can be undertaken to compensate. Such renovations will possibly be simpler and more economical in a resilient house. Are current houses resilient to the demands of aging? To answer this question, it is necessary to understand what resilience is and then measure it. The objectives of this article are: (i) to expose the level of resilience of houses regarding the impacts of aging; (ii) to present and discuss the results; and (iii) to prescribe changes in the house to increase its resilience. For this purpose, two post-occupancy evaluation instruments were prepared: an impact questionnaire and a resilience ruler. This research was conducted based on the Design Science Research method. Additionally, a case study was used to test the evaluation instruments and obtain specific data from *Residencial Sucesso Brasil*, part of a social housing complex located in Uberlândia, Minas Gerais, Brazil. The primary factor contributing to the diminished resilience of the residential units at Residencial Sucesso Brasil compared to the original design and the requirements of aging was the elimination of illuminating areas. It is necessary and urgent to establish a collaborative relationship between architects and engineers and the residents of the residential complex to facilitate the construction of more resilient housing.

Keywords: Aging in place. Post-occupancy evaluation. Social housing. Sustainability.

Resumo

O aumento da população idosa pode ser observado em diversos países do mundo, incluindo o Brasil. O envelhecimento afeta o indivíduo como um todo e envolve alterações estruturais e funcionais naturais associadas a esse processo. Essas alterações geram impactos capazes de reduzir a independência do idoso. Para cada impacto, é possível realizar adaptações para reduzi-los. Essas adaptações serão possivelmente mais simples e econômicas em uma casa resiliente. As casas atuais são resilientes às demandas decorrentes do envelhecimento? Para responder tal

pergunta, é necessário compreender o que é resiliência e em seguida mensurá-la. Objetiva-se neste artigo: (i) expor o nível de resiliência das casas em relação aos impactos decorrentes do envelhecimento; (ii) apresentar e discutir os resultados obtidos; e (iii) sugerir alterações na casa para aumentar sua resiliência. Para isso, foram desenvolvidos dois instrumentos de avaliação de pós-ocupação: um questionário de impacto e uma régua de resiliência. A pesquisa foi conduzida tendo como base o método Design Science Research. *Paralelamente, utilizou-se o estudo de caso para testar os instrumentos de avaliação e obter dados específicos do Residencial Sucesso Brasil, parte de um conjunto habitacional de interesse social situado em Uberlândia, Minas Gerais, Brasil. A eliminação das áreas iluminantes foi a principal responsável por reduzir a resiliência das casas do residencial Sucesso Brasil em relação ao projeto original e as demandas do envelhecimento. É necessário e urgente aproximar arquitetos e engenheiros dos moradores do residencial para possibilitar a construção de casas mais resilientes ao envelhecimento.*

Palavras-chave: *Envelhecendo no lugar. Avaliação de pós-ocupação. Moradia de interesse social. Sustentabilidade.*

Introduction

The aging process and housing

People over 60 years old are considered elderly (Bonfim, 2020; Organização Mundial da Saúde, 2005). The increase in the elderly population can be observed in various countries around the world, including Brazil. According to a demographic census conducted by *Instituto Brasileiro de Geografia e Estatística* (IBGE), in 2022, the Brazilian elderly population reached 32,113,490 (15.6% of the population), an increase of 56.0% compared to 2010 when it was 20,590,597, representing 10.8% of the population (Gomes; Brito, 2023). The same institute estimated that by 2030, the percentage of elderly people in Brazil could reach 18.73% (Instituto Brasileiro de Geografia e Estatística, 2020). Parallel to the increase in the elderly, there is an increase in life expectancy, meaning that more and more people will reach advanced ages. In 1940, the life expectancy of Brazilians was 45.5 years (Crelier, 2020). In 2022, life expectancy reached 75.5 years (Em 2022 [...], 2023). That's, an increase of 30 years compared to 1940.

The aging process involves the whole person (Carli, 2004), and there are natural structural and functional changes associated with this process. Such changes are referred to as senescence. Examples include: hair whitening and/or loss; loss of skin flexibility; appearance of wrinkles; reduction in stature; loss of muscle mass; among others (Qual a diferença [...], 2023). Parallelly, there is senility, which involves changes resulting from chronic diseases, such as: coronary artery disease; hypertension; stroke; diabetes; cancer; chronic obstructive pulmonary disease; arthritis; osteoporosis; dementia; depression; blindness (Organização Mundial da Saúde, 2005).

The changes (senescence and senility) can be understood as impacts that gradually affect the life of the aging individual. Depending on the intensity of the impacts, the capacities of the elderly decline. A chart was organized discriminating these impacts and grouping them by systems and senses (See Chart 1).

The impacts resulting from aging affect the functional capacities of the elderly and contribute to the reduction of their independence, an important aspect when aiming for a better quality of life (Organização Mundial da Saúde, 2005). However, for each impact, a modification in the built environment can be made to compensate (Carli, 2004). Another chart was organized discriminating a series of housing modifications capable of compensating the impacts faced by the elderly. The modifications were grouped by building element and associated, through colors, with the systems and senses in decline (See Chart 2). It is important to emphasize that it is not necessary to carry out all the modifications listed in chart 2. These modifications can be implemented gradually, partially, or entirely, taking into account the conditions and needs of the elderly residents.

Chart 1 – Declining capabilities or impacts resulting from the aging process; grouped by systems and senses.

N	Systems and senses	Declining capabilities
1	Nervous	Reduced movement speed
2		Reduced perception speed
3		Reduced decision-making speed
4		Feeling of vulnerability
5		Reduced accuracy during tasks requiring attention
6	Cardiovascular and respiratory	Reduced cardiovascular capacity
7		Reduced pulmonary capacity
8		Reduced capacity to perform non-routine exercises requiring physical effort
9	Immunological	Reduced ability to regulate body temperature
10		Reduced amount of body water
11		Reduced capacity to react to new antigens
12	Urinary Genital	Reduced bladder control (Incontinence)
13	Musculoskeletal	Reduced bone density
14		Reduced muscle strength
15		Reduced balance capacity
16		Reduced flexibility
17		Reduced range of motion
18		Altered gait
19		Increased susceptibility to falls
20	Tact	Reduced ability to feel pain, pressure, and temperature
21	Smell	Reduced ability to smell odors
22	Vision	General reduction of vision
23		Reduced visual acuity (sharpness)
24		Reduced peripheral vision
25		Reduced ability to judge distances and speed
26		Reduced ability to distinguish colors
27		Reduced ability to see in low light
28		Reduced ability to see amidst reflections
29		Reduced ability to adjust vision to changes in light levels
30		Reduced ability to define contours
31	Hearing	General reduction of hearing
32		Reduced ability to hear high-frequency sounds
33		Reduced ability to differentiate sounds in a noisy environment

Source: Elaborated by Braga (2021), based on Carli (2004), Organização Mundial da Saúde (2005) and Bestetti (2006).

The two charts (1 and 2) can help the architect define which modifications in the house are necessary to meet the demands of an elderly resident. To do this, it is enough to identify (Chart 1) the observed declines or impacts and the systems to which they belong. Then, identify (Chart 2) through the corresponding colors, which modifications in the house can be made for to compensate the declines.

A suitable built environment can reduce the threshold of disability (Organização Mundial da Saúde, 2005; Cambiaghi, 2019) and contribute to the elderly person being independent for as long as possible. This occurs because disability arises from the interaction between the individual and the environment in which they find themselves (Cambiaghi, 2019; Bonfim, 2020). In a suitable environment, disability is not evident. Designing considering the principles of universal design and accessibility standards contributes to the creation of a suitable environment for a large portion of people, not only for those with disabilities, but also for people without disabilities and with reduced mobility (Example: the elderly).

Chart 2 – Changes in houses capable of compensating for declining abilities or impacts. 1 of 3

Legend

Color	System	Color	Sense
🟩 (light green)	Nervous system	🟥 (dark red)	Tact
🟩 (dark green)	Cardiovascular and respiratory system	🟥 (salmon)	Smell
🟦 (light blue)	Metabolic and Immunological system	🟧 (orange)	Vision
🟦 (blue)	Urinary Genital system	🟨 (yellow)	Hearing
🟪 (purple)	Musculoskeletal system		

New demands

#	Category	Demand	Nervous	Cardiovascular & respiratory	Metabolic & Immunological	Urinary Genital	Musculoskeletal	Tact	Smell	Vision	Hearing
1	Technical aids	Install support bars in bathrooms.					🟪				
2		Install handrails and/or support bars in hallways, stairs, ramps, and isolated steps.					🟪				
3		Cover exposed screws to prevent abrasions.			🟦		🟪	🟥			
4	Furniture and decoration	Remove rugs to prevent slips and trips.					🟪				
5		Install silicone, rubber, or EVA corner protectors.					🟪				
6		Adjust bed height so that the elderly can rest their feet on the floor when seated.					🟪				
7		Cover exposed screws.			🟦		🟪	🟥			
8		Adjust cabinet height so they can be used without the need for a ladder.					🟪				
9		Store clothing and objects at an appropriate height that eliminates the need for a ladder.					🟪				
10		Use larger trash bins with wheels to allow for easy transportation.					🟪				
11		Position smaller trash bins on supports to increase their height and make them more comfortable to use.					🟪				
12		Select and fix some furniture to the floor to serve as support for getting up in case of a fall.					🟪				
13		Use chairs with armrests.					🟪				
14		Position fire extinguisher in a visible and easily accessible location.	🟩				🟪			🟧	
15		Rearrange furniture and decorations considering the needs and mobility difficulties of the elderly who may use a cane, walker, or wheelchair.					🟪				
16		Install fixed and foldable seats in the shower box.					🟪				

Source: Elaborated by Braga (2021), based on Hertzberger (1999), Carli (2004), Bestetti (2006), Cambiaghi (2019), and Associação Brasileira de Normas Técnicas (2020).

Chart 2 – Changes in houses capable of compensating for declining abilities or impacts.

		New demands	
17	Fixed countertops	Adjust the height of countertops considering the reach conditions of the elderly.	
18		Install silicone, rubber, or EVA corner protectors.	
19	Partitions	Install partitions capable of supporting the installation of bars and handrails.	
20		Install partitions that are easy to clean.	
21		Cover screws to prevent abrasions.	
22	Coatings	Flooring: Use non-slip coating to prevent slips.	
23		Flooring: Use rubberized coating to reduce injuries in case of falls.	
24		Flooring: Highlight level changes through color changes to compensate for visual loss.	
25		Flooring and walls: Use waterproof coatings in wet areas to facilitate cleaning and prevent fungal growth.	
26		Flooring and walls: Replace rough coatings that may cause skin injuries.	
27		Flooring, walls, and ceiling: Replace existing coatings with others that reduce reverberation.	
28		Flooring, walls, and ceiling: Replace polished coatings with others with a satin or matte finish.	
29		Flooring, walls, and ceiling: Coatings that are easy to clean.	
30	Joineries	Install acoustic windows, sliding, lightweight, easy to operate, easy to clean, and maintain.	
31		Install windows that allow for viewing the exterior environment.	
32		Install windows that allow for darkening the room at any time of the day.	
33		Install external doors with a peephole or attached window to allow viewing of the external environment and identify visitors.	
34		Install ''Dutch doors'' that allow opening the top part while the bottom remains closed.	Enable socialization
35		Install security locks on external doors.	Prevent invasions
36		Install lever-type doorknobs.	
37		Remove locks from internal doors.	Enable rescue
38		Install door frames that allow for changing the direction of opening.	
39		Replace tempered glass doors of the shower box with laminated glass.	
40	Electrical, telephone, and network installations (1 of 2)	Install intrusion alarm (audible and visual) with automatic activation of police or security company.	Prevent invasions
41		Install gas and smoke detection alarm (audible and visual).	
42		Install fire alarm (audible and visual).	
43		Install emergency alarm (audible and visual) in the bathroom.	Enable rescue
44		Install telephone in the kitchen and bathroom.	Enable communication
45		Install intercom on all floors.	
46		Install fixtures that do not require the use of a ladder to change light bulbs.	
47		Install extra and pinpoint fixtures for reading and work areas.	
48		Install fixtures inside cabinets.	

Chart 2 – Changes in houses capable of compensating for declining abilities or impacts.

New demands

#	Category	Description
49	Electrical, telephone, and network installations (2 of 2)	Install a fixture above the main door to facilitate viewing of the lock.
50		Install motion sensors in circulation corridors for automatic activation of lights.
		Install motion sensors in bathrooms for automatic activation of lights.
		Install motion sensors on the bedroom-to-bathroom path for automatic activation of lights.
51		Install humidifier in the environments.
52		Differentiate switches and outlets from the background wall by color.
53		Provide outlet for window motorization.
54		Position outlets for various uses between 40cm to 120cm in height.
55	Mechanical installations	Install an elevator platform for movement between floors.
56		Install a stairlift chair attached to the stairs.
57		Install air conditioning.
58	Hydrosanitary installations	Adjust the height of the valves to enable their use without the need for a ladder.
59		Install valves, faucets, and mixers of the lever type with a quarter-turn.
60		Adjust the height of the toilet bowl. It should be 46 cm high.
61		Install a shower temperature limiting device.
62	Walls	Construct walls capable of supporting the installation of bars and handrails.
63		Construct walls with sound insulation in walls shared between housing units.
64		Properly construct openings for the installation of frames to allow passage and rescue. — *Enable rescue*
65		Construct lighting and ventilation openings facing pleasant and quiet areas (gardens, squares, and parks). — *Enable contemplation*
66		Construct ventilation openings that allow for viewing the external environment while sitting or lying down. The opaque windowsill should be no more than 40 cm high.
67		Construct lighting and ventilation openings that allow direct but not excessive lighting.
68		Close lighting openings at the end of corridors to avoid glare.
69		Construct openings that allow cleaning and maintenance without the use of a ladder.
70	Alterations that may include various elements of the building	Replace isolated steps with ramps of appropriate slope.
71		Adapt stairs according to NBR9050 (Brazilian standard for accessibility).
72		Adapt ramp inclinations according to NBR 9050.
73		Adapt, at least, one bathroom per floor to meet the needs of the elderly.
74		Adapt dimensions of spaces considering the level of mobility difficulty of the elderly who may use a cane, walker, or wheelchair.
75		Provide contrast through color between different elements of the building.
76		Restrict access to areas that may pose a risk to the elderly.
77		Adapt spaces and openings to allow the elderly to have contact with neighbors. — *Enable socialization*
78		Place the elderly person's bathroom close to their bedroom to minimize the effects of urinary incontinence.

Housing is one of the most important parts of the built environment for the elderly and it represents tranquility and security (Carli, 2004; Portella; Woolrych, 2019). Even when facing difficulties, a considerable portion of the elderly express the desire to remain in their homes (Carli, 2004; Holder, 2023). Housing is a place of memories, of strong emotional attachment, and the possibility of remaining is synonymous with autonomy and independence (Woolrych *et al.*, 2019).

To enable the elderly to stay in their own homes, it may be necessary to make renovations to adapt them to their physical, emotional, and social needs. Such renovations will possibly be simpler and more economical in a resilient house. However, are current houses resilient to the demands of aging? To answer this question, it is first necessary to understand what resilience is and, secondly, to find a way to measure it.

Whats is resilience?

The study of this characteristic began in engineering around 1818 (Garcia; Vale, 2017; Trogal *et al.*, 2019) when it was defined as the ability of a body to absorb energy, deform, release energy, and restore it's original shape (Callister Junior; Rethwisch, 2021). In the 1970s, the term began to be used in ecology, where it was defined as the ability of an ecosystem to absorb changes in its variables and thus be able to persist (Holling, 1973). This definition contributed to the popularization of the term, which over the decades, began to be used in other sciences, disciplines and various contexts. In the context of the built environment, the study of resilience found fertile ground and definitions proliferated. In this context, there seems to be no exact definition of resilience yet; however, it has been related to the ability of the built environment to respond, absorb, and adapt to different impacts and demands over time (Pickett *et al.*, 2014; Hassler; Kohler, 2014; Garcia; Vale, 2017).

This capacity may be associated with excessive consumption of resources: (i) building; (ii) human; (iii) financial; (iv) technological; (v) energy; and (vi) natural resources. In the case of cities, it is a challenge to become resilient and sustainable at the same time. Toronto, Canada, was once considered one of the most resilient cities in the world; however, at the same time, it was deemed less sustainable (Garcia; Vale, 2017).

In order to bring these two concepts closer together at the building scale, the following definition for resilience was proposed: It is the capacity of the building to undergo changes to meet new demands while keeping certain elements unchanged[2]. Thus, an attempt was made to establish a limit (Walker *et al.*, 2004; Garcia; Vale, 2017) for the resilient behavior of the building and, consequently, to avoid excessive resource consumption.

The concept of limit also exists in engineering, where resilience is a characteristic observed during the elastic regime of a material and its limit corresponds to an event called material yield; in the context of the building, it was suggested that resilience is a characteristic observed during the absorption regime (see Figure 1): If the building is able to meet the demands of its residents through simpler renovations, restricted to certain building elements, it is considered resilient. Otherwise, the building is considered non-resilient. It is worth noting the proposal that a resilient building does not equate to a building suitable for the purpose for which it was designed, but to a building easily adaptable to a new need.

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[2] To understand this article, consider this definition of resilience.
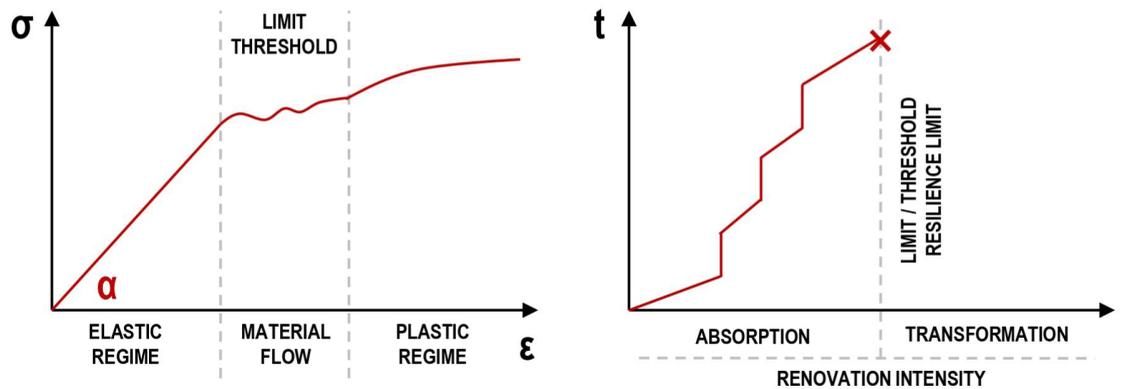
Figure 1 – Comparison between the limit in engineering (on the left) and the limit in architecture (on the right).
Source: Elaborated by Braga (2024), based on Walker *et al*. (2004) and Callister and Rethwisch (2021).

How to measure resilience?

To measure resilience, two post-occupancy assessment instruments – POA were prepared: (i) Impact Questionnaire; and (ii) resilience ruler. The first aims to measure the level of discomfort experienced by the elderly when using their house, and the second aims to measure the level of resilience of the house (building). While the Impact Questionnaire gathers data from interviews with residents, the resilience ruler gathers data from the analysis of architectural design.

Objectives of the article

Through the application of these instruments, the objectives of this article are: (i) to expose the level of resilience of the houses in a low-income residential area regarding the impacts of aging on its residents; (ii) to present and discuss the results obtained; and (iii) to prescribe changes in the house in order to increase its resilience.

Relevance

The topic of social housing, more precisely, that resulting from *Programa Minha Casa Minha Vida – PMCMV* (Effective: 2009 to 2018), has been and continues to be extensively studied in Brazil. Despite the large number of descriptive and prescriptive researches, quality problems in houses still persist, especially in those already delivered and inhabited. Some examples of observed problems include: (i) Incompatibility between the project and the variety of family profiles; (ii) Difficulty in making house adjustments; (iii) Construction errors and early onset of structural pathologies; (iv) Inadequacy of developments to local realities; and (v) Standardization of projects regardless of location (Amore; Shimbo; Rufino, 2015). The *PMCMV* was resumed by the federal government in February 2023. The new projects, works, and services should

> [...] Taking into account aspects of accessibility and sustainability. Units need to be adaptable and accessible for use by people with disabilities, reduced mobility, or elderly individuals, and should pay attention to social, economic, environmental, and climate sustainability (Programa [...], 2023, online, our translation)[3].

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[3] In the original: "[...] *levar em consideração aspectos de acessibilidade e sustentabilidade. As unidades precisam ser adaptáveis e acessíveis ao uso por pessoas com deficiência, com mobilidade reduzida ou idosas, e devem ter atenção à sustentabilidade social, econômica, ambiental e climática* [...]".

Considering: (i) the aging population; (ii) the legacy of the *PMCMV* and its resumption; and (iii) the new requirements of the program; it is opportune to continue the study and seek architectural solutions capable of meeting the needs of the elderly who already live in the houses offered and also those who will still inhabit them.

Materials and Methods

This research was conducted based on the Design Science Research method, advised when intending to develop and prescribe innovations to solve problems (Dresch; Lacerda; Antunes, 2015). At the same time, the case study method was used to gather specific information and test the evaluation instruments.

The POA instruments in this article were developed based on the instruments already used by the MORA[4] research group. The instruments were adapted with the aim of specifically measuring the impacts resulting from aging and the level of resilience of the houses in relation to the new demands generated by this process.

Impact questionary

The Impact Questionnaire (see Chart 3) is a POA instrument divided into five parts: (i) Identification; (ii) General questions; (iii) Measurement of negative effects; (iv) Measurement of surface cleaning difficulty; and (v) Photographic documentation. The first part, identification, aimed to gather information about the location of the house, the date, time of the interview, and the resident's contact phone number. Identification was important for organizing research data; however, to ensure the privacy of the interviewees, their data should not be disclosed.

The second part, general questions, aimed to collect socio-economic data and the health status of the interviewee. In addition to age and income, the incidence of major diseases resulting from aging (Senility) was investigated.

The third part, measurement of negative effects, aimed to assess the level of discomfort felt by the elderly during daily activities in their homes. To formulate the questions, the data from Chart 1 were used. Declines were associated with daily activities performed in the home, and 38 questions were formulated from there.

The fourth part, measurement of surface cleaning difficulty, aimed to assess the difficulty of cleaning the house. The formulation of this part took into account the decline in metabolic immune systems.

The fifth part, photographic documentation, aimed to discriminate and identify photos of the investigated houses.

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[4] The MORA Group – Research in housing – at the *Universidade Federal de Uberlândia, Faculdade de Arquitetura e Urbanismo e Design*, corresponds to a physical and virtual space, open to criticism and reflection, and whose researchers seek to establish a relationship between the academic environment and practice through actions that effectively contribute to the improvement of housing.

Chart 3 – Impact Questionnaire Fragments.

General questions
Has your home been renovated, extended or has a balcony been built? ( ) Yes ( ) No
Sex of the interviewee: ( ) Male ( ) Female
How old are you? ___
What is the monthly income of the entire family? ( ) Has no income ( ) 1 to 2 minimum wages ( ) 2 to 3 minimum wages ( ) 3 to 4 minimum wages ( ) more than 4 minimum wages
Do you have heart disease? ( ) Yes ( ) No
Do you have high blood pressure? ( ) Yes ( ) No
Have you ever had a stroke? ( ) Yes ( ) No
Are you diabetic? ( ) Yes ( ) No
Do you have lung disease? ( ) Yes ( ) No
Do you suffer from arthritis? ( ) Yes ( ) No
Osteoporosis? ( ) Yes ( ) No
Do you feel depressed? ( ) Yes ( ) No
Do you have difficulty seeing? ( ) Yes ( ) No
If the interviewee describes any of the illnesses, it is worth documenting the description.

Measuring negative effects
Cause (Major event): Aging

Threats		Negative Effects on the Home and Family The interviewer must read only the question. The questions should be asked in order.	Perception. Does the interviewee notice the effect?		Level of discomfort. If the interviewee notices the effect, ask: How much does this bother you?			Comments:
			No	Yes	Little	A lot	None	
( ) Hearing decline	1	Misunderstanding words during a conversation due to noise from the street or neighbors. Do noises from the street or neighbors make it difficult for you to hear and talk?						
	2	Misunderstanding words during a conversation due to noise from other residents of the house. What about the noises from other residents of your house?						

Measuring the difficulty of cleaning surfaces

Impacts: Declining Capabilities		Negative Effects on the User or Built Environment	Difficulty level				Comments:
			Yes or no?		If the answer is "yes", ask: A lot or a little?		
		As we age, many of our capabilities decrease. So I ask:	Yes	No	Little	A lot	

ATTENTION. Ask: Do you clean your own house? ( ) Yes ( ) No. If the answer is "Yes", ask questions 32 to 38.

Decline of metabolic and immune systems	32	When the floor gets dirty, is it difficult to clean?					
	33	and the walls?					
	34	What about the kitchen and bathroom countertops?					
	35	When the bathroom floor and walls get dirty, are they difficult to clean?					

Source: Braga (2021).

Resilience ruler

The resilience ruler (see Chart 4) is a POA instrument composed of 4 parts: (i) Identification; (ii) Legend; (iii) Assessment grid; and (iv) Calculation spreadsheet. The first part, identification, is identical to that developed for the Impact Questionnaire, serving the same purpose. The second part, Legend, clarified the abbreviations used.

The third part, assessment grid, was divided into items. Each item was structured as follows: (i) Room; (ii) Resilience assessment scale; (iii) References. The grid was elaborated based on resilience indicators (see Chart 5), in other words, characteristics that the built environment must have to be able to recover from the impacts suffered (Parreira, 2020). In the case of this research, some building characteristics capable of contributing to the increase in simplicity of renovations in relation to the demands resulting from aging were defined based on Chart 2.

The fourth part, calculation spreadsheet (Chart 4), aimed to synthesize the data obtained in the assessment grid and assist in calculating the overall resilience level of the house.

Chart 4 – Resilience Ruler Fragments and Calculation Example. 1 of 2

Identification
Housing unit identification (Write address): Date:_____ Time:_____ Phone(s) (whatsapp):_____
Resilience Assessment Framework
Attribute: Accessibility associated with aging
Legend: SAL – Living room / TV / Dining room; COZ – Kitchen; SERV – Service; BHO – Bathroom; DORM – Bedrooms; CIRC – Circulation; VAR – Balcony; GAR – Garage; DEP – Storage; COM – Commerce;
Note 1: Data collection method: Walkthrough or analysis of the architectural project; Note 2: The number of rooms must be adapted to each home; Note 3: All rooms must be analyzed, except when the item does not require a certain room; Note 4: Item C – If the room has more than one access span, consider only the most resilient one for analysis.

Room	Resilience Assessment Scale					References for parameter proposition
	None	low	moderate	high	very high	
	A	B	C	D	E	
A	Evaluate the type of wall used in the rooms (BHO and CIRC). If there is more than one type of wall in the room, consider the least resilient type for the answer. 1º) Masonry; Ans.: D 2º) Drywall; Ans.: B					
CIRC		•		•		
BHO		•		•		

Spreadsheet						
	Evaluation Scale					Totals
Sum of responses by level						
Importance	A = 1	B = 2	C= 3	D = 4	E = 5	
Score per level						
Overall level of resilience: (Total score) / (Total responses)						

Source: Braga (2021).

Chart 4 – Resilience Ruler Fragments and Calculation Example.   2 of 2

Example of application of resilience ruler			
Items evaluated		Resilience level	
A	Capacity of the construction system to unite more rooms	None	1
B	Capacity of the construction system to integrate kitchen with dining room	Moderate	3
C	Capacity of the construction system to incorporate the balcony into the apartment's room	Very high	5
Total (Sum of resilience levels)			9
Overall level of resilience: (Total score) / (Total responses)			3

Source: Braga (2021).

Chart 5 – Resilience indicators.

Atributo: Accessibility Associated with Aging		
Walls		
	A	Able to support the installation of grab bars and handrails;
	B	With acoustic insulation when shared between houses;
	C	With passageways wide enough for an elderly person to pass through, regardless of the orthosis used (cane, walker or wheelchair);
	D	With openings for lighting and ventilation facing pleasant and low-noise áreas;
	E	With opaque parapets of adequate height (40cm);
	F	With openings for lighting and ventilation that allow controllable direct sunlight.
Others		
	G	To have a compartment or area for the installation of an elevator in cases with more than one floor;
	H	To have ramps of adequate width and slope according to NBR9050;
	I	To have one bathroom per floor with adequate areas for approaching and using furniture according to NBR9050;
	J	To have circulation areas between partitions with adequate width according to NBR9050;
	K	To have no isolated Steps.

Source: Braga (2021).

To exemplify the functioning of the resilience calculation for a house, consider the following example: imagine a resilience assessment ruler (see chart 4, example of application of resilience ruler). The overall resilience of the house was obtained through the arithmetic mean of the resilience levels of each item on the ruler, that is: Overall resilience = (Sum of individual resilience levels) / (Total items evaluated). In this example, the value obtained after the arithmetic mean was 3, meaning that, considering the evaluated items, the house is moderately resilient. Thus, the assessment ruler is capable of providing the resilience level regarding a specific item and regarding the house as a whole. When intending to calculate the resilience level of a sample of houses, the arithmetic mean of the overall resilience of each house is calculated.

The object of the case study

In order to test the evaluation instruments and obtain specific data, the *Sucesso Brasil Residential* was chosen as the object of the case study in this research. The residential area was one of the case study objects used by other researchers from MORA research group. It is located in a peripheral neighborhood in the southern region of Uberlândia, Minas Gerais, Brazil, and comprises 211 single-family houses (See Figure 2). It is part of the largest Social Interest Housing Complex (SIHC) produced by *PMCMV* in Uberlândia, consisting of 3,632 houses intended for families in income bracket 1 (0 to 3 minimum wages). The houses in this SIHC are single-story, semi-detached, and separated by a common wall on one of the side boundaries of the plot. For each plot, there is a house located in the central region (See Figure 2).

SIHC Shopping Park – 3,632 houses (on the left); Residencial Sucesso Brasil – 211 houses (on the center); Residencial street (on the right);
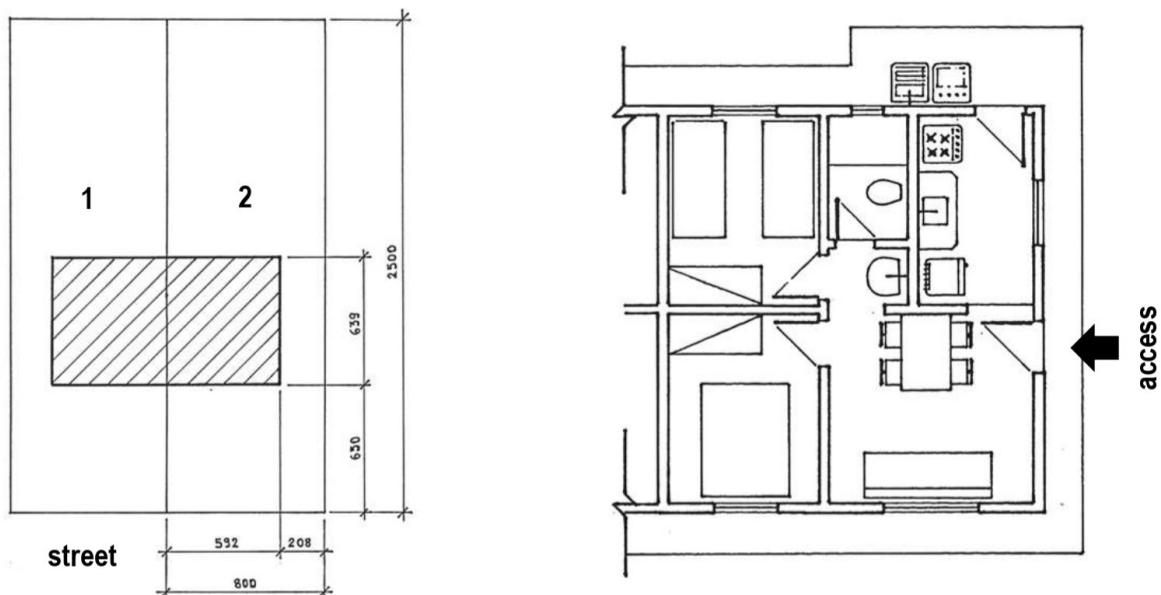
Location plan (on the left); Layout plan (on the right);

Figure 2 – Case study subject: Residencial Sucesso. Brasil, Uberlândia, MG.
Source: *Google Maps* images (2011-2019), drawings, and montage by Braga (2024).

Execution of POA and organization of results

The POAs were conducted during the COVID-19 pandemic. Therefore, it was decided to collect data from only 11 houses, which represents 5% of the case study object. The objective was to reduce the risk of contagion among the elderly, considered a high-risk group.

The questionnaires were administered on November 5th, 6th, and 7th, 2020, at the following times: 8:30 AM to 11:00 AM and 2:00 PM to 4:30 PM. The ruler application took place during the week of November 25th to 31st, 2021.

The selection of houses for POA took into consideration three criteria: (i) The presence of elderly people; (ii) The resident's availability to participate in the research; (iii) The existence of architectural surveys and photographic documentation containing the necessary information to fill out the ruler.

The questionnaires were administered in pairs, consisting by the author of the dissertation and a volunteer architect and researcher. The interviewers wore biological protection masks and used alcohol gel to protect and disinfect objects and hands. Disposable masks were offered to each interviewee at the beginning of the interview. Efforts were made to maintain the greatest possible social distance. The ruler was applied using architectural projects of the houses, without the need for a site visit or interview.

After completing the POA, the responses were compiled into digital spreadsheets using Libre Office 6.4 software. The data were entered manually. The spreadsheet was configured with formulas to calculate the responses. The quantification of the responses was done automatically by the software. Finally, the data were expressed and summarized manually into graphs and tables using the text editor of Libre Office 6.4 software.

Results and discussion

Figure 3 summarizes the responses obtained from the application of the impact questionnaire in Residencial Sucesso Brasil. On the horizontal axis, each number refers to one of the questions asked. On the vertical axis, each number refers to the number of people who felt discomfort or difficulty performing a specific task in the house. The red and yellow colors refer to the level of discomfort reported, much and little, respectively. For example: observe that, in column 16, 6 people reported much discomfort and 3 people reported little discomfort. The horizontal dashed line marks the halfway point of the sample. The discussion will focus on the impacts felt by more than half of the respondents.

Fear or discomfort in changing ceiling light bulbs was the negative effect with the highest number of reports (column 16). Changing ceiling light bulbs involves climbing on a chair or ladder, a risky action for elderly residents. Similarly, fear, discomfort, or pain was detected when stretching to use high outlets and cabinets (column 15). Possibly, due to the lower risk of falling, bending down to use low outlets or cabinets generated less discomfort (column 14). Trips on rugs and slips were also reported. Reduced balance and decreased motor response speed (Carli, 2004) can increase the risk of falling in all these cases. In the elderly, the risk of bone fracture is higher due to osteoporosis (Carli, 2004; Organização Mundial da Saúde, 2005), and recovery is slower and more difficult. A fall, followed by a fracture, can result in premature dependence for performing common daily activities. In Brazil, for example, falls are considered the 3rd leading cause of mortality in people over 65 years old (Carvalho, 2024).
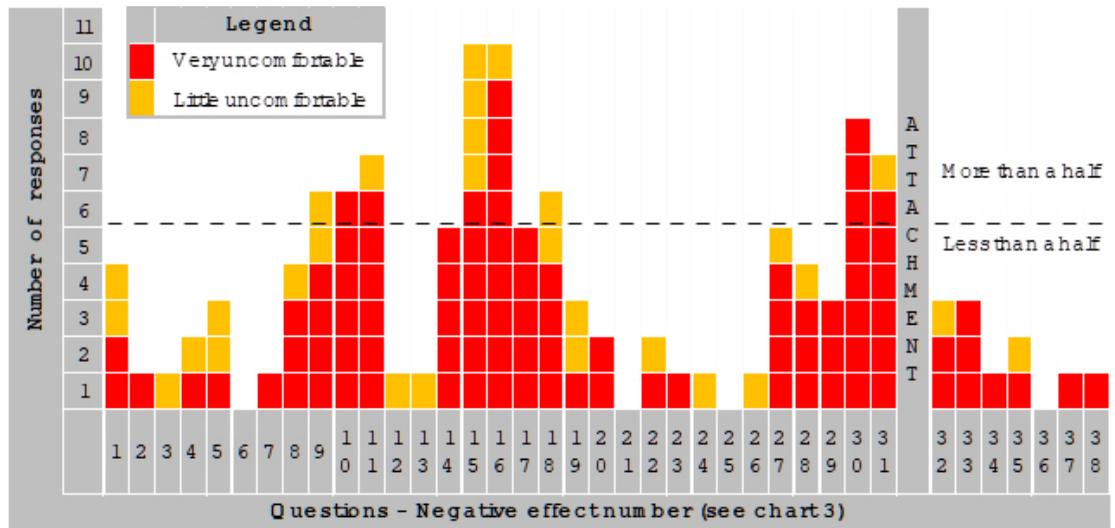
Figure 3 – Results of the impact questionnaire.
Source: Braga (2021).

Discomfort due to excessive heat (column 30) and cold (column 31) was also relevant. Due to the reduced ability to control body temperature (Carli, 2004), very hot and cold environments can contribute to the onset of hypothermia or hyperthermia in the elderly.

Regarding the difficulty of climbing steps or stairs (Columns 9, 10, and 11), the level of discomfort increased as the number of steps increased. However, even the transposition of only 3 steps (Column 9) caused discomfort in more than half of the respondents.

Of the 38 effects measured, the most important results were, in descending order: (1st) Fear or discomfort in changing ceiling light bulbs; (2nd) Feeling that the house is too hot in the summer; (3rd) Fear, discomfort, or pain when stretching to use high outlets and cabinets; (4th) Feeling that the house is too cold in winter; (5th) Difficulty or discomfort in climbing 15 or more steps; (6th) Difficulty in climbing 7 steps; (7th) Difficulty in climbing 3 steps; (8th) Trips on rugs.

In Chart 6, the results of the resilience ruler application in *Residencial Sucesso Brasil* are presented, both in the post-renovation design and in the original house design. Each resilience indicator was evaluated. At the end of the chart, the overall resilience level of the sample was obtained. The discussion will mainly focus on the post-renovation results.

Item A: Evaluation of the type of walls used in bathrooms and exclusive circulation areas – the post-renovation sample was considered resilient (level 4). This item assessed the ability of the walls to support the installation of bars and/or handrails. In the evaluated houses, all walls were built of ceramic brick masonry, whose strength allows for the fixation of bars and handrails without the need for reinforcement. This characteristic was considered positive, as the installation of bars is simple, using a drill, nylon plugs, and screws.

Item B: Evaluation of shared walls between houses and the existence of acoustic insulation – the post-renovation sample was considered moderately resilient (Level 3). The original houses already shared walls because they were semi-detached. Despite the possible privacy and acoustic comfort problems generated by this fact, the observed expansions maintained the sharing of walls without insulation. With declining hearing, it becomes more difficult to understand words in a noisy environment (Carli, 2004). The sharing of walls without proper acoustic treatment exacerbates this condition and reduces privacy. In addition to the walls, it was observed that the windows used have gaps, preventing proper sealing. This results in: wind, dust, and noise entering.

Item C: Evaluation of the width of the access openings to each of the rooms – the post-renovation sample was considered moderately resilient (Level 3.42). In the evaluated houses, doors of various widths (60, 70, and 80 cm wide) were found. Depending on the difficulty of movement and the orthosis used by the elderly, doors with clearances less than 80 cm wide may hinder access to various environments in the house, reducing their independence. This fact becomes even more problematic when inaccessible rooms correspond to common use areas (kitchen, living room, bathroom, service area, and external area).

Chart 6 – Results from the application of the resilience ruler.

	Item assessed	Post-renovation project		Original Project	
		Level / Score		Level / Score	
A	Assessment of the type of walls used in bathrooms and exclusive circulation areas	4	Resilient	4	Resilient
B	Assessment of shared walls between houses and the presence or absence of acoustic insulation	3	Moderately resilient	3,43	Moderately resilient
C	Assessment of the width of the access gaps to each of the room	3,42	Moderately resilient	3,29	Moderately resilient
D	Assessment of the quality of the external view from each room	2,36	Less resilient	3,5	High Resilient
E	Assessment of the natural light entry in each room	2,35	Less resilient	4	High Resilient
F	Assessment of an elderly person's ability, while inside the environment, through a door or window, to visually perceive the uncovered exterior environment	2,20	Less resilient	3	Moderately resilient
G	Assessment of the elderly person's ability to handle window opening and locking controls	2,58	Moderately resilient	2,6	Moderately resilient
H	Verification of the existence of an area or compartment designated for elevator installation.	–	–	–	–
I	Evaluation of the characteristics of the ramps found	1	Not resilient	–	–
J	Evaluation of the approach areas and furniture use in the bathrooms	2,21	Less resilient	2	Less resilient
K	Evaluation of the width between enclosures in circulation areas	3,27	Moderately resilient	3	Moderately resilient
L	Verification of the existence of isolated steps	3,95	High Resilient	4	High Resilient
Summation of scores		30,34		32,82	
Total number of items assessed		11		10	
Overall resilience level of the sample		2,76	Moderately resilient	3,78	Moderately resilient

Source: Braga (2021).

Item D: Evaluation of the quality of the external view of each environment (except bathroom, circulation areas, service area) – the post-renovation sample was considered slightly resilient (Level 2.36). The elderly tend to spend more time at home contemplating the landscape (Hertzberger, 1999; Portella; Woolrych, 2019). Observing the landscape can mean more pleasure, less loneliness, and more social contact. In the analyzed houses, poorly planned expansions and openings prevent the contemplation of the external garden, city, or nature. The construction of walls at the front boundary of the lot prevents most of the visual contact of the elderly with the street and neighbors (see Figure 4).

Item E: Evaluation of the entry of sunlight into each room (except circulation areas) – the post-renovation sample was considered slightly resilient (Level 2.35). In 2021, 92% of the houses

in Residencial Sucesso Brasil had already undergone expansions. Most of the expansions did not preserve the illuminating areas of the original Project (see Figure 4). As a result, internal rooms were generated with: (i) Little or no natural light; (ii) Poorly ventilated; (iii) Hot in summer; and (iv) Cold in winter. The scarcity of natural light requires lamps to be used even during the day (see Figure 4).

Figure 4 – Luminaires on during the day; Suppression of illuminating areas; Construction of front wall.
Source: Braga (2021).

Item F: Evaluation of an elderly person's ability, while inside the room, through a door or window, to view the uncovered external environment (except bathroom, circulation areas, service area) – the post-renovation sample was considered slightly resilient (Level 2.20). Through openings (windows and doors), the elderly can see the external environments. Architects should be concerned not only with the quality of the external view but also with the necessary comfort to appreciate it. In *Residencial Sucesso Brasil*, the window height (sill 120 cm high) prevents the appreciation of the external environment by a seated or lying elderly person.

Item G: Evaluation of the approach and use areas of bathroom furniture – the post-renovation sample was considered slightly resilient (Level 2.21). Eight of the analyzed expansions did not add new bathrooms to the original house. The original bathrooms have a width of only 110 cm. The space between the edge of the toilet and the wall in front is only 60 cm. This prevents the safe use of the bathroom by the elderly dependent on orthoses (cane, walker, or wheelchair). Ensuring space for approach and use of the room is highly relevant when seeking resilience. The resizing of a building compartment may involve the demolition and construction of masonry, structures, and even foundations. This contributed to increasing the complexity and cost of a renovation.

Item H: analysis of the existence of an area or compartment intended for the installation of an elevator – none of the analyzed houses have two floors, making this issue irrelevant to the object of the case study. However, it is important to anticipate space for the installation of this type of equipment when designing and building houses with more than one floor. In addition to the elevator, the stairlift can be a solution, depending on the conditions and needs of the elderly.

Item I: Evaluation of ramp characteristics found – only one of the post-renovation houses was built with a ramp whose excessive inclination and insufficient width prevent safe movement of an elderly person. Ramps tend to take up a lot of space, and their use may be unfeasible in small spaces such as those found.

Prescriptions for increasing housing resilience

In the case of *Residencial Sucesso Brasil* and SIHC Shopping Park, architects and other construction professionals are recommended to:

- Preserve the existing illuminated areas in the original project. This can be achieved by respecting the minimum required clearances already demanded by municipal legislation. This will facilitate: (i) the construction of external gardens for contemplation; (ii) the creation of more comfortable internal rooms, with natural light and ventilation;
- Avoid designing or building level differences greater than 1.5 cm between rooms.
- Build or replace front closures with railings that allow visibility of the street and greater contact with neighbors;

In order to go beyond the limits of the study object, in addition to the above recommendations, architects and other construction professionals involved are recommended to design and build houses that have:

- Walls capable of supporting the installation of bars and handrails without the need for reinforcement in circulation areas and bathrooms;
- Walls not shared between residences. When sharing cannot be avoided, use acoustic insulation;
- Doors with a minimum clearance of 80 cm, allowing passage by a person regardless of the orthosis used (cane, walker, or wheelchair);
- Opaque sills lower than 40 cm in height. This will allow for the contemplation of the external environment by a seated person (wheelchair user) and even lying down;
- Compartment or area designated for elevator installation; stairs with sufficient width for a lift chair. It should be noted that these equipment have a high financial cost. When dealing with social housing, it is recommended to design and build houses with only one floor;
- Ramps according to *NBR9050*;
- At least one bathroom per floor with adequate approach and furniture use areas according to *NBR9050*;
- Corridors and circulation areas between rooms with a minimum width of 90 cm. However, it is emphasized that a width of 120 cm is more comfortable for wheelchair users.

Final Considerations

Designing a house resilient to the impacts of aging does not equate to designing a house suitable or adapted to the elderly, but rather a house endowed with specific characteristics (resilience indicators) capable of facilitating future adaptation. When designing, the architect must consider the possibility of the residents aging in place.

The concept of resilience in the field of architecture is not yet a consensus. Establishing a limit for resilient behavior can be a way to: (i) refine this concept and bring it closer to the initial definitions developed for engineering and ecology; (ii) bring resilience closer to sustainability.

The instruments used in this research have proven to be practical and precise. However, they should be used with caution and reflection, as they have not yet been sufficiently tested. New applications may reveal more potentialities and deficiencies, and these aspects will require improvement.

The renovations carried out on the houses at *Residencial Sucesso Brasil* contributed to reducing the resilience of the buildings in relation to the original design. This reduction is attributable to the disregard of fundamental technical requirements, including the respect of minimum mandatory clearances and the establishment of illuminating areas. In addition to the prescriptions proposed by this research, it is necessary to engage architecture professionals with the residents of the residential area. The participation of architects and the implementation of appropriate prescriptions will contribute to the construction of houses that are more resilient to the aging of their residents.

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