

# Minimum housing spaces, flexibility and sustainability: a reflection on the basis of ergonomics intervention

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**Abstract.** This article discusses the quality of internal life space in apartments of residential buildings in the northeast region of Brazil, especially the possibility to adapt environments with small areas (according to local building codes) to the needs of different arrangements of families (considering 4 members per family). The research had a gradual approach and used multimethod strategy: (a) studying the universe of residential buildings whose apartment's inner area is between 50 and 60m<sup>2</sup> and were constructed in Natal-RN between 1998 and 2008, as well as not linked to social housing programs and occupied for more than one year; (b) selecting a building to do a Post Occupation Evaluation (POE), using walkthrough, technical observation and questionnaires; (c) choosing of two housing units to do an ergonomic intervention (based in interviews and detailed measurements). The results show the technical possibility to modify the units, but these modifications have a high (social, economic and environmental) price, because in general the space of units projected is not flexible. So, the paper concludes that this type of enterprise needs to be rethought, since part of them is (social and ecologically) unsustainable.

**Keywords:** minimum house spaces, post occupation evaluation (POE), ergonomic intervention, space flexibility, northeast of Brazil culture

## 1. Introduction

The actual social preoccupation with economic and environmental sustainability requires the questioning of many aspects of everyday life, particularly daily practices. One of these interrogations is the housing that usually (and increasingly) is offered in form of vertical buildings and standardized units with small dimensions. Such conditions affect internal space and make it difficult to adapt environments to the needs/aspirations of their inhabitants, a situation that influences satisfaction and quality of life.

However, nowadays, consumers tend to purchase units with increasingly smaller dimensions due to the attractiveness of a large common area. In other words, the physical dimensions of housing are reported as less important than other variables, notably the collective areas [10]. It is important to verify if the reduction in the habitation space has

reflected in quality of indoor space and in quality of family life.\*

Although, paradoxically, the study of residential satisfaction is essential to promote adequate architecture projects, it has not been taken into account by the designers, and they are not very aware of what happens in the built environment and thus the need of users are not always met [8].

To contribute to this debate, this paper presents a research in the northeast region of Brazil, discussing the possibility to adapt minimum space to the requirements of local culture and different family arrangements (considering 4 family members). Therefore, we studied vertical buildings, located in Natal, whose housing unit's useful area varied between 50m<sup>2</sup> and 60m<sup>2</sup> and architectonic program required two bedrooms. Due to this condition the areas of the rooms were very similar to the minimum area specified by local building codes. After selecting a building, the interior space of its apartments was

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analyzed based on the approach to customer's satisfaction with environmental and dimensional factors that affect their functioning.

As part of a research conducted by the first author of this article and oriented by the second [13] reworked according to IEA2012's focus, this paper is divided into the following items:

- Method presentation: developed from a strategy of gradual approach centered in: studying building conditions in Natal between 1998 and 2008; conducting a Post-Occupancy Evaluation (POE) in one of these buildings, using walkthrough, technical observation and survey [8]; studying the internal environment of two housing units and showing the ergonomics intervention [3-7-11].
- Results presentation: developed in three sub-items, i.e., a) studies of vertical housing initiatives using minimum space conditions in the city; b) POE in the chosen condominium, with emphasis on the assessment of internal environment, c) Ergonomics interventions into two habitation units, with a focus on their users' needs, well-being and comfort.

In this article the names of buildings, builders and residents will not be informed, and will not be identified the number of each analyzed unit. This condition is established in the Informed Consent Form in order to respect the anonymity of participants.

## 2. Methods

Methodologically the research design made a gradual approach of the object of study and used multimethod [2-5]. It involved:

- (i) Survey of residential buildings built between 1998 and 2008, and with a total area of 50 to 60m<sup>2</sup> in their housing units.
- (ii) Selection of 01 condominium as a case study through POE [8] to analyze its negative and positive points. The criteria for this choice are:
  - the condominium is being used (occupied) for more than one year (so the residents can have an opinion about it);
  - there is an average of 4 people/apartment, similar to that calculated by the 2000 Brazilian Census [6] for the Northeast (4,1 person/house) and the city of Natal-RN (4,4 person/house);
  - the area of the apartment is among the largest found in this range - a condition that increases the possibility of a good evaluation;

- the majority of residents are from the Brazilian Northeast (facility the crop's cultural studies);
- Acceptance by the administration and residents.

In its stage, the research drew the walkthrough and visited 50% of units to apply a questionnaire and to carry out technical inspection.

- (iii) Selection of 02 apartments for conducting the phases diagnosis and assessment of the ergonomics interventions [3-7-11], indicating the reforms to adapt the space to the needs of residents, involving environmental and dimensional factors that affect the operation of the unit. To understand these families' needs and behavior the study used interview, behavioral observation, characterization of users (individual physical measurements and space requirements) and identification of furniture and equipment available and/or to acquire.

## 3. Results

### 3.1. General view

According to the criteria previously indicated, the research identified 35 vertical habitation enterprises. These buildings usually contain 4 units/floor, very similar spatially (Figures 01 and 02). The units' inner area varies between 52,0 and 59,0 m<sup>2</sup>. All architectonic programs include living/dining room, kitchen, 2 bedrooms, 2 bathrooms, service area, and a small (optional) balcony.

In general the variation in the area of the room is minimal, and we can observe two types of arrangement of the inner area of the units, both based on the grouping of the bathrooms (social and suite), probably to reduce the costs of constructions: in the first arrangement the bathrooms are isolated from the rooms (Figure 01); in the second, one bathroom is connected to the rest of the wet area of the dwelling (kitchen/service - Figure 02). Since the wet area and the presence of internal divisions in masonry highlight limited flexibility of these habitations' internal spaces.

This scenario shows, once again, the tendency of local builders to focus their efforts on implementing standard projects that seek high financial returns [4-9], whose architectonic proposals are characterized by environments with the minimum dimensions allowed by Natal's Construction Code [12].

Only 17 of those 35 buildings were inhabited for 12 months or more. The researchers visit (*in-loco*) 13 of these buildings and had initial contact with the

administration. In order to continue the investigation were selected the “ABC” building.



Figure 01. Ground floor, Building I. [13] based on promotional material of building



Figure 02. Ground floor, Building I. [13] based on promotional material of building

#### 4.2 POE in the ABC building

The POE was used to understand the occupation of habitation units and their inhabitants, so, then 02 units could be chosen for the intervention.

The ABC building has 02 towers with 12 floors and 4 apartments/floor (total of 96 units). It has a concrete superstructure, masonry locks and aluminum frames. The architectonic program of standard units has living/dining room, balcony, 2 bedrooms, 2 bathrooms and kitchen/service area (Figure 03). The common area includes party saloon, swimming pool and multiuse square. Its is well maintenance.

In the research moment, 06 habitation units were unoccupied and the total population of ABC building was 403 persons (4,5 persons/unit).

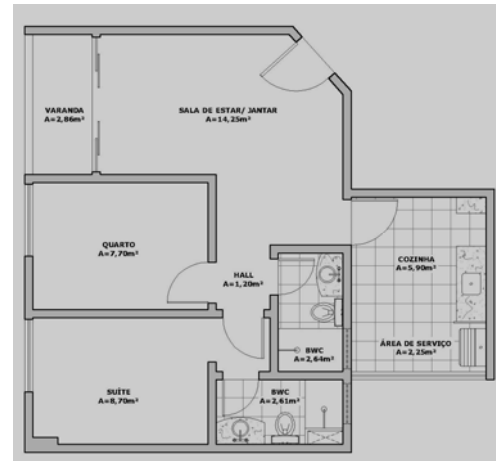


Figure 03. Standard unit of “ABC” Building

The POE shows that small families (maximum 3 members) are satisfied with the apartment, but bigger ones are not. They know that the apartment space is not sufficient to all of their needs, especially in cases of different generations living together (parents, children and grandparents). Some units merged balcony and living room (to amplify this last).

In general, the living room obtained the best evaluations, while the social bathroom received the worst. Part of the poor assessment of the bathroom was due to the fact that its window opens directly to the kitchen/services, so it usually remains closed (therefore, it is hot and dark).

It is difficult to use the combined kitchen/services because many of the family activities require more space than it is available, like washing/ironing clothes. The kitchen’s biggest problem is the maintenance of traditional habits/practices of the Brazilian northeast family, such as scaling fish or preparing typical food (like “cangica” or “pé-de-moleque”), which are activities that require some space.

People say they do not use (or rarely use) the common area, with the exception of young children.

#### 4.3. Ergonomic study in two units

Two apartments (U1 and U2) were selected for the development of design proposals. This choice was based on specific needs of the family. The work prioritized the ergonomic and functional phases of the intervention. While these steps have

been essential for the process of designing, the result is long, and, therefore, it is summarized in this paper through frameworks.

#### a. Unit 1

The apartment is of north-east orientation and it had already undergone some alterations from the original design, such as balcony and living room merge, placement of plaster niches and reduction of bedroom to make a large wardrobe in the suite (Figure 04). These unit characteristics are described in Table 1.

It is inhabited by a 63-year-old woman, her mother (83) in a wheelchair, the maid (30) who takes care of the elderly, and a granddaughter of the elderly (22) who spends two days per week in Natal-RN (she sleeps in her aunt's room or in the living room). All occupants have short stature (heights from 1,40m to 1.65 m). Although the elderly can eat her meals and stand up without help, she still has serious mobility problems, requiring a wheelchair to move between rooms. She also needs help while dressing and bathing.

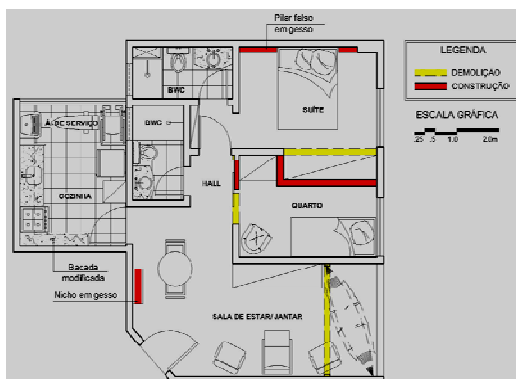


Figure 04. Unit 1 - Situation in the survey

To reorganize the environment were necessary demolition/construction of fences, installation of lightweight insulating elements in the central area of the unit (Figure 05), as well as changes in furniture (exclusive design).

The wall between the bedrooms was replaced by an armchair facing both sides (gaining several inches in both rooms). The hall that gives access to the bedrooms was changed (the walls were completely removed/relocated to allow better movement of the wheelchair).

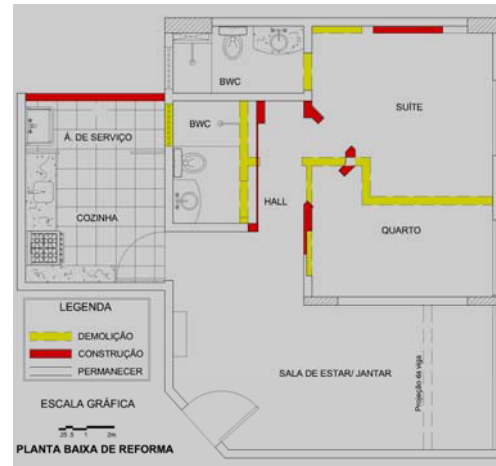


Figure 05. Unit 1 – Proposition

The other recommendations to this Unit were: **Bathroom of suite:** to modify the door place, tall cabinet and details of the masonry; **Bedroom of suite:** to remove the false pillars (plaster), niches for placement of objects and books, and replacement of the bed by bed bachelor (shortest projection) with bunk bed (over-accommodation of the niece).

Considered critical places to solve family problems (especially considering the use of a wheelchair), the bathroom and the bedroom of the elderly were objects of an ergonomic intervention.

In the bathroom (Figures 6 e 7) the increase in area was obtained by replacing the partition wall by granite. Moreover, safety bars (vertical and horizontal) were placed, as well as complement elements (paper, towel holder) accessible to the elderly which, being of small stature, required heights slightly shorter than those indicated by NBR9050 [1]. To ensure better ventilation, the window was shifted to the outer frame, therefore, isolated from the kitchen /service.

In the bedrooms (Figure 8), the area was increased (becoming higher than the original design) by demolishing the wall between rooms and placing a wardrobe with four doors, two higher and 2 accessible. It has also been detailed in MDF with laminate coating to protect the wall and receive the wheelchair. This provides for the placement of an air-conditioning unit not facing the bed, couch and curtains.

Table 1  
Unit 1 - Characteristics

LOCAL	CHARACTERÍSTICS		
	ACTIVITIES	FURNITURE / EQUIPMENTS	USERS NECESSITIES
<b>Living</b>	meals watch TV rest / sleep read talk visiting (if any) handcrafts	niches with shelves fixtures dining table (2 chairs) rocking chair 2 seats network TV furniture	sofa dining table that receives the largest wheelchair sideboard table (center or corner) for support
<b>Kitchen Services (merged)</b>	prepare / cook food store food / utensils dishwashing washing ironing store material / cleaning utensils store wheelchairs	countertop sink and stove support suspended cabinets (high) pantry cupboard (wall) laundry tub clothesline ceiling 2 overhead lights part in granite refrigerator stove ironing board clothes	microwave oven washing machine ladder to access high cabinets difficult to travel with a wheelchair frame for placement of controlled external opening home and reduce heat (direct sunlight in the afternoon)
<b>Bedroom (elderly)</b>	sleep dress watch TV hygiene (if required) taking medicines handcrafts	wardrobe (2doors) bed (twin bed in the bottom) armchair TV fan ceiling lamp	increase in current area greater wardrobe (sliding doors) air conditioning curtain (reduce morning sun and create darkness) reduce the discomfort of sleeping company
<b>Bathroom (social)</b>	personal hygiene	Workbench with Cuba sanitary Box	Facilitate the use of a wheelchair Avoid open window right into the kitchen (sounds and smells)
<b>Bedroom 2 (suíte)</b>	sleep dress watch TV handcrafts read	wardrobe (2doors) double bed TV fan 2 side lamps	greater wardrobe (sliding doors) curtain (alleviate morning sun and create darkness)
<b>Bathroom (suite)</b>	personal hygiene	Workbench with Cuba sanitary Box	

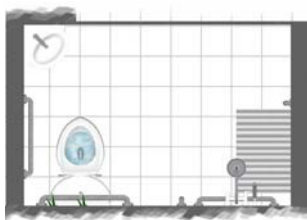


Figure 6. Elderly bathroom.

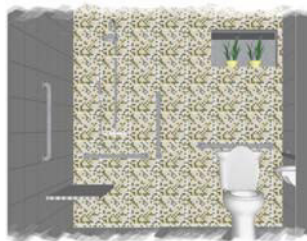


Figure 7. View of elderly bathroom.

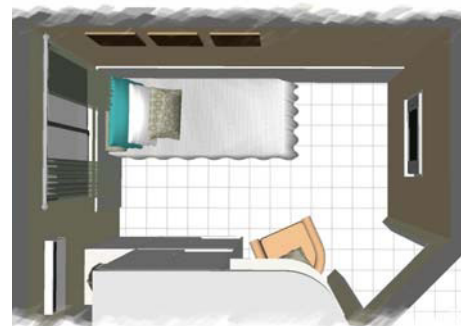


Figure 8. Elderly bedroom.

### b) Unit 2

The apartment is of northwest orientation. Changes made before the research include: merge of balcony and living room, alteration of the bench support to the stove and removal of kitchen door (Figure 9). The unit main characteristics are shown in Table 2. It is inhabited by a couple (medium height, age: 35 and 32 years old) and their two children, a almost teenager (12) and a boy (3).

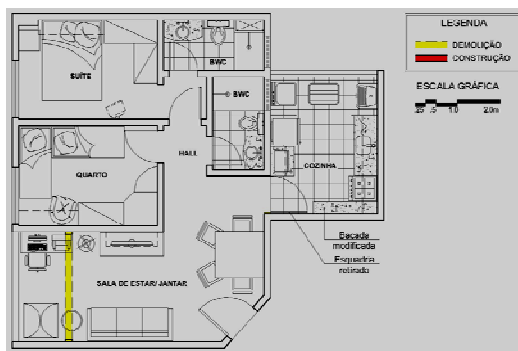


Figure 9. Unit 2 Situation in the survey

The children's beds (particularly inappropriate for the 11-years-old daughter) were replaced with high beds (standard sized) with tables underneath (Figure 14). The wardrobe (2 doors/child and central space for television, DVD and toys) was placed in front of the beds, but still leaving enough space for free access to the window. The bedroom received curtains and fan (one of the occupants is allergic and cannot sleep using air-conditioning).

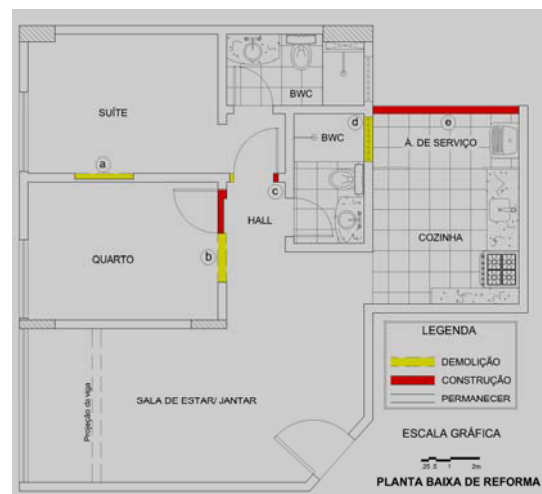


Figure 10. Unit 2 – Proposition

General recommendations propose to this unit (Figure 10):

**Living:** to remove the toys and computer, and add more seats, side table, chair, puff, TV furniture with niches for ornaments and electronic, drawers and space for DVDs and CDs (Figure 11). At the dinner table add most masonry and niches to decoration and meals (Figure 12). Use a picture as camouflage for the light's framework (it is in bathroom side wall).

**Kitchen / service area:** to remove the sink and the cabinet above it, replacing with a large granite sink with cabinets for cleaning supplies (below) and clothesline (above, hung from the ceiling); placing squarely on smoked glass.

**Bedroom of suite:** furniture preserved; layout changed to facilitate the movement.

**Social bathroom:** no changes needed.

**Bathroom of suite:** placement of sheet metal duct, with output directed to the exterior of the building through the opening frame in the kitchen/services (bathroom's ventilation).

The children's bedroom received an ergonomic proposal (Figure 13) which attempt to create a space for two occupants of different ages and sexes. To this end, the door was replaced by a centered sliding wall



Figure 11. Living.



Figure 12. Dining space.



Figure 13. Children Bedroom (superior view).



Figure 14. View of children beds.

Table 2  
Characteristics of Unit 2

LOCAL	CHARACTERISTICS		
	ACTIVITIES	FURNITURE / EQUIPMENTS	USERS NECESSITIES
<b>Living</b>	watch TV talk visiting (if any) use computer play toy storage family meals	sofa - 3 seats TV high fixed shelves dining table (4 seats) computer desk with chair little tent to play (children) basket for toys	sofa larger dining table sideboard
<b>Kitchen / Services (conjugated)</b>	prepare / cook food food / utensils storage dishwashing washing ironing material / cleaning utensils storage	countertop sink and stove support suspended cabinets (high) base cabinet (side cooker) refrigerator stove microwave partition in granite padding clothing washing machine ironing board	control external opening frame and solar control (direct sunlight in the afternoon) improve conditions of clothesline (invade the kitchen and hinders circulation) ladder to reach high cabinets
<b>Bedroom (children)</b>	sleep dress study play	"L" shaped wardrobe (2doors) beds for children (1.30 m long cradle adapted) armchair ceiling lamp	appropriate bedding (especially for girl) define specific areas for each child table for study fan TV
<b>Bathroom (social)</b>	personal hygiene	workbench with cuba sanitary Box	reduce odor internal (doors and windows closed) Avoid direct opening to the kitchen (sounds and smells)
<b>Bedroom 2 (suite)</b>	sleep dress watch TV read	"L" shaped wardrobe in double bed nightstand television in high support fixed shelves (above the bed) fan	circulation area unresolved adjust position of the TV (inadequate)
<b>Bathroom 2 (suite)</b>	personal hygiene	Workbench with Cuba sanitary Box	

#### 4. Final comments

More than detecting problems in the functionality of housing units and users satisfaction, the study showed that families live in relatively inappropriate conditions, and that the modification of their space requires rebuilding actions of medium or large size (demolition of walls, re-structuring of layout, change of coatings...). In many cases the spontaneous accommodation of families (especially the largest) is very difficult, because common equipment/ furniture (purchased in stores) cannot be used. The accommodation of this popular furniture in the reduced space is unviable – they are simply dimensionally incompatible. In resume: the limited flexibility of space reduces the sustainability of the enterprise.

The research did not aim to answer fully all ergonomic and functional problems that can occur in that type of housing, by selecting two extreme cases. It is confirmed therefore, the need to seek appropriate solutions to each situation, facing the challenge of meeting the needs of each resident, whether children, teenagers, adults or the elderly, people with disabilities or not. This knowledge shows the need to have designer pay greater attention to the application of the ergonomic principles of housing. However, this issue has still been little discussed in Brazilian schools of architecture and urbanism.

The recommendations/suggestions proposed for the studied dwellings are not rules/models to be applied in all cases of vertical dwellings with minimum dimensions: each case has its peculiarities. Thus, these recommendations suggest that: (a) by appropriate intervention even an environment with reduced dimensions can be adapted to the ergonomic and functional needs of its users; (b) these changes have a high cost if the unit's initial design is not flexible.

In fact, an architecture project meant to meet a large number of users supposes that all occupants would have the same or very similar needs. But, as reality shows, the persons are not similar, and one of the most important activities of the architect is to create adequate space built to different people [11].

In habitation projects, however, the cost of these (always necessary and predictable) changes rests with the occupants, but families often cannot afford another significant expense, and the buildings are not designed to facilitate them. Moreover, reforms that

require demolition/ reconstruction mean problems for the neighborhood (such as noise and dust) and unnecessary waste (environmental implications). One wonders, therefore, about the sustainability of such architectural model.

The main reflection generated from this research (and this article) is the urgent need to rethink the design model used in this type of housing (vertical and small size units), particularly in regions such as Northeast of Brazil, where families still some practices of traditional culture. The adequacy (or inadequacy) of the project and its initial condition of flexibility can characterize the proposal as (more or less) sustainable and socially fair (or unfair).

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