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Parametric design of affordable housing under Ecuadorian design and construction regulations

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Abstract– ***New building trends toward a sustainable future that promotes the utilization of materials and energy have profoundly changed the concept of social housing in Ecuador, requiring flexible, personalized, and adaptable living spaces. This article describes the parametric design process for collective housing in Guayaquil, based on the principles and guidelines established for suburban areas. Digital technologies, such as parametric modeling (PM) and digital fabrication, were used to generate and materialize a project, exploring the combination of design parameters based on municipal regulations for its development. The original contribution lies in the design strategies for creating new types of social housing using algorithms applied to informal urban areas.***

Keywords-- sustainability, social housing, parametric modeling, flexible architecture.

I. INTRODUCTION

Parametric design applied to affordable housing (VIS) in Ecuador allows for the optimization of resources, compliance with regulations, and adaptation to local conditions through algorithms and adjustable variables. The housing conditions that converge today respond to the need for adaptable and flexible spaces that can be transformed into various uses within the home, allowing for semi-private and communal developments that contribute to housing progression [1].

One of the regulatory bodies that legislate the adaptability and standardization of affordable housing is the MIDUVI (Ministry of Housing and Urban Development) in its VIS standards [2]. These standards comprise a set of statutes establishing that affordable housing is defined by the fact that the spaces it comprises are the minimum necessary to establish a minimum social livable standard. These spaces include spaces such as the living/dining room, kitchen, shared bedroom, private bedroom, shared bathroom, and shared patio, which affirms that this is a minimum spatial and functional consideration [3].

Affordable Housing (VIS) is a key sector for the social, urban, and economic development of informal and emerging societies seeking housing dignity. This type of construction encompasses several productive chains that contribute to job creation, contribute to building family wealth, reduce social inequalities, and improve citizens' quality of life [4].

According to a Plan International study published in 2022, 1.5 million people in Ecuador live in overcrowded, self-built homes. Furthermore, 25% of households in the country are made up of five or more members and have only one bedroom. This situation is a result of high levels of informal employment (5 million inhabitants, according to the National Institute of Statistics and Census) and the lack of affordable housing solutions for the most vulnerable sectors of the population.

In the city of Guayaquil, 12% of this percentage of residents is concentrated in the suburban area, comprising a total of 600,000 people without a steady job. Consequently, their access to housing is zero, generating a monthly income below $200 [5].

Faced with this reality, many citizens choose to use their own resources to finance the construction of their homes, without a planning process or guarantee that these buildings meet habitability standards.

In Guayaquil, according to a 2023 assessment by the Ministry of Urban Development and Housing (MIDUVI), 1.1 million homes were built that do not comply with municipal regulations and violate public roads, green space consumption, and residential space, directly and indirectly affecting natural resources and the safety of the territory. These high housing shortages demonstrate the deficiencies of buildings and the poor living conditions of the population, facing the risk and vulnerability of housing solutions that do not meet the growing socioeconomic and regulatory dilemma [6].

In this sense, social housing is not a goal or objective, but rather a means to improve the population's quality of life. Therefore, the professor believes that the development of comprehensive social housing projects should be promoted, as the current supply is still very limited.

Nationally, according to MIDUVI data, there are 823 registered real estate projects in 34 neighborhoods; However, of that amount, only 26% or 71 projects are from the VIS segment and none of these contemplate a parameterized development with a focus on sustainable development in interrelation with the emerging needs of the population [7].

This attributes the weak supply of these types of projects to the multiple challenges faced by developers, as well as the negative perception that exists among the population, due to the association of social housing with low-quality construction solutions [8], without considering the benefits it can offer to the entire community [9].

II. MATERIALS AND METHODS

A. Design principles of suburban social housing

Principles on housing developments have been extracted from specific literature focused on affordable housing by Rivera-Mateos (2024) [8], particularly the guidelines for social housing. Based on flexibility as the guiding principle of the project, ways of conceiving internal spaces for a variety of lifestyles are created. The first guideline adopted in this research is urban unity. Proposed constructions must adhere to morphological attributes such as sizing and functionality.

In this sense, alignments, building heights, and massiveness must be adequately studied to guide design actions. Interventions in suburban areas of Guayaquil, well equipped with infrastructure, require proposals for new buildings that generate energy efficiency while expanding open areas for public space. Implementation must avoid segregation and instead generate greater integration between public and private spaces. The intention is to seek design alternatives that favor the creation of implementations centered on the concept of an open block [10].

To create flexible and adaptable housing units, it is essential to propose a circulation system that offers spatial alternatives to the units. As will be seen in the discussion of this article, horizontal and vertical circulations, with different stair positions, allow for different layouts of the housing units. Another guiding principle was to create housing units with different areas, to promote various types of spaces [11].

B. Regulations and Ordinances

In accordance with these initial parameterization elements, it can be concluded that the design of the material will be convenient for:

- **National Regulations (MIDUVI, NEC-SE-EC, COA)**

Minimum floor area: From 50 m² (single-family).

Floor height: Minimum 2.50 m (for ventilation).

Seismic-resistant structure: Reinforced concrete walls or steel framing (NEC-SE-EC, high seismic zone).

Basic services: Connection to drinking water, sewage, and electricity is mandatory.

- **Municipal Ordenances (Guayaquil)**

Minimum lot size: 6 m wide x 15 m deep (90 m²).

Setbacks:

3 m wide (sidewalk).

2 m wide (side and rear) (for ventilation).

Density: Maximum 2 stories without special permit.

For lease-to-own housing, the guidelines and requirements described for the first segment will apply. All Low-Income Housing typologies focused on this segment must be submitted in compliance with and adhere to the following current regulations:

- Ecuadorian Construction Standard NEC.
- Ecuadorian Technical Standards INEN.

All types of affordable housing, focused on this segment, must be submitted in compliance with and adhere to the following current regulations:

C. Parameterized design of the form

Defining the word algorithm can be defined as "the complex set of rules that allow the resolution of a given problem." In architectural design, a parametric design refers to the design elements defined and manipulated by variables contained in the MP. A design is parametric when a computer is used to automatically modify it as parameter values change during the design process [12].

A MP involves constraints, defined as a priori, that allow parameters to be combined in an investigative manner, with unexpected results. Thus, the algorithm propagates changes based on known restrictive parameters, but with typically unexpected results. The propagation of a change between parameters, which are related, produces rapid and effective changes [13].

The main change in parametric design is that this process does not seek to create a single, a priori, defined form for each construction element or building, but rather to find possible alternatives and then select the most appropriate option [14]. The MP contains three algorithms. The first is the order of the sequence of nodes containing the parameters and their properties.

The second is propagation, which evaluates each node and its constraints expressed by formulas, functions, or operations. The third allows data to be displayed in three dimensions. The so-called form-finding process implies that a form can be found unexpectedly by combining parameters previously established in the algorithm [15], [16]. Thus, it is found a posteriori, through variations also called generative, as they allow experimentation, comparison, and selection of new families of complex forms, delineated by parameters. Using the Grasshopper plug-in, this concept was explored during the design process.

Due to technical and regulatory constraints, which weigh heavily on housing costs, regular geometries will be adopted for the units and a specific area for the sanitary facilities. Furthermore, with the aim of generating diverse facades, another principle was to create windows with different geometries, promoting different views and light penetrations into the interior spaces [17].

Also, with the same purpose, different shapes were proposed for the zenithal openings in the roof. Using a set of principles, the results section discusses options for housing units derived from combinations of parameters, whether the type of circulation system, stairs, sectorization, connections between levels, and the position of sanitary areas—that adapt to new contemporary ways of living [18].

D. Method

In this study, the project was developed using the principles and guidelines presented in the previous section and the parameters presented in the section "Parametric Form Design." However, the nature of the research required the use of new digital technologies, such as digital modeling and fabrication. The study comprises five stages of parameterized modeling, thus allowing the five dimensions of the architectural project to be addressed.

III. Results and discussion

A. Parametric design and its influence on the design of VIS

The basic definition is based on the spatial utility of the homes, influenced by the basic and regulatory spatial design that considers that parameterization as a design strategy addresses utilitarian elements such as:

- Useful area: Minimum 50 m² (according to MIDUVI for VIS).
- Floor height: Minimum 2.50 m (RSE).
- Minimum areas:
  - Bedroom: 9 m² (sleeps 2).
  - Kitchen: 4 m² + natural ventilation.
  - Bathroom: 2.25 m² (with shower).
- Parking: 1 space per dwelling (in residential developments).

By correlating this basic spatial definition with the parameterization algorithm, which can be used with 3D design tools such as Grasshopper (Rhino), and by integrating preliminary data into Python (a programming platform), we can obtain:

```python
# Parametros ajustables
superficie_total = 50  # m²
num_dormitorios = 2
altura_piso = 2.50
```

Fig. 1 Parametrización del diseño espacial base de la VIS
Note. Parametric Modeling in Social Housing (Briones, 2025)

This design structure responds to the fact that the initial housing development parameter is established within the spatial parameters of surface area by height and internal layout of uses (spaces). Therefore, the first parameter validates the input information for the design of a spatial parameter.

As a next parametric consideration, the climatic conditions of Guayaquil, as part of the Ecuadorian coastal region, lead to input data such as maximizing cross ventilation and shading, a relevant east-west orientation to reduce direct solar impact, and roof slopes for optimal rainwater drainage with a functional percentage. These input elements must be aligned with current municipal regulations such as minimum setback, frontage, and height.

In accordance with these initial parameterization elements, the material design can be determined to be appropriate for the functional and regulatory parameters, generating the following model:

```python
# Clima
orientacion = "Este-Oeste"  # Para evitar sol de la tarde
techos_inclinacion = 20  # Grados para lluvias

# Normativas
area_minima = 50  # m²
retiro_frente = 3  # metros
altura_piso = 2.50  # metros

# Materiales
muro_material = "Bloque_hormigon"
cubierta_material = "Teja_ligera"
```

Fig. 2 Parametrización del diseño funcional y normativo de la VIS
Note. Parametric Modeling in Social Housing (Briones, 2025)

B. Identification and classification of housing types in the intervention area

As a result of preliminary assessments, the housing types present in the intervention area (suburb of Guayaquil) were identified, and those listed in the same block were then considered. Therefore, this article only explains the established social housing typologies as traditional, including concrete block housing, zinc roofing, and dividing structures, enclosing spaces made of wood.

Specific parameters were devised for the horizontal housing algorithms. Initially, the objective was to define the general parameters. As the research progressed, some design strategies were established to meet specific needs. The reference projects provided the necessary parameters to initiate the design of the algorithms for creating residential units through the MP. There are two types of parameters:

1) for general building definitions and

2) for the specific elements of the building.

The objective of the proposal is to provide housing for families of one (15 m² units) to six (50 m² - regulatory standard), which represents the primary population in suburban areas. This algorithm (Table 1) contains a set of building parameters:

a) variations in width and length of each unit (from A to F);

b) one, two or three-story unit;

c) specific location of hydraulic zones;

d) five types of stairs;

e) definition of the dimensions and positions of the mezzanine openings;

f) types of window frames and their position (based on Modulor);

g) dimensions and position of the walls;

h) dimensions and location of six types of skylights;

i) dimensions of terraces, windowsills and benches;

j) two types of doors, and

k) kitchen sink countertop dimensions.

Unit types were generated from combinations of units A, B, C, D, E, and F. Parameter manipulation allowed for the generation of a large number of unit types, with large variations in area, from 15 to 50 m². Since the stated objective was to create a variety of unit types, primarily derived from strategic traffic location, parameters were inserted into the algorithm to enable such combinations.

TABLE I

Parameterization of spatial units

Parameters	Minimum	Maximum	Geometry/dimensions
Unit width	3.0	6.0	
Length of unit A	3.0	12.0	
Length of unit B	3.0	12.0	
Length of unit C	3.0	11.0	
Length of unit D	3.0	11.0	
Length of unit E	3.0	12.0	
Length of unit F	3.0	12.0	
Hallway width	1.2	2.5	

The carefully designed algorithm generated a diverse set of units, with the goal of creating three units for each modularity [19]. Following this step, the unit elements were detailed: floors, stairs, walls, windows, doors, benches, and washbasin countertops.

The flexible arrangement of stair types and spaces by use allowed for the distribution of social, private, and service areas in different positions within the space. Furthermore, the possibility of generating different openings in the units provided alternate heights and different internal views.

This figure provides a schematic view of the main decisions made to define the building components.

Le Corbusier's Modulor system was adopted to define the windows that contribute to the dynamic facade. The parametric approach promotes many alternatives for the openings of the VIS units. The diversity of the units, resulting from the manipulation of parameters, responds to new contemporary lifestyles, which demand flexibility and the ability to adapt to different internal and external environments.

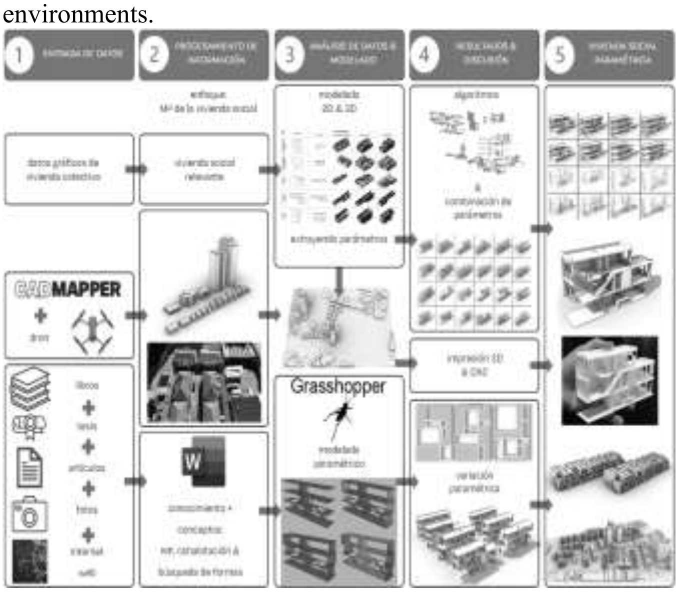

Fig. 3 Five dimensions of the VIS project
Note. Parametric Modeling in Social Housing (Briones, 2025)

A. Discussion

The design process began after surveying the existing typologies in the blocks selected for the intervention (suburb of Guayaquil). The first guideline adopted was urban unity. The urban village was created to promote typological diversity while respecting the height of the existing village. The proposed new housing respects the identified urban morphological attributes [20]. Furthermore, the building alignments and heights were carefully studied to guide design actions.

The parametric design can be modified and updated more quickly after changes that normally occur during the process. These were propagated in the three-dimensional model without the need to restart the modeling, making the process nonlinear and thus allowing for constant changes and updates with great agility [21]. The definition of parameters, their connections, and the tests required for verification are time-consuming until they prove to be efficient in generating combinations and achieving good results.

It can be concluded that the location of the circulation system, hydraulic areas, and the spatial distribution of units are the main design strategies for defining the architectural aspect of the building. The flexibility to integrate social or intimate spaces depends on the position of the staircase, as well as the kitchen and bathrooms. Thus, three strategies were adopted:

a) adopt the central position of public circulation (z);

b) concentrate the hydraulic areas next to this central circulation (x, y) and

c) promote different spaces by adopting types of stairs, located in different places.

Instead of sharing rooms in a house for cohabitants, privacy can be carefully maintained, for example, through mobile furniture or devices. As a result, non-compartmentalized spaces allow for flexibility and spatial adaptation for users over the years of family life (Fig. 4).

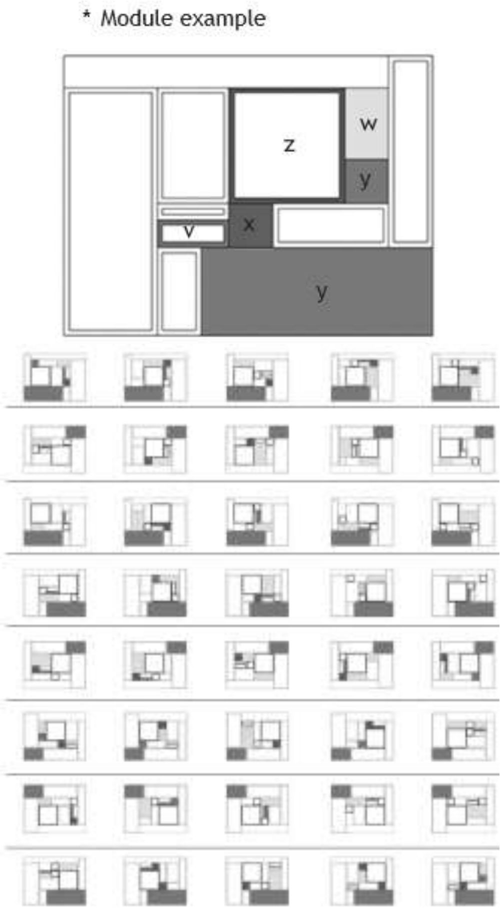

Fig. 4 Types of parameterized housing modulation VIS
Note. Parametric Modeling in Social Housing (Briones, 2025)

II. Conclusions

Parameterized construction offers numerous advantages over traditional methods of producing affordable housing, especially when combined with digital technologies, providing a more flexible, adaptive, safe, efficient, and sustainable building environment. This systematic review of suburban housing assesses recent advances in digital modular construction toward a sustainable and climate-neutral built environment, identifying trending spatial, functional, and regulatory parameters for the development of the ideal model [22].

Three key pillars of the VIS project were defined within the research: digital tools, construction solutions, and environmental sustainability. This review examines the integration of digital technologies with modular construction methods, expanding the analysis to include circular and bioclimatic initiatives, renewable energy sources, and passive building design strategies. While most articles focus on the use of Grasshopper (Rhino) parameterization, there is a growing emphasis on Python programming that leverages input and output data to meet functional and spatial objectives in accordance with current regulations.

Furthermore, modeling tools around functional analysis are frequently discussed, reflecting the trend toward flexible and progressive housing. Despite interest in parametric and generative design, the integration of machine learning and artificial intelligence applications for sustainable modular construction strategies remains underexplored [23].

Furthermore, the findings highlight the potential of digitalization in modular construction to improve efficiency and ensure environmental sustainability in the architecture, engineering, and construction sectors.

The parameterized prototype indicated greater adaptability and vertical progressivity on the ground, representing a breakthrough in sustainable housing [24]. This research underscores the importance of integrating parameterization into modern VIS construction to address the housing affordability crisis, as it influences cost reduction by generating full spatial utilization and addressing horizontal and vertical progression.

The results demonstrated that adopting the parametric form design principles method in construction can provide efficient, effective, and sustainable solutions, thus contributing to resilience and sustainability.

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