“Houses for everybody” Brazilian competition

An application of shape grammar and space syntax for analyzing low-income housing

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This article focuses on the use of both shape grammar and space syntax as tools to identify and encode the principles and rules behind the design of low-income housing in Brazilian context. The idea is to use such rules as part of a methodology for analyzing quality space in social housing plans and aims to understand to which attributes of contemporary society redefine certain patterns of familial social conduct, particularly their ways of living and how these attributes impact housing spatial patterns.

Keywords: shape grammar, space syntax, design methodology

INTRODUCTION

The problem of housing in Brazil was accentuated from the second half of the twentieth century due to the territorial explosion of cities and the deterioration of urban and social conditions. The intensification of the Brazilian housing problem made it urgent to debate the need for new solutions for social housing (SH), with focus on increasing quality at affordable costs.

The Brazilian housing deficit is estimated in 6,068 million households in 2014, of which 83.9% are located in the urban area, according to the Ministry of Cities (Brazil, 2014). The ‘My House, My Life’ Program (PMCMV) was created in March 2009 as one of the initiatives of the Brazilian government to supply the search for housing, stimulate civil construction, generate jobs and combat the economic crisis. Although widely disseminated throughout the country, the PMCMV presents several problems such as standardization, lack of service to the needs of the residents, and not completely solving the demand for quality SH in Brazil.

Facing this reality, it is possible to perceive that the production of national SH reveals a link to the modernist logic of standardization of typologies, defined for the “medium” Corbusian man, thus determining the way of designing and constructing housing from the twentieth century to the present days. The architects of the industrial era were faced with the problem of responding it the demands of the masses, made up pf different users with different needs. However, the modernist strategy for this issue was to use an “ideal” or “medium” user model as the basis for designing home appliances from dwellings.
Thus, one of the advantages proclaimed by stan-
dardization and repetition indefinitely referred to the
economy of time and intellectual work, since design-
ing all possibilities individually, in response to the real
differences of the users, demanded tome and big-
ger budget for development and execution of the
projects (Mitchell in Duarte JP, 2007).

The contest “Houses for everybody - National Pub-
lic Contest of Architecture Project of New Typolo-
gies for Housing of Sustainable Social Housing” was
launched in March 2010 by the Housing and Urban
Development Company of the State of São Paulo -
CDHU and organized by the Institute of Architects of
Brazil - IAB, Department of São Paulo. The objective
of the contest was to present new solutions to the
Brazilian housing problem, seeking to increase the
quality of housing developments of social housing in
Brazil, the contribution to improve the typologies for
SH, especially considering diversity, flexibility, sus-
tainability and adaptability, in addition to seeking
new conceptions of market professionals, typologi-
cal patterns to enrich the technical company aiming
at a more human and multiple city in its urban form
and content. (CDHU 2010).

The criteria used to evaluate the projects, as pub-
lished on the IAB-SP website were as follows (IAB
2010):

1. Implementation in the field - verification of
the possibilities of field implementation of the
proposal, considering: morphology (accom-
modation to the natural profile of the terrain),
geographic orientation and climate;
2. Needs Program - creativity, objectivity and
clarity in its service; attention to the areas re-
quired for the various environments and rec-
ommended volumes;
3. Building Legislation and General Standards -
attention and compliance with building legis-
lation in effect in the city of São Paulo;
4. Accessibility - compliance with general legis-
lation providing for facilities for people with
various physical disabilities; integrated solu-
tions and harmonics with those used by other
users;
5. Constructive technique - structural system;
building and special building systems; build-
ings system; between the systems and techni-
cal elements of the architectural complex; cri-
terion and logic in the choice of general spec-
fications; effectively necessary and justifiable
finishing materials; fire design and facilitation
of scape in the event of an accident; economy
and feasibility.
6. Environmental Comfort - natural ventilation
lighting, thermal load reduction and acous-
tic protection systems; artificial lightning sys-
tems;
7. Harmony and proportion of the architectural
ensemble;
8. Contribution to technology, sustainability
and ecology.

The housing typologies were organized into six cate-
gories: “ground houses”, “terrace houses”, “two floors
houses”, “three floors buildings”, “four floors build-
ings” and “six and seven floors buildings”.

In view of the foregoing, the projects awarded
1st and 2nd in each category represent, in theory,
good design solutions for SH, thus constituting a rich
object of study for the development of better design
solutions for Brazilian SH (Mendes 2014). Thus, an
Analytical Shape Grammar was developed as a method-
ology to understand the social housing’s composi-
tional logic, using those projects as a corpus.

OBJECTIVES
Adopting a structuralist perspective, this research
aims to develop a methodology for the analysis of SH
projects for the generation of parameters that guide new design solutions with varied typologies. For this, the theories of Shape Grammar (Stiny and Gips 1970)) and the Social Logic of Space (Hillier & Hanson 1984) were used as theoretical references.

Grammar, in turn, was developed as a methodology to understand the compositional logic of social housing. And its formalism was employed aiming the analysis.

**PROCEDENTS**
The Shape Grammar (SG), developed in the early 1970s by George Stiny and James Gips, consists of a rule-based form generation system that originated in the generative grammar of the linguist Noam Chomsky (1957) and the system of Production of the mathematician Emil Post (1943) (Celani et al. 2006).

Shape grammars are a system of algorithms developed to generate and understand graphical compositions through direct computation, with makes use of forms, replacing indirect computation that uses texts or symbols, and can be defined as both generative and descriptive. This methodology of composition elaboration is formed by a set of rules that, step-by-step, give rise to a set of compositions that belong to the same language or style (Knight 2000).

In architecture, analytical grammars have been elaborated primarily to describe or analyze historical styles or language used by architects, for it starts from something already ready for rule-making. Synthetic grammars, in turn, depart from the rules inferred in analytical grammar for the generation of a set of objects, in this case dwellings, with similar configurations. Among other applications of synthetic grammar, they are used to generate spatial arrangements of residential plans which has resulted in more variety of alternatives (Mendes, Celani and Beirão 2015).

Duarte (2007), for example, used the grammar initially for analytical purposes, in order to describe the projects of the patio houses in the social housing of the Malagueira in Évora, Portugal - project developed in the 1970s by the Pritzker-prize architect Álvaro Siza. This is an important reference for the present research because it allowed to define a generative system to create custom houses that belong to the same language. Different combinations of the inferred rules allow to generate the existing houses and the new projects, that even different from the originals maintains the quality established by the criteria of the contest (Mendes, Celani and Beirão 2015).

**DESIGN METHODOLOGY**
The present work was made using the shape grammar as method of analysis of the corpus (winning projects of the contest) and space syntax (Hillier & Hanson 1984) as a method of evaluation of both the corpus analyzed and the projects generated by the grammar.

The analytical shape grammar was developed to understand the logic of the awarded projects in the contest, to recognize and infer rules or design patterns (Alexander 1969), and to generate, in an original way through synthetic grammar, new projects that present characteristics of design quality of the analyzed houses (corpus). Rules inference is intended to grasp the logic underlaying the project, in other words, to describe in rules the reform patterns identified in the projects.

Space syntax shows that social organization presents spatial content and vice versa, and in this spatial organization is possible to find patterns that determine a spatial configuration of the plant noticed through relational attributes. From this configuration, it is possible to understand the impact of the same in the human behavior and are generated accessibility conditions that give rise to a hierarchical spatial differentiation.

The theory of Social Logic Space is used to evaluate and verify if the new projects generated from the grammar present similar characteristics to the competition.

Through the space syntax methodology, the projects warded in 1st and 2nd, and the projects generates by the grammar were analyzed using the Jass.jar program as a tool through the convex maps
generated through the plants. These were analyzed for integration measures calculated by Real Relative Symmetry (RRA). In this way, justified graphs were generated from the distribution of labels on the convex spaces of the same socio-spatial sector and linked according to the flow and connection of each environment, determined by the modern domestic sectorization based on Amorim (1997, 1999) that are: social, intimate, and service spaces, as well as the mediating space.

Based on the analysis of the projects of the “Housing for Everybody” contest, a methodology was defined to define the rules of composition of the plants. First of all, we sought to define the vocabulary of forms, that is, to identify a finite set of primitive forms that made up each project. Thus, it was sought to work with two-dimensional forms, since what was interesting was to analyze the categories of the contest mentioned. From the definition of the vocabulary of forms, the compositional rules were defined for each case study.

The main operations used to determine the rules used in the composition of the analyzed dwellings were: rotation, mirroring and addition of forms. Based on the organization of the information and the design of rules, it was noted that the projects suggest proposals that prioritize the flexibility of spaces, rationalization of the construction and typological diversity. [figure 2]

For the development of the rules, it was based on the analysis of each plans of the winning projects of the competition, simplifying the environments of the houses to a closed polygon, without thicknesses of walls, doors or windows. From this, the SG rules were inferred based on the winning houses of the contest, that is, the SG rules have the property of generating the own plans of the winning projects.

From the inference of the rules, it was possible to understand which rules were most used for the corpus generation. Some of the most frequent rules, being these rules of type A -> B (finding A, replaced by B), were the rules that when finding a bedroom, add circulation; when finding a bedroom, add a bathroom; when finding a circulation, add a living/dining room; when finding a circulation, add a bedroom; when finding a living/dining room, add a kitchen; among others.

The spatial syntax is of extreme importance in

![Figure 2](image_url)

3 of the awarded projects analyzed. House 1, ground house; house 6, terrace house; and house 9, two floors house.
this step, since it evaluates with greater property the relation between the corpus and the generated houses. With the rules ready, it was verified that they had the capacity to form the corpus and it was possible to start the derivations, thus generating four new houses. For the generation of the new houses, the most frequent rules were used in corpus generation, since these rules are the most comprehensive and objective for the creation of new plans.

The similarity between the corpus and the generated houses is present in the configuration of the plans, in the design language and in the intention of the project. The configuration of the plans is similar in the houses of the corpus and in the houses of the derivations in terms of the positioning, connectivity and quantity of the SH environments. In most corpus houses and in all the generated houses the access is through the living/dining room and this environment connects with the kitchen and circulation; the circulation connects to the bedrooms and the bathroom, and in some cases the bedroom and bathroom are directly connected to the living room; the kitchen connects to the service area. Both the corpus and the houses generated by the SG have a living/dining room, a kitchen, a service area, a bathroom, 2 or 3 bedrooms, and some have a balcony or courtyard and area that allow future extensions. [figure 3,4,5]

DISCUSSION
The accessibility analysis, which is done by making the connectivity between the adjacent spaces in the plant and seeing the relationship between them, showed that in 3 of the 4 derivations (75%), the most integrated spaces are spaces belonging to the social sector, and 1 of the cases (25%) is a circulation that is considered a mediating space between sectors. However, in 100% they are free circulation environments. While the more segregated spaces, the service area is shown as 1 of the results obtained (25%) and another was a courtyard of derivation 2 (see graph 11 - figure 6) that is an even more reclusive space because its access is made exclusively by the service area, which is one of the most segregated spaces of a house.

By making an analysis of the visibility, which is done through the connectivity of the environments that are seen from a certain room, and comparing it with the analysis made regarding accessibility, a certain degree of difference is noted. This difference means that the ‘depth’ - the measure that determines the depth of the spaces in the houses - generates more compact graphs for visibility than for accessibility in 100% of cases.

This difference in accessibility and visibility analysis exists because most of the time the field of vision easily encompasses multiple spaces - it comprises the area where a person is able to capture visual stimuli without moving the head, that is, the area covered by the vision (Leme 2003), while to get access to certain places it is necessary to overcome obstacles and to go through other rooms.

After all the analysis of the houses generated by the grammar, the 9 samples of the winning projects were resumed. It is noteworthy that although the plants of the derived houses are different, the results obtained were similar among themselves and to the awarded projects.

The spatial configuration was also studied graphically through sector justified graphs. It is possible to verify that in 11 cases (84.62%) there is possibility of having access to the house through the social sector,
Figure 4
Derivation of one winning project in the contest, which composes the corpus. Being house 1, example of the ground houses

Figure 5
4 projects created from the generated SG.

Figure 6
Graphs generated from the houses studied.
and topologically, the intimate sector is the furthest in 84.62% of the houses. [figure 6]

When looking at the image above, it is verified that there is also no pattern among the graphs and that in most cases the sectors are not well spatialized which generates graphs with several labels of the same sector scattered and with greater topological distance.

It is possible to verify this argument when comparing graph 5 of the original projects with the 10 and 11 of the derivations, for example, in the latter the sectors are better distributed because they are more united and each area of the house is well defined. Because it was a contest, and probably did not require any standard room layout, participants were supposed to use the freedom they had to devote more to exploring plasticity than functionality, so we find houses with no well-defined areas with regard to sectorization.

CONCLUSION
This research arose from the problematic of the Brazilian housing deficit and the criticism of the main characteristics of housing developments built in Brazil. The proposals of the CDHU/IAB competition stimulated the research, since they are considered by experts as good solutions for SH. The personalization of the housing unit is the objective of this research, contributing to the development of housing projects, in response to standardization of types, monotony and repetition of existing housing developments.

The shape grammar created allows the generation of new projects of social housing more diversified, personalized and that incorporate the characteristics of the winning projects of the contest analyzed. The SG created has great potential to generate different housing plans, with principles of flexibility and adequacy to the needs of its inhabitants.

After using grammar and syntax as tools to identify and codify the principles and rules behind social housing projects in the Brazilian context, it was possible to analyze qualitatively the space. In addition to understanding what the attributes of contemporary society redefine some patterns of family social behavior, their ways of life and how these attributes impact a dwelling.

It is noticed that there is a repetition of the results in the analyzed measures of the integration and the graphs. The typical Brazilian way of living segregates the sectors in the housing. The private and service sectors are restricted to dwellers; visitor, commonly, are restricted only to social environments, because they are more controllable. By means of space syntax and perceptible how social relations can be expressed through the spatial formation of housing.

Daily activities are linked directly to his segregation and habits often determine what each environment is. For example, resting does not require as much privacy as sleeping, so it is more common to sleep in the bedroom and rest in the living room; and in many homes, it is possible to see great integration of spaces because of the varied functions performed. Thus, is seen that the traditional way of living defines the distribution of space.

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