

The use of Building Information Modeling to set parameters for inclusionary zoning in Brazil

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Abstract

This paper presents work undertaken to establish constructive parameters in order to regulate an area delimited as Special Zones for Social Interest (ZEIS) in Fortaleza, Brazil. ZEIS consist of well-located vacant land, reserved for the construction of Social Housing, but which remain underutilized since Municipalities fail to establish its specific building codes. In face of this deficiency in policy, the research presents a study of urban parameters to regulate one specific ZEIS assisted by a Building Information Modeling (BIM) software. The method consisted of developing five mixed-income housing typologies, which were placed on a chosen ZEIS to simulate its occupancy. The model was used to extrapolate final regulating parameters, which were compared to the existing law. The methodology adopted for this study presented several limitations, which indicate the importance of shifting from traditional CAD and BIM programs to Procedural 3D Modeling as well as engaging communities in design processes.

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1. Introduction

Inclusionary zoning has been used worldwide as a tool for providing well-located affordable housing for families with lower incomes. Brazil has adopted this tool in its municipal land use codes since 2009 under the classification of Special Zones for Social Interest (ZEIS). However, the special construction and regulatory parameters for those zones have yet to be defined by municipalities, leaving most of the areas underutilized, thus not fulfilling their social function. This lack of effective regulation represents a loss in opportunity to place social housing in strategic areas of the city that can guide Brazil's growing urban areas to a more sustainable and equitable form. Meanwhile, social housing projects being built nationally have reportedly pushed many low-income families to the outskirts of the urban fabric generating a fringe of underdevelopment and inequality. This research originates from such circumstances, and presents a study of possible regulations for one ZEIS in the city of Fortaleza in the Northeast region of Brazil. In order to do so, the authors briefly synthesize zoning policies in the United States and Brazil as well as their effects. Furthermore, the paper presents a small-scale study of the architecture of affordable housing and the corresponding urban regulations, which enabled those designs. It makes use of Building Information Modeling (BIM) technology to facilitate the design and investigation process. The study identifies potentials and shortcomings of BIM technology to investigate possibilities of inclusionary zoning regulations and impacts of such developments in their surroundings.

2. Literature Review

2.1 Urban Growth and Current Housing Policy in Brazil

During the 2000s, the stabilization of the Brazilian economy consolidated economic growth and expanded the purchasing power of the middle class, increasing the number of subjects likely to obtain loans to finance the purchase of housing, which was encouraged by the government. One of these incentives was the launch of the housing program "My House My Life" (Minha Casa Minha Vida - MCMV) in 2009 by the federal government, managed by the Ministry of Cities.

The policy encouraged the production and purchase of new housing units by families earning between zero to ten times minimum wage (m.w.

is, in 2015, US\$253 earned monthly) and its initial goal was to produce about one million new homes by 2011. The program was designed not only as a housing policy but also as an economic strategy to sustain Brazil through the international economic crisis of 2008 by fueling businesses related to the construction industry. The federal government gave the private sector freedom to determine guidelines for MCMV thus conferring to them great decision-making power with regards to the definition and implementation of the financed projects (Cardoso, 2013).

Under the policy, produced housing units have been extensively criticized, because the minimum standards required become the only constructed, and developments are handed over already fully completed and offered as a rigid ultimate housing option. Developers rely on profit obtained from mass construction, which has reportedly often resulted in low constructive quality (O Estadão, 2013) instead of using technologies to reduce costs and to reinvest in better housing or social facilities (Nascimento and Tostes, 2009).

In addition to those remarks over the architecture of the affordable housing, current policies have contributed to a segregated urban model, since most of them are established in remote areas, with limited connection to the urban fabric. Developments misplaced from central regions not only fail to take into account inhabitants' life quality, but also do not consider density's potential for the optimization of public infrastructure (Figure 1).

Fig. 1. Housing complex with 1000 units built in Parauapebas (Pará) in 2012 is disconnected from urban center and illustrates suburban pattern of development.



Source: <http://espacoabertopebas.blogspot.com/2012/03/prefeitura-de-parauapebas-entrega-1000.html>

The lack of housing in well-located land is a reflection of how the state often fails to regulate land values and control speculation. The result obtained after 6 years of MCMV is a use of public funds and subsidies to indirectly benefit landowners. This may be remedied if administrations make

use of the tools established in municipal land use plans, such as the Special Zones of Social Interest (ZEIS), which are the focus of this paper.

2.2 Inclusionary Zoning and Special Zones of Social Interest (ZEIS)

In the process of building a new urban order in Brazil, ZEIS have been established as an inclusionary zoning mechanism. Its purpose was to enable housing for low-income population in valued areas, surrounded by services and infrastructure, by guaranteeing access to affordable land. Inclusionary zoning has been used worldwide as a tool to provide well-located affordable housing for families with lower income. In some American states like New Jersey and Massachusetts, for instance, inclusionary zoning is provided as a “fair share” of a development, referred to as set-aside in exchange for density bonuses (Lerman, 2006). In Brazil, the goal is achieved by spatially delimitating zones with the sole purpose to be occupied with affordable housing and institutional infrastructure. This different type of requirement forces the municipality to regulate what can be built inside the areas to accommodate lower income populations, thus lowering land costs.

The main potential of any zoning mechanism is related to its ability to attribute urban codes and construction indexes. It is important to remember that, in the study of urban land, the city is shaped by those territorial practices regulated by urban codes. These rules, i.e. parameters, are represented by values which determine desired patterns of occupation such as Floor Area Ratio, Density, Setbacks and Minimum lot size, among others. Planners and administrators may disregard that a change in parameters has an immediate impact in the final constructed product, which might lead to unappealing designs or exclusionary impacts.

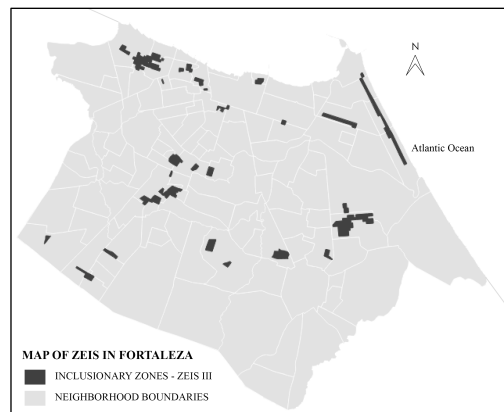
However, minimum standards of occupancy often contribute to serviced urban land having prices too high for most of the population, forcing the poorest to settle in slums. This process produces *favelas*, settlements which do not comply with occupancy codes determined by law, being regarded as illegal and more susceptible to expropriation, abusive rents and environmental risks. The rules specified in urban codes, while aiming to guarantee standards for quality housing for the entire population, often end up excluding lower income families from urban legality (Moretti, 2007).

This research does not propose changes in existing zoning or settlements but considers the potential of inclusionary regulations to reduce illegality, suburban sprawl and spatial segregation. It presents a study developed for one ZEIS in the city of Fortaleza, capital of Ceará, and the fifth largest city of Brazil with a population of approximately 2.5 million (IBGE, 2010). The Northeast of the country, where Ceará is located, has been characterized by a historical large economic and social disparity among its inhabit-

ants but has also been presenting the largest growth rates in the country in the midst of Brazil's relative economic stagnation in the last several years. However, the economic development has been accompanied by disordered urban growth and expansion of slums. Although the research presents a study of a small-scale intervention in a specific lot marked as ZEIS in Fortaleza, these particular areas strategically placed within the urban fabric, have the potential to orient Brazilian cities in a more equitable path by providing a 'right to the city' for often ignored segments of the population.

The mechanism was initially implemented as an inclusionary regulation for vacant lots in 1994 in the city of Diadema, state of São Paulo, and has been introduced in Brazilian Federal Legislation since 2001. Currently, even though the federal law does not require compliance with the ordinance, approximately 52% of municipalities with a master plan have reported the adoption of ZEIS or other inclusionary zoning tool (IBGE, 2009). Fortaleza has adopted such zoning in their municipal land use codes since 2009 and classified it in three types: I (existing *favelas* prioritized for sanitation projects), II (existing low-income housing developments) or III (vacant lots). The product of this research was to determine the constructive indexes to regulate a specific zone in the city, which is marked as ZEIS type III. In Fortaleza's zoning map the municipality has established 34 polygons of ZEIS III, which have not been regulated, totaling almost 662 acres of land (Figure 2).

Fig. 2. Map of ZEIS type III in the city of Fortaleza. Source: Shapefiles from IBGE, 2010. Map designed by the authors in 2015 based on Fortaleza LC. 62, 2009.



The authors focused on vacant land due to its vulnerability and possible manipulation by private stakeholders interested in developing market rate developments for maximum profits. Vacant land has also been identified as an attractive nuisance to crime and illegal activity such as prostitution and drug sales (Garvin et. Al, 2013).

3. Methodology

In order to investigate the possibilities of inclusionary zoning regulations, the methods adopted in this research consist of using Building Information Modeling (BIM) to design social housing typologies and to specify urban regulations. BIM is a technology, which allows agents from the Architecture, Engineering and Construction Industries (AEC) to digitally create a virtual model of a building. It is a more efficient tool than traditional Computer Aided Design (CAD) software because it not only provides simultaneous 2D and 3D visualization, but also uses predefined objects that have geometry and data. A BIM model, when completed, “contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building” (Eastman et al, 2011: 1). This means that every object within the digital model has a set of properties and parameters, which can be regulated in the software (i.e. dimensions, materials, color). Those object properties provide additional information for a future database of materials and quantities needed for construction.

Since this research was developed to connect zoning and its impact on the architecture of social housing, the BIM software ArchiCAD was utilized for a more comprehensive and yet agile creation of housing designs. In architecture, the parametric modeling approach of BIM makes it easier to change a model since its modification in a 2D plan will also adjust its representation in the volumetric model. This enables the designer to create real-time, interactive visualization of design thus increasing clarity of information in the early design stages and facilitating decision-making (Ettouney, 2008).

In order to regulate the chosen ZEIS, the BIM software ArchiCAD was used to accomplish the following three stages: (1) Architecture: to elaborate new building designs based on rules specified by the MCMV program; (2) Implantation: to place those units in the chosen lot marked as ZEIS and (3) Parameters: to derive urban indices from those simulations in order to regulate the chosen land.

Regarding stage one, a database of housing designs was developed to be implemented in the ZEIS and help define final urban rules. The typologies were created based on standard dimensions of MCMV projects, which meet the requirements specified by the federal government to obtain funding. The simultaneous 2D documentations (technical drawings) and 3D drawings generated facilitated the adaptation of the designs to those regulations, an important aspect to propose financially viable housing, which can accommodate families with varying incomes.

The goal of stage two was to simulate the occupation of the existing ZEIS as to promote urban inclusion. That task was assisted by the parametric nature of the software, which expedited the design process since when a model element was changed, the software coordinated change in all views that displayed it. The fast interaction with the model made it possible to assess visual impacts of the construction and its relationship with its surrounding.

In stage three, those final designs were interpreted into urban indices which discourage the current privatized and segregated city while promoting integration between public and private spaces. Since BIM generated a report on elements such as size of the units, amount of occupied land, building heights and materials, those tables were subsequently used to calculate the corresponding values shown in the results section.

4. Results

4.1 Typology bank – possible social housing solutions

The Typology Bank, part of stage one, consists of five blueprints with distinct dimensions created to simulate greater housing possibilities in terms of connection, density and targeted social class. They were stipulated to illustrate how a more complex combination of architecture is dependent upon flexible zoning regulations to counteract existent monotonous public housing complexes. There was a constant analysis of the particularities of each project to balance size of units, open space and density. The floor plans are briefly presented in this section along with how they can be constructed and combined in a development (Figure 3).

Fig. 3. Typology bank created based on criteria from MCMV with BIM.

Housing Typology	Floorplans	Final Volumetry: possible originating buildings
Tetris (incremental)		
Sobrado (townhouse)		
Studio and Apartment 2 BD		
Apartment 3 BD		

The “Tetris” typology (430 ft² to 732 ft²) is an incremental design characterized by the presence of an embryo unit, in which the constructor assures the completion of wet areas and the structure necessary to ensure health and safety to the occupant. The resident has the option of expanding the home according to the available resources and necessities, but within the structure initially delivered as an embryo. This ensures that the development serves families with different incomes since the price of the unit depends on how much of the embryo houses are initially constructed. The “Sobrado” Design or Townhouse (470 ft²) was considered for families earning from 0 to 3 MW. Its smaller size makes it easier to be implemented in smaller parcels according to the funds and land available as the government or developer purchases them. Apartment units were also designed as a way to build high rises and increasing density inside the ZEIS. Their construction depend on larger parcels of land and funding being available, but presents an opportunity for mixed-income developments by providing units with different dimensions in one development. Those units consist of a “Studio” with 226 ft², a 2BD unit with 452 ft² and a 3BD unit with 689 ft². The studio unit was considered as an affordable rent solution for young couples with no children who can benefit from a house close to the work environment and urban center. It would be constructed as a share of affordable home in the same building as the larger units proposed as social housing and market rate housing.

4.2 Originating Urban Regulations

The apartments were subsequently implemented within the ZEIS as to derive values, which could simulate an ideal balance between the provision of affordable housing while also guaranteeing sustainable developments and integration with the city (Figure 4).

Fig. 4. Resulting simulation from the placement of units on the site shows integration of housing with the surrounding urban context. Created by authors.



The results contrasts with what has been produced by private market under existing urban codes on the surrounding of ZEIS: current regulations enable a neighborhood characterized by high rises with low occupancy rate, surrounded by parking spaces and enclosed by high walls, which disconnect the developments from the streets. Table 1 presents the values obtained from the simulation performed for this research in comparison with what is specified in the law for that zone of the city. Parameters specified in Fortaleza's urban code include: occupancy rate, underground occupancy rate, floor area ratio (FAR – Gross floor area / area of parcel), maximum allowed height, permeability rate (not necessarily green or public space), minimum lot dimensions and minimum lot area.

Table 1. Results obtained by the placement of design housing units in the ZEIS in comparison to regulations present in the Fortaleza's urban code.

Parameter/Index	Total Lot Area (ZEIS)					Existing Law
	0.14 acres - 0.45 acres		0.45 acres - 0.50 acres			Any Lot Size
Housing Design	Tetris (incremental)	"Sobrado" (Town-house)	"L" form	Low-rise Block	High-rise Block	
FAR – min.	0.5	N/A	2.0	2.0	2.0	0.2m
FAR - basic	1.8	2	4.0	2.3	3.0	2.0m
FAR- max.	2.5	N/A	N/A	N/A	N/A	2.0m
Max. Height	9.5m	7.2m	25m	16m	30m	72m
Permeability Rate	40%	50%	50%	40%	60%	30%
Setback-Front	N/A	N/A	5.0m	5.0m	4.0m	Varies by location
Setback-Back	0.5m	2.0m	2.5m	2.5m	4.0m	N/A
Setback-Sides	2.0m	2.5m	2.5m	3.5m	2.0m	N/A
Occupancy rate	58%	65%	40%	37%	25%	60%
Undergr. Occup.	10%	0%	20%	20%	10%	60%
Lot Streetfront Width – min.	13.20m	13.20m	45m	45m	13.2m	5.0m
Lot Streetfront Width – max.	45m	45m	N/A	N/A	N/A	N/A
Density (hab/ha)	615	769	1800	1768	1827.4	N/A
Green area/open area rate	30%	20%	40%	30%	50%	N/A
Min. commercial area	Optional	1m/ 20m ² built	Ground floor	Ground floor	Ground floor	N/A

In addition to the parameters shown in Table 1, the simulations also indicated the importance of regulations regarding number of trees, number of parking spaces and the absence of walls, factors not mentioned in land-use laws, but vital to ensure livability. Existing zoning also does not include setback requirements for the sides and back of the lot, density, open space rate nor maximum lot dimensions. Those regulations are important to control the development potential of the land thus, guaranteeing its affordabil-

ity. The minimum FAR permitted is 0.2, a value too low to encourage higher densities, which is a waste of potential in a well-located area close to transit and services. Resulting simulations also indicate a need for regulations over mixed-use developments, and laws related to commercial uses.

Further study of the typology Tetris and its quantitative analysis have shown that housing options, which better adapt to inhabitants needs, are indeed financially viable and may be funded by existing federal housing program (Furtado, Miranda and Pequeno, 2012).

The existence of a design that is incremental over time brings to light the importance of zoning, which adapts to a community's and building's lifespan. This is enabled if indexes have a minimum, basic and maximum value, in which the minimum guarantees that the land will be always occupied thus restraining speculation over vacant land. The basic would regulate the use of land to its fullest extent enabling sustainable growth and the maximum would permit extra growth to a certain extent, provided that the developer or government pays a fee to compensate the additional occupation. This longer term view of zoning allows typologies which adapts to inhabitants' life and the transitions that they will undergo during the occupation of a locality, thus enabling new constructions within a planned occupancy framework. The diversity of the proposed regulations, leads to a new view of zoning as a tool that allows for flexibility, in contrast to common urban planning practices, which specify a finished and rigid urban setting. This indicates the importance of shifting from traditional CAD and BIM programs to a more flexible rule-based approach aided by Procedural 3D Modeling technologies.

5. Conclusion

This research represents an initial step in the process of regulating one lot marked as ZEIS in the city of Fortaleza, Brazil. It features a local case study of a methodology to establish land use regulations for an inclusionary zoning area and promote a less socio-spatially segregated city. BIM technology was used to define social housing typologies with the goal of understanding zoning laws and how they affect design and integration within the territory. The software allowed for creation of more comprehensive designs, which would normally take too long to be conceptualized and quantified by CAD.

The originating alternatives analyzed how architecture could change according to variances in lot size or urban regulations as well as the income of inhabitants. The typologies and urban index tables obtained from this study demonstrate how indices allowed by the municipality were es-

tablished while disregarding both the quality of the urban environment and the goal for inclusion. Other values and regulations must also be added, which are not contemplated in the land use code such as the number of parking spaces and trees, the prohibition of walls, and a percentage of commercial areas to foster mixed uses in the land and provide opportunities for work for lower-income families.

Even though this research did not propose to change the existing status quo regarding land use or question the effectiveness of zoning as a tool, it presented a case study to address the existing issue of vacant land and social housing deficit in Brazilian cities. However, for a problematic as complex as the provision of social housing, the authors acknowledge that architecture, in order to fully address communities' needs, should make greater use of participatory design approaches from its early stages of conception. Since BIM technology provides simultaneous technical drawings and three-dimensional models, it may facilitate the essential dialogue between communities and designers.

Despite the support of BIM, the typologies developed through a manual process did not represent a sufficient number of options to cover significant constructive possibilities. The process of elaborating designs and altering the model was still slow and could be further hindered if the designer lacks extensive technical knowledge of the software. Additionally, while a variation in urban parameters has a direct impact on the final constructed design, they are somewhat empirical on paper and difficult to be immediately translated into urban form.

BIM presents shortcomings as a tool to model the impacts of developments since one has to detail several aspects of the construction in order to gain an insight on the volume of the construction and how it will look in the site. This excessive level of small-scale detail is appropriate for modeling the building but not for the urban scale or simulating impacts of land use regulations. Those issues may be overcome by Procedural-based modeling software, which enables one to choose between specified attributes and parameters, so that altering a specific attribute results immediately in a tridimensional change. Software such as CityEngine allows for the establishment and simulation of parameters, which resemble urban codes. These challenges regarding the methodology indicate the importance of shifting from traditional CAD and BIM programs to Procedural 3D Modeling in order to be able to predict and better visualize the effect of public policies, not limited to zoning, on urban form.

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