PARAMETRIC MODELING OF URBAN COASTAL AREAS: VISUALIZING ALTERNATIVE SCENARIOS FOR PARTICIPATORY PLANNING

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Abstract

Over the past decades, research on the use of prospective visualization as a means to communicate with and engage the community as actors in participatory planning processes has matured through methodological discussion, all the while exploring and incorporating new technology in representation and communication. The published results on experimentation with varying levels of abstraction/realism, simplicity/complexity and interactivity can clue planners developing participatory planning activities towards the most desirable tools and methods for their particular situation. This study reports on the use of parametrically generated urban landscape visualizations in the context of participatory planning as it took place during the participatory planning stages of the revision of city planning regulations in the municipality of Natal/RN, Brazil. Amongst more general definitions, planning regulations for the municipality include parameters that govern urban morphology, such as locally-defined maximum floor-to-area ratios (FAR), minimum setbacks and maximum building height, as well as special zoning that restricts land use as deemed necessary for the purposes of environmental protection, social or touristic interest. Additionally, specific cases of landscape-protecting regulations are in place on distinct locations along the beachfront and nearby zones. The abstract nature of these regulations can greatly limit the understanding of the related parameters' values by non-expert population. While the revision of the municipal plan for Natal, which includes zoning and building regulations, scheduled for the year 2019, was required by law to include participatory planning stages, the methodology for this participation remained unclear. Whereas the construction industry-related interest groups have been intensely engaged in efforts to loosen building restrictions in environment and landscape protection zones, the general public has had little access to discussions pertaining these regulations. As a response to the perceived need to better include citizens in this process, the *Fórum Direito à Cidade* ("Right to the City" Forum) group has organized parallel workshops, to discuss and clarify planning topics being targeted in the plan's revision. As thematic groups pertaining to these topics have been set up, the need has arisen to build visual material that might help non-expert participants to better grasp the mechanisms and results of proposed regulation changes. Given an evaluation of the available resources (time, hardware, and expertise), the authors chose two techniques – 3D computational modeling and photographic manipulation – in order to represent future scenarios. As a first step, the authors used parametric-enabled software to develop definitions representing general building regulations, as well as parametric representations of specific line-of-sight rules as contained in the current city plan. Subsequently, two urban coastal areas that feature landscape protection regulations were modeled, based on CAD data. The previously developed parametric definitions were then applied to the 3D models in a variety of different density, height and line-of-sight restriction configurations, generating aerial and ground level visualizations of these areas, as they would be materialized under alternative building regulation scenarios. These visualizations were presented both as low-fidelity "flat" shaded polygon models, which could be viewed in real-time 3D, as well as photo compositions onto real backgrounds, which aimed to represent the potential for landscape line-of-sight obstruction in each of the proposed scenarios. The visualizations, despite being restricted to static images, were regarded by workshop participants as invaluable aids to comprehending building regulation and landscape obstruction. When presented in events, the visualization results have elicited strong reactions from all sides in contentious planning situations, and have been widely shared in social media, even when incomplete and even against the researchers' wishes. The chosen techniques allowed the visualization team to visually render disparate scenarios encompassing large urban areas and including several thousands of buildings, complete with prospective urban density indicators, with comparatively little required modeling effort and acceptable quantitative accuracy, even if not necessarily representing morphological realism. The modeling method has been deemed adequate for the development of additional visualization scenes based on other areas of the city, and further experiments may be done with direct participant interaction with the models.

Key words: Participatory Planning; Landscape Visualization; Parametric Urban Modeling

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1. Introduction

Participatory planning, wherein diverse stakeholders are allowed to discuss, contribute and put forth their points of view in urban matters, improves planning legitimacy and efficacy (Radinsky et al., 2017), is an integral part of contemporary democratic city administration, and constitutes a clearly stated goal in Brazilian urban regulation laws. In the Brazilian case, these laws are best represented by the "*Plano Diretor*" (literally, *Director Plan*), as established by Federal Law since the year 2001. These municipality-specific laws establish the planning goals and strategies for individual cities, including land zoning, specially designated interest areas, building codes, as well as any legal instruments that govern urban development in the municipality's territory. Most importantly for this study, these laws shape urban form in Brazilian cities through morphometric parameterization (De Castro et al., 2018), through the definition of such indexes as a building's mandated minimum setbacks, maximum Floor-to-Area-Ratio (FAR) and maximum total height. The codification of urban form through a combination of legal text, 2D zoning maps, numeric indexes, and numerous exceptional-case sections, tends to obscure the urban regulations' actual potential effects on urban form to any non-expert readers and "do not encourage the exploration of ideas and alternative development scenarios" (Pettit & Industries, 2006, p. 22.5). As put forth by Castro et al., "the difficulty in mentally visualizing the urban parameters proposed hinders the understanding and the critical judgment of the local inhabitants when comes the opportunity to appreciate and discuss new parameters" (De Castro et al., 2018, pp. 17.7). Al-Kodmany et al. agree that "currently employed methods of user participation actually disenfranchise the user because the methods of communication have not changed to accommodate a non-design oriented population" (Al-Kodmany, 1999, p. 39).

This study reports on the process of building parametric models of urban areas in Natal/RN, Brazil, as visualization aids during the participatory planning process taking place during the 2019 revision of the city's Director Plan. The study explores the viability of parametric urban modeling as a tool to represent neighborhood-sized areas, as well as the usefulness of the resulting models in communicating the potential results of changes in urban regulations as they allow for change urban in form. The resulting models were likewise contextualized in their interaction with the surrounding landscape and the resulting effects on urban infrastructural capabilities.

The following sections will describe the participatory planning process in Natal; the conceptual and technical basis for the visualization model production; the model planning, model making and presentation stages; and finally the authors' considerations on the study.

2. The Director Plan

Natal is the 420-year-old capital and most populous city in the Brazilian state of Rio Grande do Norte, with an officially estimated 884.112 inhabitants as of the year 2019, comprising over half the population of the Greater Natal area. Its geographic location is defined by the Atlantic coast to the east, while the Potengi river splits its territory into two sections, with the North Administrative Zone sitting off the river's North bank, and the East, West and South Administrative Zones lie on the opposite side. Sandy beaches, vegetation-covered sand dunes and mangrove vegetation are the most prominent visible natural landscape features and are preserved by law, whereas the remaining territory has been largely occupied and built upon, characterizing a conurbation state with neighboring municipalities.

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Current urban regulation (the 2007 Director Plan) for Natal determines three main zoning types for the municipality: 1) Environmental Protection Zones (including the dunes and mangroves); 2) Densifying Zone (mostly the core areas possessing consolidated infrastructure and deemed fit for higher population density); 3) Basic Density Zone (the remaining areas of the city). Beyond these, the plan marks Social Interest Areas ("*AEIS*"), Touristic Interest Zones ("*ZET*"), Maximum Building Height Control Areas, and a Historical Heritage Special Zone. While the Densifying and Basic Density Zones differ mostly in the maximum allowed FAR and Building Height, all other specific zones require individual regulations stating allowed land use types and indexes.

Brazilian Federal law mandates Director Plans be updated every 10 years. The revision process for Natal's Director Plan began in 2017, under the conduction of the local Planning Department, (*Secretaria de Meio Ambiente e Urbanismo de Natal* – SEMURB). This process was criticized from the very first public audience, due to a lack of transparency on which parts of the Plan were actually to be revised, and for what reasons. Technical data and studies that would allow for the comprehension of environmental, social or economic conditions that might support future decisions were likewise absent or not publicized. A group of professors from the Federal University of Rio Grande do Norte (UFRN) demanded a more transparent revision process. The perceived inconsistencies were testament to difficulties in advancing the planning debate and comprehending the actual demands motivating changes in the Director Plan.

In the following year, a change in municipal administration precipitated a hiatus in the Plan's revision, as the SEMURB's technical staff was partially replaced. During this period, UFRN professors formally organized the Right to the City Forum outreach project (Fórum Direito à Cidade – henceforth, "FDC"), aggregating participants from various disciplines related to urban planning and administration. The FDC is focused on providing citizens with informational material that might further the planning understanding, and ultimately bringing together the academic community and civil society in the discussion.

The Plan's revision process was resumed in early 2019, structured around three levels: 1) workgroups designed to help SEMURB with building material and organizing public workshops; 2) participatory workshops wherein the citizens could report on perceived issues, potential, and proposals for the city and the Plan; 3) a Core Managing Group composed of organized civil society and public administration representatives tasked to conduct and decide on the revision process. As of April 2019, the FDC detected possible areas of interest (and contention) for the following steps, prompting the development of the first proof-of-concept visualization models presented in this study.

Subsequent events, however, disregarded the originally agreed-upon revision methodology, as official workshops started without prior participant training and discussion or workgroup discussion, and with no definitive Managing Group composition. This prompted a citizen group to take legal action, once again halting the process until SEMURB was able to properly organize all planning support instances. The revision was resumed in August/2019 – however at this point under the intense pressure of a politically established timetable that would force all activities to take place during the remaining months of 2019, thus compromising due comprehension and participation by the society.

Within a month, nine workshops (three per week) were to take place, directed at distinct social segments (academia, business entities, NGOs, professional organizations, citizen associations)

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and at the municipality's four administrative sub regions. Two of these weekly workshops were to take place on weekdays, during work hours, severely impairing effective societal participation. These workshops consisted of three phases: 1) technical outlook on the city, with a display of general data on population density, income, building standards, infrastructure, social and environmental factors; 2) community outlook, with workgroup discussions; 3) definition of priority issues as discussed in workgroups, to be carried forward into the following public audience stage of the process.

The first phase of the workshops was made up of a series of 15-minute, digital presentation-aided talks, in which previously enlisted institutions and societal groups addressed the participants on an auditorium that could seat approximately 200 people, followed by three-minute interventions by other participants. During the second phase, workgroups were split into classrooms and shown printed maps representing aspects pertaining to each of the groups' thematic interests. Participants were to discuss issues and potentialities and write these on paper for display on the room's walls. A group of three SEMURB technical staff was in place in each room place to support workgroup activities. The third phase took place immediately following the second, with participants agreeing upon a set of planning priorities.

The FDC considers that, rather than offering wide social participatory opportunities, these workshops symbolized a mere formalization of the revision process. Technical data were presented by SEMURB that had not been previously distributed, meaning participants came unprepared. As a reflection of the established workshop timetable, the building industry and business sectors were heavily invested and numerically overwhelming in all workshops. Any workshop-related news was displayed directly on SEMURB's website, with little to no mass media insertion, and thus little social outreach.

Independent parallel meetings and events were also held during this period. The FDC participants were contacted by distinct groups who wished to discuss and understand aspects related to the revision process, ranging from local citizens likely to be affected by regulation changes, to specific academic and technical events, and political councilor audience invitations.

Natal's mayor was absent from all public workshops, but did make himself present in a parallel event held by a business interest group, in which he reaffirmed his commitment to the business sector's wishes to "verticalize" the city's coastal areas, regardless of any divergent scientific advisory or social demands. If that were to be so, the Director Plan was to be rebuilt purely in line with purported "economic development" interests, in a set of proposals by the local executive power and business sector that was based upon four main points: 1) reducing or extinguishing AEIS and ZET; 2) abolishing building height control; 3) loosening building potential restrictions (such as FAR); and 4) increasing Special Urban Operation areas (on which additional building potential may be granted).

3. On Urban Visualization

The benefits of visualization for participatory planning are widely discussed (Al-Kodmany, 2002; Batty, Steadman, & Xie, 2004; Hoch, et al., 2015; Lovett, et al., 2015). Different authors have classed uses for visualizations in urban planning as informing, consulting, involving and empowering (Pettit & Industries, 2006); or education, exploration, explanation and engagement (Batty et al., 2004). As such, "visual information is a common ground for the transmittal of

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information that overcomes racial, social, and language barriers. The conversion of abstract data into imagery greatly reduces the risk of confusion while honoring the inherent human preference for visual information. Communication of ideas is as important as the information itself." (Kheir Al-Kodmany, 2002, p. 190). Al-Kodmany (2000) surmises that visualizing data and design proposals is both important in allowing participants to understand proposals, as well as effective in drawing out the public's concerns. Visualization has, thus, the potential for being an integral part of the planning process, from the initial steps of assembling participants and interpreting real world data, through the organization and negotiation of societal interests, the discussion of planning alternatives, the decision-making stages, and the post-implementation evaluation steps.

Al-Kodmany (2002) has mapped the *tools* used for visualization in planning to four traditional tools and their technologically-enhanced counterparts. While low-technology traditional tools are remaining viable tools and should be combined with computer tools so as to make use of the best aspects of either, the author notes computerized tools "can significantly enhance, or even transform, public participation planning. Traditional, noncomputerized tools are not capable of the sophisticated analysis, display, and visualization that may enable the public to make more informed decisions." (Al-Kodmany, 2002, p. 190).

Within this context, this study focuses on computer-generated three-dimensional visualizations. These have been used in such diverse participatory scenarios as street-level urban redesign (Al-Kodmany, 1999); web-based and Augmented Reality (AR) or Virtual Reality (VR)-enabled city-scale reproductions (Remaking Cities Institute, 2019); landscape planning with Canadian First Nation communities (Lewis & Sheppard, 2006); assessing housing density scenarios (Salter et al, 2009); urban forestry planning (Tyrväinen et al., 2006); assessing building code limits and compliance (De Castro et al., 2018), among others. Despite this, recent research shows that few city planning agencies use 3D software, with application mostly centered on university-led research (Remaking Cities Institute, 2019).

As the possibilities for visualization are ever expanded by technological advancement, it's imperative to reflect upon the issues of *when* to use them, *what* to include and *how* to display them (Lovett et al., 2015). In order to answer these, the main objectives of visualization – "to convey understanding of the proposed project; to demonstrate credibility of the visualization itself; to avoid bias in responses to the proposed project." (Sheppard, 2001, p. 194) – are to be kept in mind.

Dfferent stages (the *when* question) may demand different visualization design strategies – and continuously employing visualizations at various times can help participants not only contribute to the decision-making process, but also feel more confident in the visualization strategies. The current study can be clearly associated with the early phases of participatory planning: the Director Plan regulations represent broad urban form parameters, rather than the more specific design principles which might come up in later stages. As general guidelines for this stage, literature suggests the use of bird's eye view images of the selected area, with visuals restricted to a relatively abstract level of detail – thus avoiding distractions that might be provoked by the discussion of minor (and, at this point, inconsequential) representation details (Lovett et al., 2015).

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The matter of detail and perspective, as it relates to the aspect of *realism* in visualizations, is an issue in itself (part of the *what* question). Realism (here understood as the approximation between a visualized scene and its real-world counterpart) can provide the observer with a sense of familiarity and facilitate orientation (Lovett et al., 2015), and may instill excitement and commentary in participants, whereas the lack of detail and realism may make it difficult to judge the aesthetic qualities of a development. The level of realism expected of a visualization will be adequate to the level of accuracy of the represented data (the more realistic, the more accurate the data must be) (Sheppard, 2001) and the planning stage it reflects (the later in the process, the more advantageous it can be to employ higher realism) (Lovett et al., 2015).

High levels of realism in visualizations carry a certain risk, in that "the images can be so realistic and persuasive that they become misleading for people. The more realistic that the maps and images appear, the more danger there is that they will be accepted as 'truthful'"(Al-Kodmany, 2002, p. 208). At the same time, "it can be argued that even simulations with a lower degree of realism can still contain the most important information needed for a specific purpose"(Lange, 2001, p. 165). Moreover, such choices as the viewpoints offered can be a result of ponderations on professional knowledge, significant landscape features, model scale and available data, and potentially shape the observers' impressions on the visualization and the message it conveys (Lovett et al., 2015).

Sheppard (2001) raises the point of *ethics* in landscape visualization models. The author argues that if "the power of visualizations to influence decisions is so great, then any variability or unreliability in the visualizations has the potential to mislead the viewer"(Sheppard, 2001, p. 187). In order to fulfill their purpose, as means of contributing to better decision-making, visualizations need not only be *accurate*, *representative* and *clear*, but also be *transparent* (in that the process leading to the modeling results is understandable upon inspection and any errors are self-evident, never masked by the sophistication of technology); and *legitimate* (in that the level of accuracy of its results can be demonstrated through a description of the modeling process and the key assumptions and decisions taken). This may include presenting sets of indicators together with the visualizations, so additional information can be associated with the visual data (Lovett et al., 2015; Sheppard, 2001).

Finally, the *how* question pertains to the visualizations' presentation modes and their associated interactivity factor. Three-dimensional models, which constitute the main product generated in this study, can be displayed and shared in a variety of modes, which go from static plan or perspective views to interactive and/or immersive models experienced in virtual reality (VR) or superimposed as augmented reality (AR) (Al-Kodmany, 2002; Hudson-Smith, & Batty, 2005; Institute, 2019).

Still images carry the advantage of being a familiar form of representation, as well as being easily distributed along a variety of media – print, digital presentations, or over the internet (Lovett et al., 2015). In regards to urban visualization, these may range from simpler architectural massing projections, to more detailed and realistically rendered computer images, and digital compositions involving real photographs, computer models and hand-drawn sketches (Kheir Al-Kodmany, 2002; Lange, 2001). Literature suggests that, especially at the site scale, the resulting images can be best utilized when displaying various alternative scenarios, in order to establish a common baseline and comparatively explain the results of different planning and design alternatives.

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Research has shown real-time three-dimensional models can generate additional participant engagement and understanding of proposed scenarios, by allowing users to look and move around a virtual environment, and even hear sound (Lindquist, Lange, & Kang, 2016; Remaking Cities Institute, 2019). These correspond to its properties of *immersion* (allowing the user to feel "transported" to a different place) and *interactivity* (allowing the user to freely navigate the scene, alter such characteristics as sunlight and time of the year settings, or even model construction parameters). Increasing immersion and interactivity does, however, greatly increase the technical and organizational challenges related to interface usability (Lovett et al., 2015) – often requiring active facilitator staff, participant training and specialist equipment (especially in the cases of immersive technology such as VR, AR or multiple-projection rooms). (Hoch et al., 2015; Lovett et al., 2015; Remaking Cities Institute, 2019; Salter et al., 2009).

Available resources are thus a defining factor for any visualization project. As "time, budget, staff expertise, computing facilities and data are also important considerations" (Lovett et al., 2015, p. 88), special care must be taken in the definition of the tools and methods used to build and present models. The development of a visualization model requires source data (digital terrain models, CAD and GIS data, and other numeric data of varying natures), and the model's validity is directly related to the quality of available information. This planning includes the choice of modeling software, workshop location preparation, staff training, as well as mapping out the stakeholders' motivations, goals, and access to technology (Al-Kodmany, 2002; Remaking Cities Institute, 2019; Salter et al., 2009). Taking the visualizations on site and/or distributing them online is an important strategy in order to reach out to citizens. Low cost and wide accessibility are paramount to increase the reach of societal participation (Hudson-Smith et al., 2005). Given enough resources, several authors have experimented with building online databases akin to "virtual cities" on which proposals can be presented and continuously consulted by all citizens with access to the relevant technology (generally, a personal computer or smartphone/tablet devices) (Hudson-Smith et al., 2005; Pettit & Industries, 2006; Remaking Cities Institute, 2019).

4. Planning for the visualizations

Having considered the conceptual and technical conditions discussed thus far, the team involved in this study set up a plan for building the visualization models under the following set of definitions:

- *Available resources*: the rapid rate of workshops and parallel events in the August to September 2019 period, totaling up to four weekly presentations, denoted a very short time allotment for modeling activities. Only one of the members of the FDC team possesses expertise in three-dimensional computer graphics modeling. All modeling and other production tasks were carried out in desktop computers, using software licenses available to UFRN. Regarding source data, there is little to no openly available GIS data on the city of Natal; the available CAD files date back to the year 2007; population data is an aggregate estimation based on the latest 2010 census; and some amount of aggregate information on sanitation infrastructure was available through the FDC's members and secondary contacts.
- *Scope*: considering the neighborhood is the basic administrative unit as described in the Director Plan for Natal, and that special interest zones often span a large portion of these units, the scope of the visualization needed to cover neighborhood-sized tracts of land, roughly 5 square kilometers in area. Moreover, given that coastal landscape, urban

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densification and building height were the main topics of contention, visualizations must clearly represent topography and building massing.

- *Level of detail/realism*: owning to a dearth of GIS data and the scarcity of time, staff and computational resources, the computational visualizations were to display a low level of detail, low complexity and low realism. The resulting models would remain compatible with visualization in the early stages of planning, relevant in the communication of proposals to all participants, and appropriate to the relatively low accuracy of available source data.
- *Presentation*: the visualization would need to be presented in several different locations and conditions, often on short notice, and aimed at varying audiences. This meant the products should require the simplest possible infrastructure – which in this case would preferably amount to digital projections assisted by a presenter from the FDC team. To that end, still images were chosen as the main form of presentation, with animation used sparingly to aid in concept explanation during live talks or in short videos.
- *Viewpoints:* the use of still images meant fixed viewpoints would have to be set. As such, the team chose to prepare bird's eye perspective views that would display the entire modeled area, for concept explanation and multiple scenario comparison, as well as street-level perspectives set on spots that would allow for the identification of key landmark buildings and natural features. The latter could also be combined with photographs, generating digital collages and improving upon the contextual qualities of image realism, without requiring significant additional preparation resources.
- *Additional displayed data*: beyond assessing the effects of urban morphology changes on the landscape, it was deemed necessary to account for its effects on urban infrastructures. This meant the potential for population and building density change would need to be calculated based upon the visualization model's parameters.
- *Software*: given the basis for the model consisted solely of CAD files denoting topographic contours and two-dimensional street and building outlines, the team forewent specific GIS software and instead decided that modeling speed and ease of use would be the focus of the process. Despite having previous experience in modeling architectural massing according to Natal's building codes using ESRI's CityEngine software, the team opted to use McNeel's Rhinoceros 6 software, which, allows for greater ease of use through visual programming of parametric modeling through the Grasshopper interface.
- *Methodology Validation*: given the constant variation in participants, the short timeframe of the process and individual sessions, the team decided not to apply quantitative strategies such as surveys, instead opting to observe participant behavior and reactions to visualizations in an exploratory fashion, noting down and later discussing significant interactions during all events.

5. Ponta Negra

The neighborhood of Ponta Negra, a former fishing village, was the target of housing expansion in the 1970s and a tourism industry boom in the 1990s and early 2000s. It is located in Natal's South Administrative Zone, and contains one of the most recognizable natural landmarks in the city, a tall sand dune known as "Morro do Careca". The most prominent road in the area is the four-lane Engenheiro Roberto Freire Avenue (Figure 1). This road's position is also relevant in that it is one of the main borders marking a restricted maximum height zone, within which no building may exceed 7,5m in height. This measure, taken to protect the coastal landscape and ensure Morro do Careca can be seen by approaching visitors, was put in place by a 1984 "ZET" municipal law.

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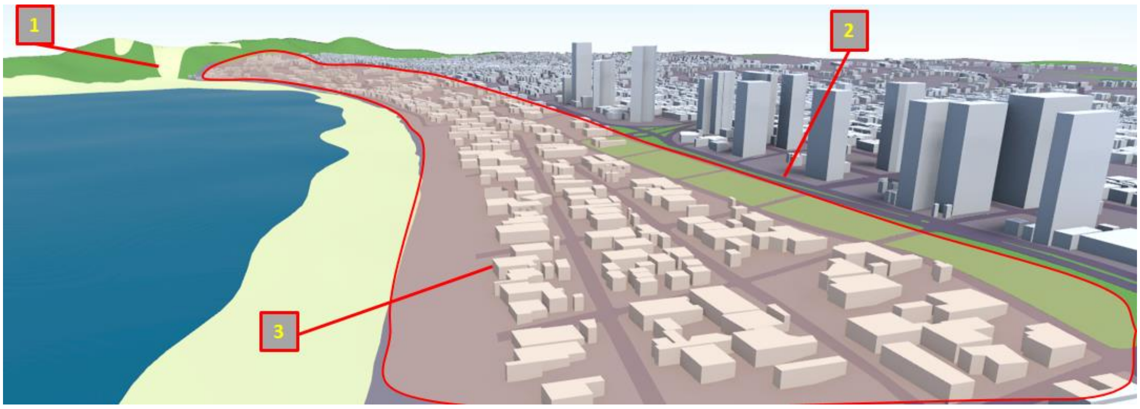
Figure 1. **Ponta Negra. 1: Morro do Careca; 2: Engenheiro Roberto Freire Avenue; 3: approximate “ZET” outline**

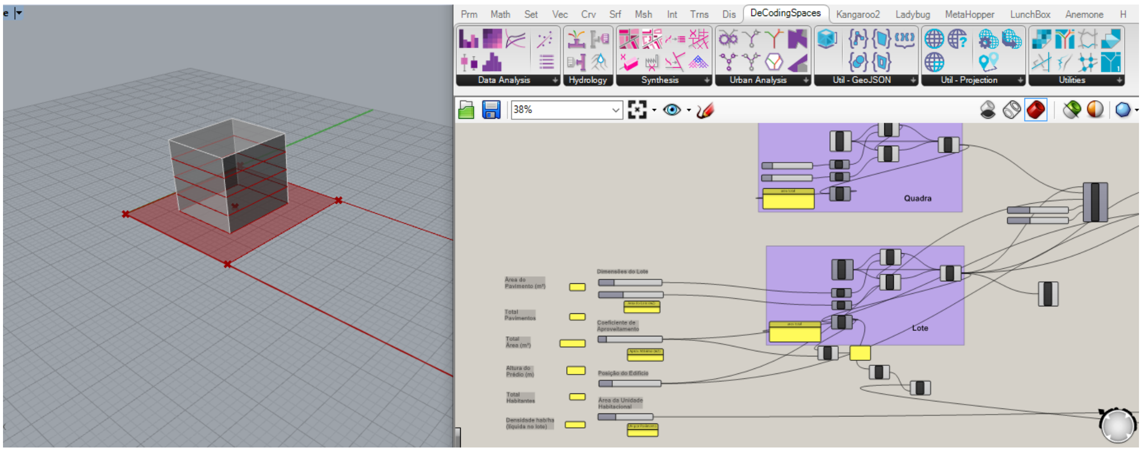


Source: Authors’ original work.

As part of the discussions on an FDC workshop on coastal areas, Ponta Negra was chosen as the first proof-of-concept visualization area for this study. The modeling process began with the importing of the topographic contours present in a publicly available CAD file into the Rhinoceros software, originating a topographic surface, which was then subdivided into blocks, streets, and the sandy beach terrain. Building outlines were then imported and extruded up to the relatively homogenous 7,5m height that represents the general building height found in the neighborhood. This resulted in a total of 6.914 extrusions. A number of taller individual buildings, which can be identified visually were then manually adjusted to the correct height. We regret not having access to building height GIS data, which would have significantly sped up and improved accuracy of these steps. Given the visualization’s goals, however, the overall intended message was not significantly affected by this general inaccuracy.

The next stage in visualization was the programming of the Grasshopper algorithm aimed at representing Natal’s Director Plan building rules which are potentially targeted for change in the revision process (especially FAR indexes and building height limits). The modeler decided to employ the DecodingSpaces Grasshopper extension, which includes ready-made components for defining parcels limits based on a block shape; buildable area based on street position and setbacks; and final building height, based on FAR calculation.

Figure 2. **Initial experiments with Natal’s building parameters using Grasshopper software**



Source: Authors’ original work.

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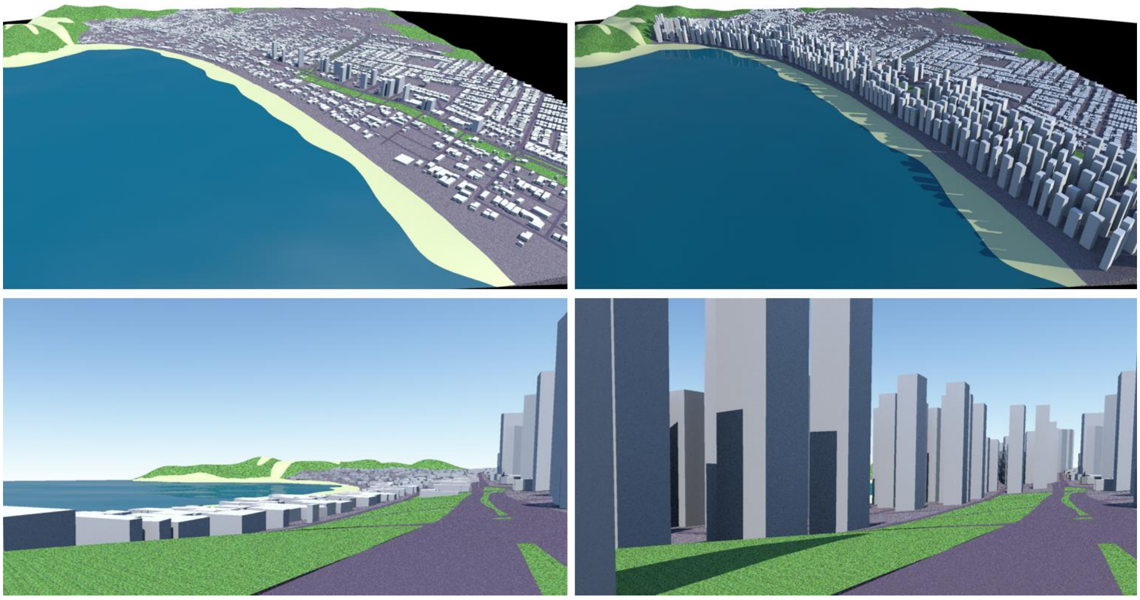
After developing the necessary definitions in Grasshopper, the modeler imported block shapes pertaining to the ZET in a separate layer of the Ponta Negra Rhino model, and proceeded to recreate each block (a total of 61) with a new, automatically-generated parcel structure, based on the DecodingSpaces' PlotWidthThreshold parameter. This created larger parcels, appropriate for taller buildings. Three new models were created on alternate model layers, by generating buildings with FAR indexes of 1.2, 2.0 and 3.5 (the 1.2 index is the baseline FAR, and 3.5 represents the highest currently allowed FAR in the city of Natal). These could then be displayed side-by-side, both from bird's eye view and street-level viewpoint (Figure 3). Additionally, sun shadow projections were also generated, displaying the effect of building height increase in the shading the Ponta Negra beach.

Figure 3. **Ponta Negra visualizations: Bird's eye view, current (top left); Bird's eye view, FAR 3.5 (top-right); Street-level, current (bottom-left); Street-level, FAR 3.5 (bottom-right)**



Source: Authors' original work.

These results were presented in an independent FDC workshop in late April 2019, and were deemed technically viable, clearly understandable, and appropriate for wider publication and discussion.

6. Praia do Meio

The Praia do Meio neighborhood is located further North from Ponta Negra, nearing the location where the Potengi River meets the Atlantic Ocean. It is an especially complex territory in that it contains acute slopes, a beachside ZET, and a concentration of low-income families living in an AEIS, which partially overlaps the ZET. Pending further regulation, plots inside the AEIS cannot be legally merged, and maximum building height is set to 7,5m. The privileged seaside location puts this area in the midst of intense conflict between the building industry and the local population, and makes it a prime target as the building industry pressures for building law alterations during this revision process.

Praia do Meio has another particular situation: from a designated lookout point, an observer is able to see the coastline, as well as landmarks such as the beachside "Hotel Reis Magos" and

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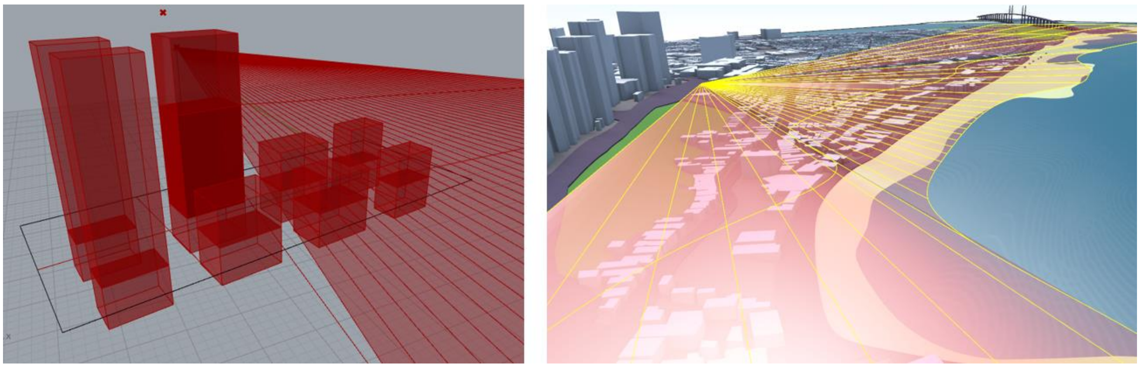
the seventeenth century “Fortaleza dos Reis Magos” (Figure 4). The need to protect this vantage point resulted in a 1987 municipal law determining that buildings within the ZET must not block an observer placed in the lookout point from visually discerning the coastal line.

Figure 4. **Praia do Meio. 1: Approximate border for the AEIS; 2: Approximate border for the ZET; 3: lookout point; 4: Overlapping AEIS and ZET; 5: Fortaleza dos Reis Magos**

Source: Authors’ original work.

The Director Plan and complementary ZET and AEIS laws represent these complex three-dimensional determinations as a series of texts and 2D maps, obscuring the actual building rules from all but the most dedicated observers. As a means of clearing up these issues, the modeler developed a Grasshopper algorithm that replicates the line-of-sight rules defined in the ZET law, and can be set to automatically cut off building extrusion height as they reach this limit (Figure 5).

Figure 5. **Left: abstracted model of the line-of-sight rules serving as a cut-off point for building height; Right: visualization of the cutoff plane applied to the model**



Source: Authors’ original work.

Visualization models were then produced comparing the current situation with the maximum potential building limits as the law currently allows, and alternative scenarios that ignored the AEIS and ZET zones. The bird’s eye views show us that, by suppressing the ZET line-of-sight laws, urban form in the area could become much like neighboring zones (mostly tall buildings),

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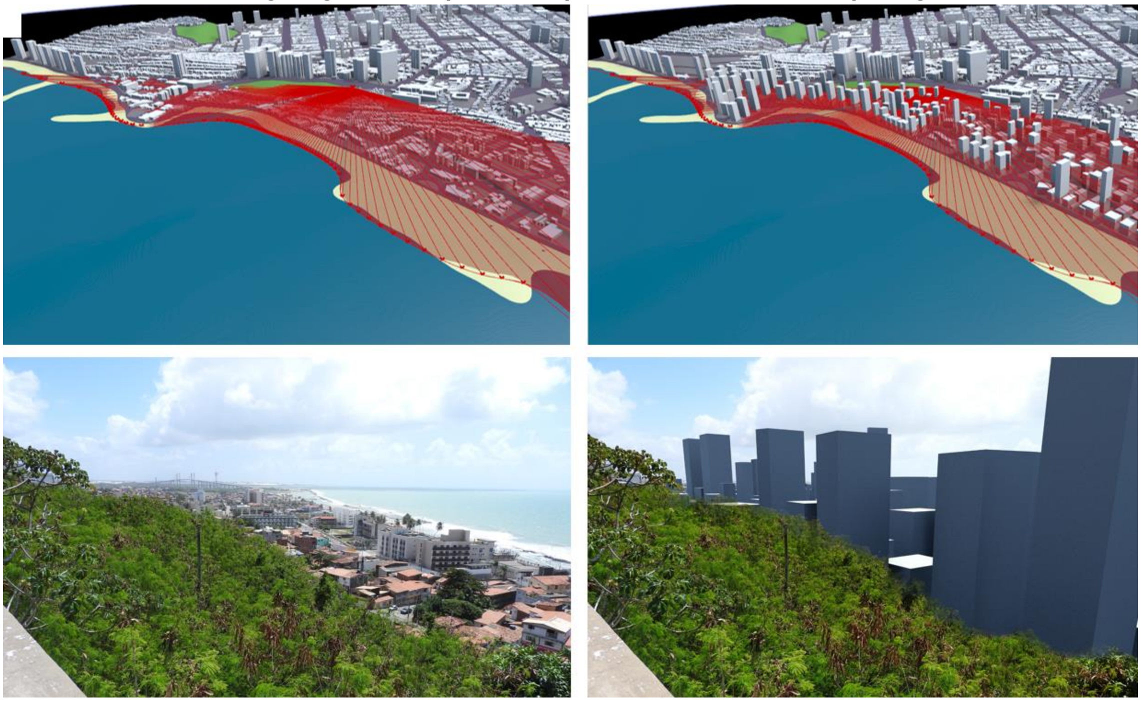
which would in turn completely nullify the landscape value of the lookout point. The street-level views were created from this lookout point, and digitally composed onto photographs, in order to further visualization realism and improve landmark recognition (Figure 6).

Figure 6. **Praia do Meio visualizations: Bird's eye view, current (top-left); Bird's eye view, FAR 3.5 (top-right); Street-level, current (bottom-left); Street-level, FAR 3.5 (bottom-right). The current ZET building height cut-off plane is represented in red in the top images**



Source: Authors' original work.

In addition to the visual representations, the generated models were cross-referenced with demographic information in order to calculate the potential population density in each alternative visualization scenario. Current estimates are of approximately 110 people per hectare. Our visualization that fully utilizes the current building potential, at 60% habitational land use and 60 square meter housing units, elevates that number to 340p/ha. A scenario in which the AEIS was suppressed and FAR elevated to 3.5 resulted in 780p/ha. A final scenario in which all of the previous changes were made and the ZET was also suppressed, increased this to 800p/ha. Considering the current sanitation plan for this area calculates infrastructure based on an estimate of 144 p/ha for year 2024, all alternative scenarios pointed to a severe infrastructural overload. The multiple generated scenes also clearly show that: 1) contrary to general misconceptions, the ZET law does not limit buildings to single-floors, and does allow for taller buildings of over 30m in height at certain points; 2) Increasing FAR directly increases population density; 3) contrary to the discourse put forth by building industry advocates, increasing building height does not significantly increase population density.

These visualizations were incorporated into digital slide presentations, in which zoning, FAR, height limits, AEIS, ZET, infrastructure load, and other aspects were explained with additional zoomed-in images, abstracted or contextualized as deemed necessary for the explanations. The FDC also produced annotated images and short videos explaining these aspects for distribution over social media, and printed informative flyers, as requested by local Praia do

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Meio residents. Presentations of these visualizations were held in the Praia do Meio community center, in academic events, as well as in the SEMURB workshops.

7. Praia do Meio

These visualizations have assumed a disruptive role in the discussions of a revision process that was apparently ill-suited for effective participation. The lack of data opened up the workshop sessions to severe bias and preconceptions, and the FDC was able to present technically grounded data to confront extreme proposals by the business sector, which, in some cases, called for an end to all building height limits and the increase of FAR indexes to 7.0. By presenting the impact of such practices on the landscape appreciation and on infrastructure, the visualization team was able to steer the discussion into the realm of more responsible proposals, appropriate to the city's environmental, social, economic and infrastructural characteristics.

The reaction to the presentations was overwhelmingly positive, accruing extensive applause and compliments on the visualizations' ability to clear up misconceptions and confusion created by the municipal laws. The relationship of trust between the University and resident communities, established over previous years, resulted in multiple invitations for public presentations. After each of these, there was overwhelming confirmation by participants of the educational value of the images. Not all reactions, however, were as positive. Building industry and business groups advocating vertical densification reacted angrily to the information, and accused the researchers of "irresponsibility", and even "terrorism", especially when they had access to the images without proper introduction on the objectives of the study and the methods used to create them. It is unclear if they themselves anticipated the visual impact of their proposals, which are often restricted to increasing indexes and suppressing building limitations. As a clear sign of their stance, at one point during the workshops, a business industry spokesperson suggested "we all stop talking science and start getting to what really matters".

While the visualization team attempted to restrict access to the images to avoid misuse and out-of-context dissemination, SEMURB and the local executive administration eventually required all presentations be sent for display in their website. This resulted in the images (especially the most "extreme cases" generated) being sensationalistically shared on social media without proper attached information, which increased the reach of the images, but did not positively contribute to quality discussion. Comparatively, the purpose-made, one-minute videos prepared by the FDC to properly explain the situation appeared to be much less eagerly shared.

8. Final Considerations

The team has received requests from various stakeholders to produce similar visualizations featuring other areas of the city. The team considers it viable to answer such requests, due to the comparatively low amount of resources required by the parametric modeling technique, especially since the required Grasshopper definitions have already been put in place.

The authors confirm the visualizations' power to elicit strong reactions from audiences, and consider the experiments had an outstanding contribution in educating participants and exposing the effects of possible changes in the city's regulations. We also note the relationship with local residents has been further reinforced by our stance in the defense of their right to the

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city. Further studies resulting from this research might lead to an exploration of workshops in which participants can directly interact with the model's parameters, in order to increase their understanding of the underlying principles, and generate new proposals for future scenarios.

The politically charged nature of the debate surrounding the revision of Natal's Director Plan, the rushed timetable and the lack of publicly available data, compounded by worrying political statements, seem to leave little room for qualified technical discussion. While the debate is still ongoing, as the local administration rushes to approve a revised plan by the end of 2019, the FDC will continue to take active part in the promotion of participatory planning through scientific means.

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