# Cityzoom's Visual Dominance Analysis: Visibility in Urban Environment

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**Abstract**: The preservation of historical areas is frequently impregnated with passionate arguments and very few objective data. In this paper, it is argued that objective data could emulate less passionate discussions and lead to more consistent conclusions. Strategies aimed at preserving the visual relevance of historical buildings (Lehnerer, 2009) may, in some cases, prevent new designs to be built in old and traditional areas. Visualization Models can help to structure public opinions based upon quantitative and qualitative assessments of the urban scene. CityZoom's Visual Dominance Model quantifies the visual impact of buildings from multiple points of view and indicates the positions from where targeted buildings or urban scenes would be more or less visible. The Model is applied in a case study in the city of Porto Alegre to demonstrate how analytical assessments of visual impact could be used to mediate discussions on new objects in preservation areas. The analysis has indicated that CityZoom's visual dominance parameters can be quantitatively used to describe the visual impact of new buildings and therefore help urban planners and users to be less subjective and more assertive when discussing urban preservation strategies.

## 1. Introduction

Contemporary Urban Planning Systems present, more often than not, deploy strategies aimed at preserving the visual protagonism of landscapes or historical buildings through viewing corridors, visual basins or viewsheds (Lehnerer, 2009). In many circumstances, the application of such strategies do not take into account that new buildings may not substantially affect or even contribute to the visual prominence of a historical building. Sometimes, regulation strategies may end up generating excessively rigid building constraints and thus inhibiting the social and economic development of city sectors.

The visual impact of new objects on historical buildings is related to the study of visual perception of urban objects in different settings. The creation of objective criteria for the cityscape analysis has been supported by different theories (Gestalt, etc). Lynch (1960) defined that places are understood and interpreted from specific physical elements of the existing space, represented in mental images which are constructed from the visual memory of reference points. Cullen (1961) proposed the concept of serial vision to illustrate the complex and fragmented way in


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which urban scenarios unfold before an observer's eyes. Benedikt (1979) diffused the concept of isovist, a basic modeling of the available field of view from a specific point of view, which enabled the conversion of visual perception into quantifiable metrics (Morello, 2017). Turner *et al.* (2001) introduced the concept of Visual Graph Analysis (VGA), shifting the focus from geometric measures towards connectivity and graphs measures: while isovists describe how visual conditions vary across space, VGA describes the relationship of a point with the whole structure of intervisible points (Izaki, Derix, 2017).

City Information Modeling software commonly offer visibility and/or occlusion analysis models: CityEngine enables the simulation of the field of view of a passer-by (CityEngine, 2019), ArcGIS supports the assessment of objects viewed from different stand points (ArcGIS, 2019) and CityZoom software quantifies the visual impact of buildings from multiple points of view (NTU-UFRGS, 2019). These computational tools can be applied to describe the visual impact of urban scenes based on quantitative assessments of the visual impact of new buildings upon the existing urban environment.

CityZoom, developed by the Urban Technology Group (UTG -UFRGS), supports the impact analysis of cityscapes regarding urban strategies, policies and regulations. CityZoom enables the 3D modeling of urban fabrics, the 3D simulation of urban rules, the environmental analysis (shading and lightning) and 3D visual perception analysis (Turkienicz *et al.*, 2008). Cityzoom's Visual Dominance Analysis Model computes the relative dominance, in an observer's field of vision, of different objects during a route travelled by this observer.

In this paper, two visual impact methods supported by Cityzoom's Visual Dominance Model are used to investigate the interference of new buildings in historical preservation areas. These methods were applied in a case study for a set of blocks of the city of Porto Alegre, Brazil, in which new buildings proposals were simulated near a historical building. The visual dominance of simulated buildings and the historical building were computed with CityZoom's Visual Dominance Model and a comparative analysis performed.

The description of the analysis is divided into three sections. In the first section, Cityzoom's Visual Dominance Model is described and the methodology of the analysis is presented. In the second section, the results of the case study are presented. The last section presents the discussion and conclusions.

## 2. Methodology

CityZoom's Visual Dominance Model is based on the representation of visible and occluded spaces defined by Benedikt (1979), in which, given a region D of the space where inside is located a point of view x and material surfaces Sm, an isovist (Vx) is defined as the set of all points within D which are visible from x, i. e., $Vx = \{ v \in D: v \text{ is visible from } x \}$. For a point located on a surface Sm to be visible, it is necessary that no other surface obstructs the direct connection between the analyzed point and the point of view x. This definition can also be extended to a set of Vx in order to represent the visibility of an observer traveling a certain path. In this case, the visible surface areas of the various isovists are superimposed and the space covered by them is considered visible.

The definition proposed by Benedikt (1979) considered, exclusively, the two-dimensional space. Therefore, in order to create a three-dimensional representation, it would be necessary to describe the reach of the observer's field of view in the vertical plane. Considering a horizontal viewing angle equal to 360º and a vertical viewing angle equal to 180º, a half sphere representing the visible space from a point of view is obtained, with its dimensions given by the maximum range of the observer's vision (Dalton; Dalton, 2015; Thiel, 1997). In order to simulate the human vision, Cityzoom's Visual Dominance Model utilizes a specific viewing direction, such as proposed by Derix *et al.* (2008): the viewing angles are constrained around the viewing direction according to the limitations of the human vision. This delimitation of the viewing angles results in a conical field of vision, which is used to define as visible the surfaces exposed directly to it. A Gaussian distribution centered in the viewing direction can be used to gradually distinguish what is in the central view, rich in details and of greater importance to the model, and what is in the peripheral vision, with few details and less importance.

In order to enable the computation of performance measurements for each part of buildings' façades, Cityzoom disaggregates the surfaces of 3D models into sets of triangles. Each of these triangles is an object capable of storing information about its geometry (perimeter and area), its performance (shading, illuminance, visual dominance) and the objects to which it belongs (building, lot surface, street surface). This computational model enables the description of a building's visual dominance using two different sub-models.

In the View Plane sub-model (upper half of Figure 1), the field of view of an observer in a specific position is represented in a View Plane which is disaggregated in pixels. CityZoom identifies the triangles "address" appearing in the View Plane, enabling the Visual Dominance of a building to be calculated as the quotient between the area (in pixels) occupied by the analyzed building in the View Plane and the total area of the View Plane.

In the Point Cloud sub-model, each one of the façades' triangles receives the information of its visibility from a specific point of view. By calculating, for the façade of a building, the area corresponding to all its visible triangles, it is possible to obtain the total visible facade area of the analyzed building from a specific point of view. The simulation of multiple points of view using a point cloud and the computation of the visible facade area of a selected target building – i.e. building whose visible facade area will be computed the analysis – for each element of the point cloud enables the visualization of how much facade area of the targeted building is visible from different points of an urban area. The Point Cloud sub-model is illustrated in the bottom half of Figure 1.

Such descriptions of buildings' Visual Dominance can be used to quantify the visual impact of new buildings upon existing scenarios. Test scenarios were defined where new buildings occupy the background of a historical interest building and differential visual impacts of these new buildings were measured, according to the following procedure:

- 1. Modeling of the scenarios: the 3D model of the analyzed area is generated in CityZoom from shapefiles containing the information of topography, roads, islands, lots and buildings.
- 2. Definition of the observer's point of view: for the View Plane sub-model, points of view are defined in the 3D model in order to simulate possible paths traveled by an observer around the area of visual interest. For the Point Cloud sub-model, an area was defined to receive a set of equidistant points representing an observer's possible point of view.
- 3. Simulation of new buildings: new buildings are simulated near the building of historical interest using the CityZoom's Urban Rules Simulation tool.
- 4. Visual Dominance Analysis: the Visual Dominance can be quantified following the simulation of the observer's view for each of the simulated points of view ( View Plane sub-model) or by assessing the visible facade area of targeted buildings from different points of view using the Point Cloud sub-model. The results are represented for each

simulated scenario, colored according to the amount of the targeted building's facade area it visualizes.

– The Cityzoom's Visual Dominance Model was applied in a case study for a set of blocks located in the *Quarto Distrito area* in Porto Alegre. The analyzed area contains a Methodist Church listed as a municipality's building of cultural and historic interest. The City Urban Rules allow, in the neighboring lots, the construction of new buildings with greater height and gross floor area than today's existing ones. The visual interference of these new buildings with respect to the church can be assessed computing the visual dominance of these targeted buildings. The case study modeled the analyzed area in CityZoom and simulated new buildings in the background of the historical church.

## 3. Analysis/Results

The Viewing Plan method compared different scenarios of Visual Dominance whereby the historical church and the new buildings are associated. Figure 2 presents the location of the simulated points of view for the View Plan method and a comparison between the existing views of the historical church and the simulated viewpoints from the same position. Figure 2 also

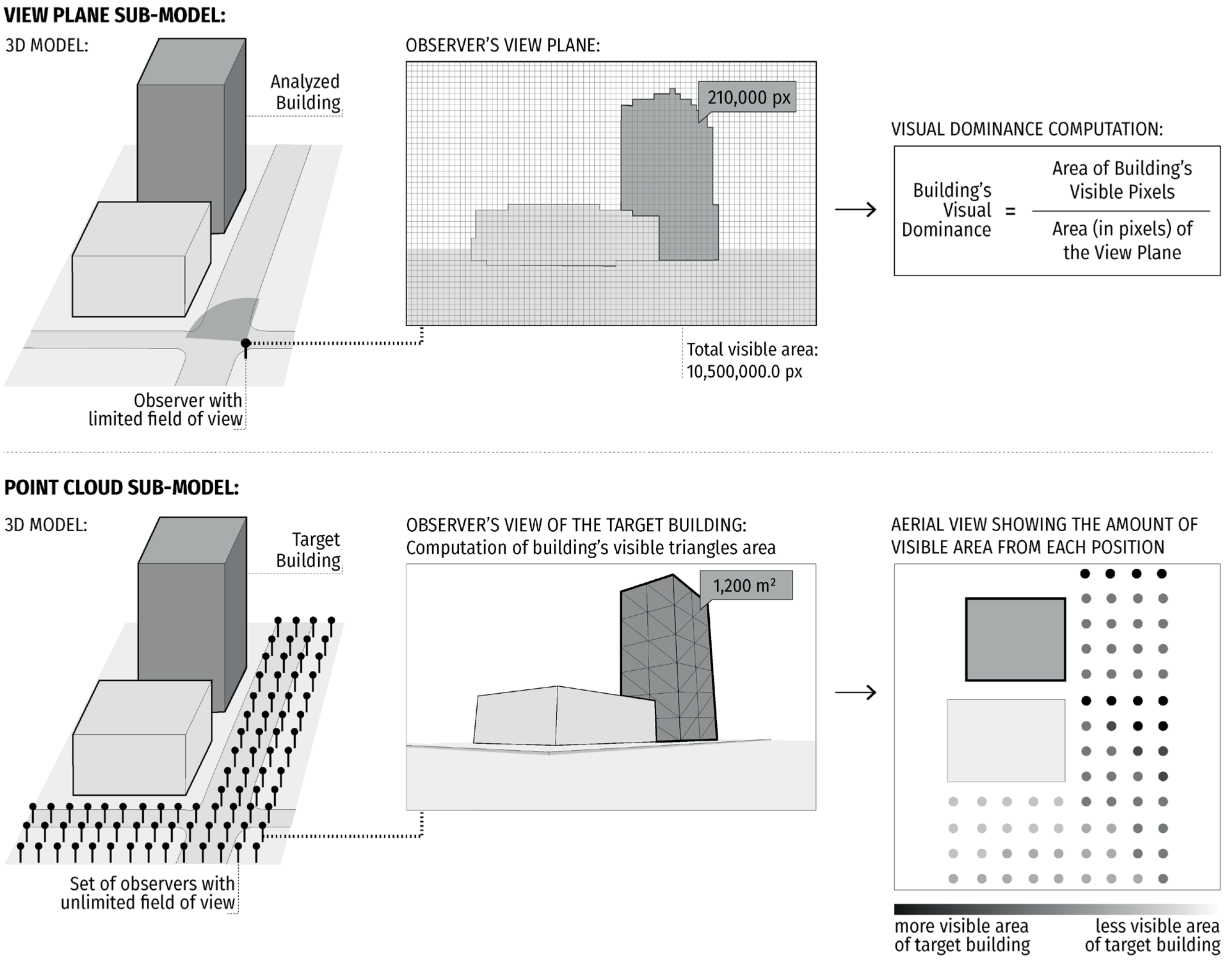


Figure 1. *CityZoom's illuminance analysis sub-models: View Plane and Point Cloud.*

presents the modeled buildings for each simulated scenario and the observer's Viewing Plan for these simulated scenarios: the historical church is represented in black color, while the church's existing neighboring and the simulated buildings are represented in gray.

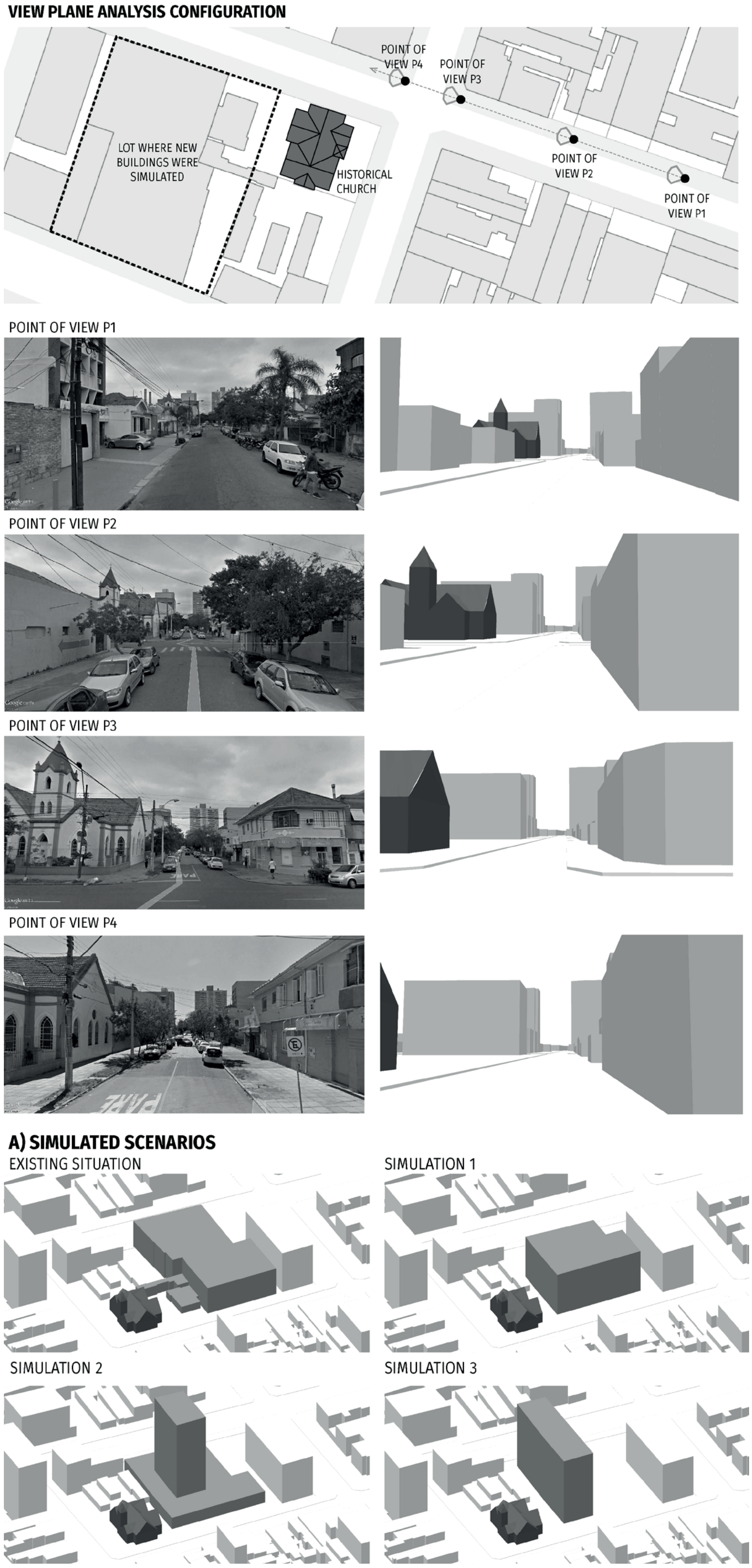


Figure 2. *Analysed points of view and simulated neighboring buildings (images of the existing situation taken from Google Earth).*

In the upper half of Figure 3, images are organized in a table, in which each column represents a modeled scenario (the existing situation and three simulations) and each line contains the View Plane from one point of view: the upper lines present points of view which are farther from the church (P1 and P2), while the lower lines present closer points of view (P3 and P4). The bottom half of Figure 3 describes how the Visual Dominance changes as the observer travels from Point of View 1 (P1) to Point of View 4 (P4). Bars indicate the point of view strength with respect to a particular building in that it occupies more or less area of the observer's field of vision from that specific point of view. The graph indicates that a) the visual dominance of the historical church increases as the observer travels from position P1 to position P4 and b) the proportion of dominance values do vary from different positions.

Figure 4 presents the results of the Point Cloud application, with Aerial Views of the analyzed 3D Model and an isometric perspective zooming in the area around the targeted buildings. Each horizontal row of images of Figure 4 correspond to a modeled scenario, while each column presents the resultant analysis using a specific building as target: on the left column, the histori-

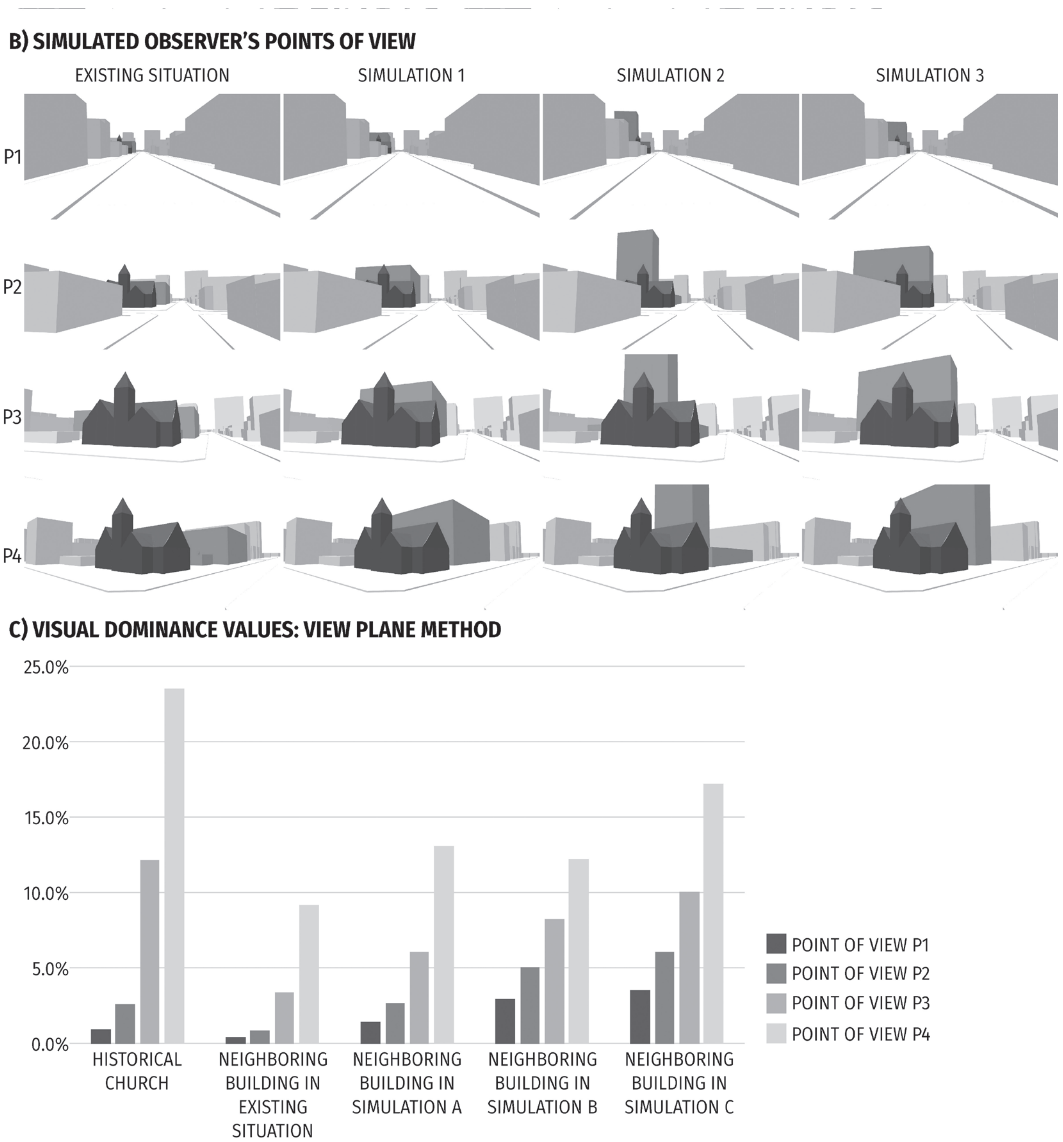


Figure 3. *Observer's Points of View and Visual Dominance values for each point of view according to the View Plane sub-model.*

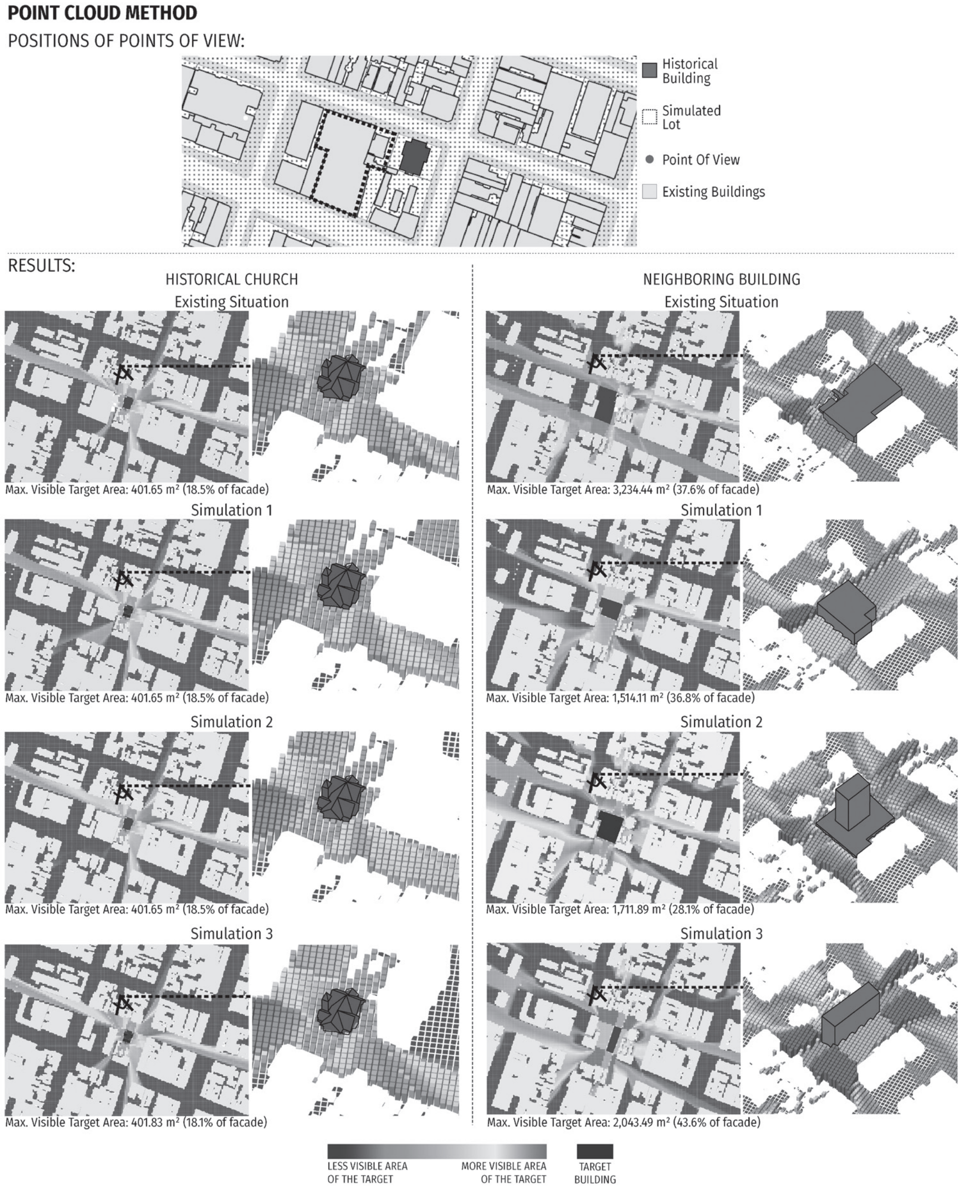


Figure 4. *Results of the Point Cloud Analysis: aerial view and isometric perspective representing the visibility of target buildings (colored in black) from each position of the surrounding area.*

cal church and, on the right column, the neighboring buildings. In the Aerial Views, each point is colored according to the visualized area of the targeted buildings: the darker the colors the higher percentage of the targeted building's facades is visualized. In the isometric perspective, the same color scale is complemented : the taller bars represent viewpoints from where the higher percentage of the facade area is visible.

If the observation value of the church does not significantly change, the simulated buildings's observation value is significantly different to each scenario: the taller buildings of simulation 2 and 3 become visible from farther away and can be seen along a great length of the street axes which are adjacent to the historical church. In other words, at long distances the church do not have as great protagonism as the new buildings: simulation 3 features the highest percentage of " protagonism" with respect to the two other simulations. At short distances this protagonism is substantially shared with the new buildings.

The point-cloud analysis demonstrates that the prevalence of the new buildings along the examined route (P1 to P4) also extends to the adjacent neighbourhood. Figure 4 shows that a new "new landmark" was established in the studied context, somehow "competing" with the church. The level of visual competition varies according to the simulated building's shape.

## 4. Discussion/Conclusion

This paper aimed to demonstrate that the Cityzoom software could be used to quantitatively describe the visual impact of buildings in historical preservation areas, enabling the comparison between a) the visual dominance of existing buildings and proposed ones; b) the visual dominance of specific buildings from different regions of a given urban area. The achieved results demonstrated that CityZoom software can numerically capture differential visual dominances present in urban scenes. CityZoom can effectively support discussions on built form thresholds and urban form regulations if the tool and its functionalities are heuristically used to enlarge the planner's or the user's perception of the built environment. In fact, both the planner or the user usually retrieve localized perceptions of the urban space: CityZoom analytical tool allows these agents to acquire a precise awareness of the simultaneous impacts imposed by new buildings on historical areas. The first methodology offers a dynamic description of the space depicted from different *snapshots* of a specific route whereas the second methodology supports the assessment of the relative visual value of specific urban regions with respect to landmarks and/or significant landscapes.

## References

ArcGIS (2019), Esri ArcGIS: Overview (Esri, S.I.). Available at: https://www.esri.com/en-us/arcgis/about-arcgis/overview. Accessed in: 21 june 2019.

Benedikt M. (1979), *To Take Hold of Space: Isovists and Isovist Fields*, in *Environment and Planning B Planning and Design*, vol. 6, jan. 1979, pp. 47-65.

CityEngine (2019), CityEngine: Advanced 3D city design software (Esri, S.I.). Available at: https://www.esri.com/en-us/arcgis/products/esri-cityengine/overview. Accessed in: 21 june 2019.

Cullen G. (1961), *The Concise Townscape*, Van Nostrand Reinhold Company, London.

Dalton R., Dalton N. (2015), *The Problem of Representation of 3D Isovists*, in *Proceedings of the 10th International Space Syntax Symposium*, University College of London, London, 141, pp. 1-18.

Derix C., Gamlesaeter A., Carranza P.M. (2008), *3D Isovists and spatial sensations: Two methods and a case study*, in Haq S., Hölscher C., Torgrude S. (eds.), *Movement and orientation in built environments: Evaluating design rationale and user cognition: Proceedings of EDRAMOVE & SFB TR8 Conference on Spatial Cognition, 28 May 2008*, pp. 67-72.

Izaki A., Derix C. (2017), *Evolution of Planning with Visual Conditions*, in Piga B.E.A., Salermo S. (eds.), *Urban Design and Representation: A Multidisciplinary and Multisensory Approach*, Springer, Cham, Switzerland, pp. 83-99.

Lehnerer A. (2009), *Grand Urban Rules*, 010 Publishers, Rotterdam.

Lynch K. (1960), *The Image of the City*, MIT Press, Cambridge.

Morello E. (2017), *Visibility Analysis for Open Spaces in Urban Areas: Coupling Environmental Quality and Human Comfort Assessment*, in Piga B.E.A., Salermo S. (eds.), *Urban Design and Representation: A Multidisciplinary and Multisensory Approach* Springer, Cham, Switzerland, pp. 57-68.

NTU – Urban Technology Group (2019), *CityZoom*, NTU, Porto Alegre, Brazil. Available at: https://ntu-ufrgs.com/cityzoom. Accessed in: 21 june 2019.

Thiel P. (1997), *People, paths, and purposes: Notations for a participatory envirotecture*, University of Washington Press, Seattle.

Turner A., Doxa M., O'Sullivan D., Penn A. (2001), *From isovists to visibility graphs: a methodology for the analysis of architectural space*, in *Environment and Planning B: Planning and Design*, vol. 28(1), pp. 103-121.

Turkienicz B., Gonçalvez B.G., Grazziotin P. (2008), *CityZoom: a Visualization Tool for the Assessment of Planning Regulations*, in *International Journal of Architectural Computing*, pp. 79-95, jan. 2008.