Urban growth and landscape: spatial discontinuity and urban resilience.

Otavio M. Peres; Marcus V. Saraiva; Maurício C. Polidori

Laboratório de Urbanismo – FAUrb - Universidade Federal de Pelotas (UFPel)

Rua Benjamin Constant, 1359 – Sala 109 – CEP 96010-020 – Pelotas-RS

otmperes@gmail.com, marcus.saraiva@gmail.com, mauricio.polidori@terra.com.br

About the authors

Marcus V. P. Saraiva holds a degree in Architecture and Urbanism (Federal University of Pelotas, Brazil) and is a Master's degree student at PROGRAU - Federal University of Pelotas, Brazil. He is currently a researcher at Urbanism Laboratory, acting mainly at Configurational Urban Systems with emphasis on geocomputation and GIS, planning, urban modeling and urban ecology.

Otávio Martins Peres holds a degree in Architecture and Urbanism (Federal University of Rio Grande do Sul, Brazil) and a Specialization degree in Regional Management of Water Resources (Federal University of Pelotas, Brazil). He has experience as Professor of the discipline Architectural Design and Urban Planning of FAUrb/UFPel for two semesters. He is currently a Master's degree student at PROGRAU - Federal University of Pelotas, Brazil and a researcher at Urbanism Laboratory, acting mainly at Configurational Urban Systems with emphasis on geocomputation and GIS applied to architectural and urban design, planning, modeling and urban ecology.

Maurício C. Polidori holds a degree in Architecture and Urbanism at UFPel (Federal University of Pelotas, Brazil), Specialization in Energy and Environmental Planning at UFRGS (Federal University of Rio Grande do Sul, Brazil), Master degree in Urban and Regional Planning (UFRGS, PROPUR) and PhD in Sciences (UFRGS, PPGECO) at concentration area of Landscape Ecology, with emphasis in urban studies. He is currently a Professor at Federal University of Pelotas, acting in the area of Urban and Regional Planning with emphasis in urban and environmental planning, simulations, urban design, spatial analysis and instruments, mainly at urban planning, urban morphology, urbanism, environment and GIS.

Abstract

Contemporary urban studies approaching disciplines of Urban Ecology, Ecology of Landscape and Urban Planning have indicated the city as an ecosystem with resilience properties. Morphologic self-organization movements, natural landscape articulated and inherent in urban growth dynamics, can be assumed as urban resilience mechanisms. From systems framework, this paper explores the relationships between urban growth dynamics and natural landscape, by three distinct scientific bases: theoretical, empirical and methodological. The main aim is to outline a dynamic of urban growth articulated to natural landscape. Water resources are indicated as tipping point to phase transitions in urban growth morphologies. This theoretical statement is applied in simulation urban growth model SACI (City Environment Simulator), which apply in a dynamic cellular automaton the potential-centrality model (Krafta, 1994). The urban modeling mechanism captures the "edge effect" on water resources buffers, self distributing urban growth tensions, axial and diffuse. Associated with urban modeling, the theoretical statement could be empirically tested in simulations, replicating the urban growth reality of Pelotas city (1815-1965). This work helps to overcome pessimist visions about the urban phenomenon and the future of cities, approaching city by viewpoints as a richest human artifact, with intrinsic expansion dynamics associated with resilience and permanence properties over time; one way to coexisting urban systems and natural resources.

Keywords: urban modeling; urban growth; natural landscape; urban resilience.

1. Introduction

Urban science has indicated the internal and external spatial growth as an intrinsic process in the city, an urban fabric in spaces production continually (Harvey, 1985; Soja, 1989). From this viewpoint, the spatial science has approached the city and his morphological dynamic in relative autonomy of individual decisions and social agents (Allen, 1997; Krafta, 1999; Portugali, 2000).

The land surfaces that support the cities and urban growth does not exist as an absolute plan, an isotropic formation without influence on the configurational urban systems (Nystuen, 1968). The environment around the cities are configured by innumerable attributes that influence the urbanization process in many forms are these attributes: social, economic, infrastructure or natural landscape (Benguigui et al, 2001; Czamanski et al., 2008). Given the characteristics of land surface, urban growth is faced with the natural landscape and configures interfaces where overlay urban and natural factors. These interfaces occur in many intensities of transition between the urban and non urban environment, mainly by the properties and characteristics of natural attributes (Liu *et al*, 2007).

Water resources are important attributes in shaping the natural landscape, defining resistance spaces of urbanization in much intensity (Alberti et al, 2003; Viganò, 2008). Thus, the urban spatial discontinuity and internal open spaces in the city can match the attributes of water resources, both because they were preserved intentionally or because they offer direct resistance to urbanization. The paradigm of sustainability in urban science shows the need for approaches that involve all systems that configure the urban phenomena, dedicated in interactions that occur in space-time viewpoint (Krafta, 2008).

This paper presumes that if approached urban growth and natural environment in a macro spatial and long-term way, may matched commons behaviors to reduce conflicts. The urban water systems are attributes that if preserved in the process of urban growth, enable the maintenance of properties natural and urban systems.

2. Theoretical approach

Advances in contemporary studies that approach Urban Ecology, Landscape Ecology and Urbanism have sought to overcome the pessimistic view about the future of cities, linking the urban growth phenomena to urban resilience mechanisms (Vale and Campanella, 2005). In terms of resilience, the city is like any natural ecosystem in complexity, which gives it properties to resist impacts and self-organize into new structures morphologically possible of withstanding the adverse situation (Alberti et al., 2003). In this sense, the morphological relationship between water resources and urban growth dynamics can be a way to understand the movements of compression and sprawl in contemporary cities (Czamanski et al., 2008).

Both the social and natural sciences have been adopted complexity sciences to study emergent phenomenon. Studies dedicated to relationship of urban growth and natural environment has been using models and simulations to incorporate the complex urban-ecologic interactions (Alberti et al., 2003). Systemic approaches shows that entity with many attributes, the object can be reduced in a complex system, set of subsystems and relations really important for the problem in question (Forrester, 1968). Thus, system approach converges with model approach, which deals with representation of a reality through relevant characteristics and consists the set of objects and systems that exist or can exist in the urban phenomena (Echenique, 1975).

In this sense, the environmental modeling is a theoretical procedure that involves a set of techniques to understand the complexity of the natural environment. Is a configurational process of the terrestrial surface based in many elements with spatial variability and relations on the ground (Christofoletti, 1999).

Urban modeling is defined by construction and application of digital models for an objective proposed, traditionally the cities and regional physical planning. The use of models to explore urban issues and suggest future alternatives of cities have found progress contemporary, with advances supported in non-linearity of computational processing. Actually, urban models and simulation of urban dynamics are recurring on urban science, tools that enable urban planners and scientists to explore realities not yet realized, how about the future (Batty, 2007; Krafta, 2008). Contemporary, in urban modeling is possible integrate urban, natural and institutional factors, test hypotheses about spatial configuration and urban-environmental complex interaction (Alberti *et al.*, 2003; Polidori, 2004).

In a recent editorial in the journal Environment and Planning: B, v.36, Batty (2009) presents the idea of "catastrophic cascades", the author proposes a challenge to urban theory dedicated in dynamics of urban change to discover discrete elements that catalyze the phase transitions in urban systems. The phase transition is a pattern of dynamics that occurs in some complex systems, when the system behavior is modificated abruptly. Occurs in a given moment that the system reach a threshold or converge to a situation of tipping points. A classic example of phase transition is water change states, which occur under certain conditions of temperature and pressure, modifying substantially its initial structure (Batty, 2007). According Batty (2009) proposes, the tipping points of urban dynamics in this catastrophic cascade effect are not resultant by one or few attributes, occurs when many attributes overlay in some point that influences the global phase transition and the spatial dynamics of urban system. These multiple factors associated with economic, social and environmental issues that shape the urban phenomenon as a complex system and allow the emergence of spatial discontinuity in urban form. This challenge implies that urban science would overcome the definition of what factors make up the urban system as a complex system. Focus on studying what are the tipping points and where the system converges to phase transition.

Absorbing the ideas of catastrophic cascades (Batty, 2009), this work address urban morphology and its relationship with the natural landscape, dedicated to capture the influence of water resources in spatial configurational dynamics, water resources act as a tipping point where the urban phenomenon converges to phase transition of the dynamic urban and spatial discontinuity.

However, for effective approaches integrated urban and landscape, there are to overcome the urban approach from isotropic plans (Nystuen, 1968). The concept of isotropy of the landscape is an abstraction of environment that disregards the natural aspects in urban configuration. On isotropic planes the support environment does not resist to urban growth and all lands are all considered equally fertile, isotropic approaches have been demonstrated theories with evidence in socio-spatial relations. In this sense, propose to overcome landscape configurations by isotropic plans do not invalidate the theories set out from this fundamental spatial concept, but add possibilities to capture urban morphology that emerging from relationship natural environment.

The urban theory has been shown the urban fragmentation and spatial discontinuity as unsustainable factors, primarily due to underutilization of infraestrutura and increased costs of operation. In this context, the occurrence of open urban spaces has been associated with land use retention or absence of policies and control on the territory (Jenks e Burgess, 2000). Moreover, the natural landscape is predecessor attributes represent the environment of the city, a field of irregularities that require different levels of resistance to urbanization, influencing the morphology of urban growth in the short and long term, in the micro and macro scale (Polidori, 2004). These irregularities impose different restrictions on urbanization, contributing to formation of open spaces arising from urban growth could correspond to drainage lines, flood areas and environmental interests areas.

Therefore, in this paper is presumed that the fragments or urban voids are associated spatially to natural environment spaces, the emerging dynamics of urban growth in the face of irregularities of the support plan. This result suggests recognize open spaces as structural components of the city, where urban morphologies and remote urbanization with maintenance of places of natural resistance. This dynamics can be understood how self-organization of city and indicators of urban resilience (Alberti et al, 2003; Polidori, 2004).

3. Locational patterns of urban growth

The topography that shapes the watersheds, setting drainage lines, lowlands and wetlands, contrasted to environment on terraces watersheds, are key factors to urban cores occur in the best conditions for urban sanitation that is presented in watershed scale. The urban phenomenon trends to occur in places that resemble to isotropic plans (Nystuen, 1968), in landscape settings that allow urban dynamics occur without natural restrictions.

Urban centers that occur in landscape resembles to isotropic plans, the urban growth without natural environment restriction tends to be predominantly concentric, the conversion of non-urban areas occur by the economic logic, on the territories immediately adjacent to existing city. The city growth expands on landscape attributes with greater restrictions of land development, as the streams of water resources. However, as the urban fabric needs to continue production space, overcome the landscape restrictions and urban conversion occurs in areas beyond the limits of water resources.

However, generally the opposite margin of watercourse has the same restrictions on urbanization that was overcome when the city faced with the drainage lines. Exactly at this point this work identifies a new locational pattern of urban conversion. Urban growth beyond the streams does not occurs in adjacent areas to water resources, transposing the water resource, the city builds bridges and others structures that define axis morphologically to overcome the water body. The urban growth emerges with same locational patterns that occurred the core origin, in isotropic formations where the growth vector is extended to reach areas with lower environmental restriction. At this point, diffuse urban centers growth close to terrace watersheds.

The emerging urban core, it also replicates the concentric growth, promoting the conversion of adjacent territories to reach again the limits of streams, suggesting an iterative process. On the macro scale of the city, alternations in the morphology of urban growth defines a dynamic of urban growth articulated with landscape scale, alternating concentric form initial and diffuse other, successively.

4. A mechanism for urban modeling.

To model urban growth this work applies resources of urban centrality model. Originated from the ideas of unequal growth (Harvey 1985), the centrality model is the unequal distribution of material on urban space, which leads the system to a state of spatial non balance. From the original centrality model (Krafta, 1994) a continuity effort has been undertaken to improve understanding of the mechanisms of production and reproduction of the city, particularly in studies conducted by Configurational Urban Systems group on post degree in Urban and Regional Planning, PROPUR-UFRGS.

Centrality is a spatial model that describing the morphological urban system at a given time, but also shows the system spatial non-balance. Centrality differences are places of convergence and attractiveness to urban change, which can be translated as a measure of growth potential (Krafta, 1999). This spatial non balance and the potential to change converge with social science theories that city is a phenomenon in constant production of space (Harvey, 1985). From this viewpoint, the continuous urban growth is an intrinsic aspect of the urban phenomenon, which gives it morphological autonomy and overly pessimistic visions about urban sprawl (Krafta, 1999; Portugali, 2000; Buzai, 2003).

The centrality should not be taken just as description of a given spatial morphology, but as an indicator of non balance space system, able to configurational forces and a set vectors of future urban growth. Potential occur where are bigger land use profit, places where are bigger the centrality differences of immediate surroundings (Polidori, 2004).

The model that operates from the graph theory (Krafta, 1994) is adapted to a cellular environment, associated to urban modeling cellular automata - CA (Polidori, 2004). The combined use of graphs and cellular automata allow the model exploits both global and local relations of the urban system. While CA works with spatial relations and neighborhood relations, graphs work with the connections between spatial units.

The centrality model adapted to cellular environment (Polidori, 2004) provides advances over the original model (Krafta, 1994). In cellular centrality, load distribution does not occurs only through the graph shortest path. The urban growth model SACI - *Simulador do Ambiente da Cidade* (Polidori, 2004) reproduce urban morphologies through the load distribution: axial, polar and diffuse.

In an iterative process, the distribution of cellular centrality sets up a landscape of spatial opportunity, overlaid to a natural environment of unequal resistances. This process produces a dynamic urban growth, emerging from a non-deterministic and semi-stochastic logic (Polidori, 2004). As the city grows, it tends to encounter spaces with the highest natural resistances concentrating potential growth on natural-urban interface. These linear interfaces configure spaces of tension and environmental conflicts between urban and nature, the formation of an urban edge effect. The urban edge effect is an indicator of urban resilience, an indicator of urban-natural conflicts and an indicator of changes in morphological urban growth (Polidori, 2004; Czamanski et al, 2008).

Morphologically the urban edge effect configures expansion in line fronts. If the landscape is approached from water resources and streams, the edge effect is more evident by overlapping linear forms of the urban growth and system of water. In short, the edge effect on water resources is an indicator of tipping points of urban attractiveness and natural environment resistances. If urban dynamic occurs with similarities to phase transition, water resources are indicated as tipping points of catastrophic effects of urban spatial discontinuity.

In urban modeling terms, this paper presents a simulation procedure with SACI and special attention to water resources. This mechanism allowing not only simulates the dynamics of urban growth, but also movements of urban form, compact and fragmented. On SACI model, this dynamic is captured from potential urban growth, the edge effect on the areas adjacent to water resources. The "rh factor", iteratively, are the Potential (original output of model) on buffer water resources (potential on the buffer, or simply *PotBuff*) as in equation 1 below.

Equation 1. "Rh factor", potential on buffer and transference to diffuse urban growth.

$$rh^p = PotBuff / PotTot$$

Which reads:

"rh factor" is equal to the ratio between the growth potential incident in the buffer of water resources and total potential.

5. Validating the urban modeling mechanism for case Pelotas [1815-1965].

This paper proceeds in application and validation of mechanism of growth simulation developed. The studies are applied to the urban growth occurred in Pelotas case, between years 1815-1965. The spatial limits and the geographic disaggregation level is defined by a regular grid (red lines, on figure 1) with 40 rows and 60 columns, that define 2400 cells with 250m x 250m. The surface is 96 km2, a rectangle with 8 km north-south by 12 km from east to west, resulting in geographic coordinates in UTM system for the southern zone 22: a) northern limit: 6.481.900m; b) southern boundary at 6.48.990m; c) western limit: 366.750m; d) eastern limit: 378.750m.

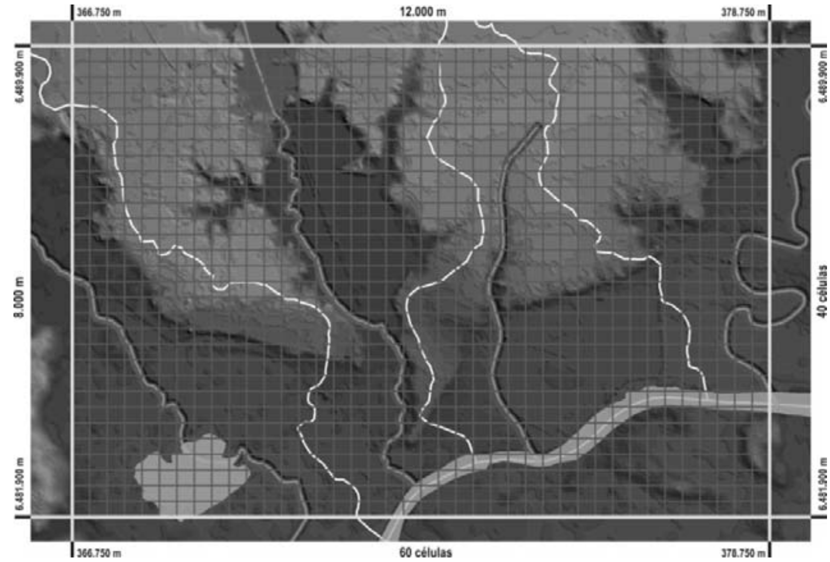

Figure 1: boundaries and geographical disaggregation for simulations in Pelotas, on graphic representation of natural landscape, topography and water resources.

Individual inputs to model were constructed, which are illustrated in figure 2 and described in following sequence:

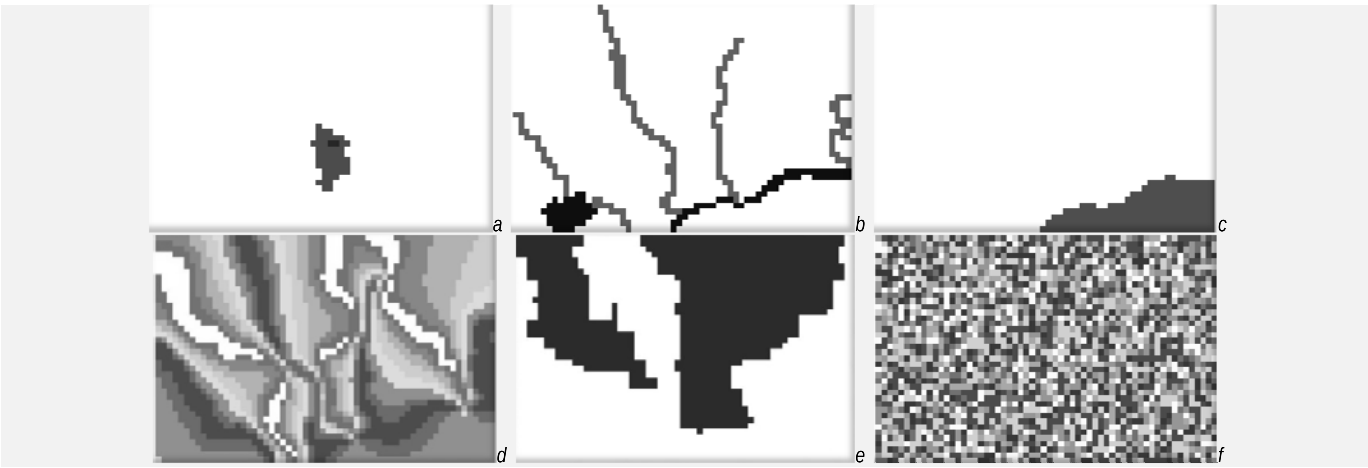

Figure 2: inputs in rectangular grids, 60x40 cells: a) urban core; b) water resources; c) outside the municipality; d) sub-basins; e) wetlands; f) random grid.

a) <u>urban core</u> (attractor, mutable; figure 2a): urban attribute loaded in two levels, weight 1.0 and 0.5;

b) <u>water resources</u> (resist, removable, weight 1; image 2b): natural attributes, resists to urban conversion, but can be removed during process;

c) <u>outside the municipality</u> (resist, freezing, figure 2c): institutional attribute that prevents the urbanization of the area not in Pelotas municipality;

d) <u>sub-basins</u> (resist, removable, figure 2d): environmental attribute, natural resistance in five classes by interpolating between streams (greater resistance level 4) and terraces watersheds (lower resistance, level 0);

e) <u>wetlands</u> (resist, removable, figure 3e): environmental attribute, natural resistance in binary differential spaces that tend to flooding (values 0 and 1);

f) <u>random environment</u> (resist, removable, figure 2f): environment resistance randomly with values between 1 and 3.

Based on empirical morphology of urban development stages Were chosen representative form of urban growth in Pelotas history. For each stage, simulations at model SACI results in a set of control outputs. In image 3, below, are presented the controls outputs of phenotype urban (Celltype), absolute centrality (CentABS), central type 1 (CentR1) and centrality type 2 (CentR2). This will be subsequently incorporated to make the numerical simulations correlation.

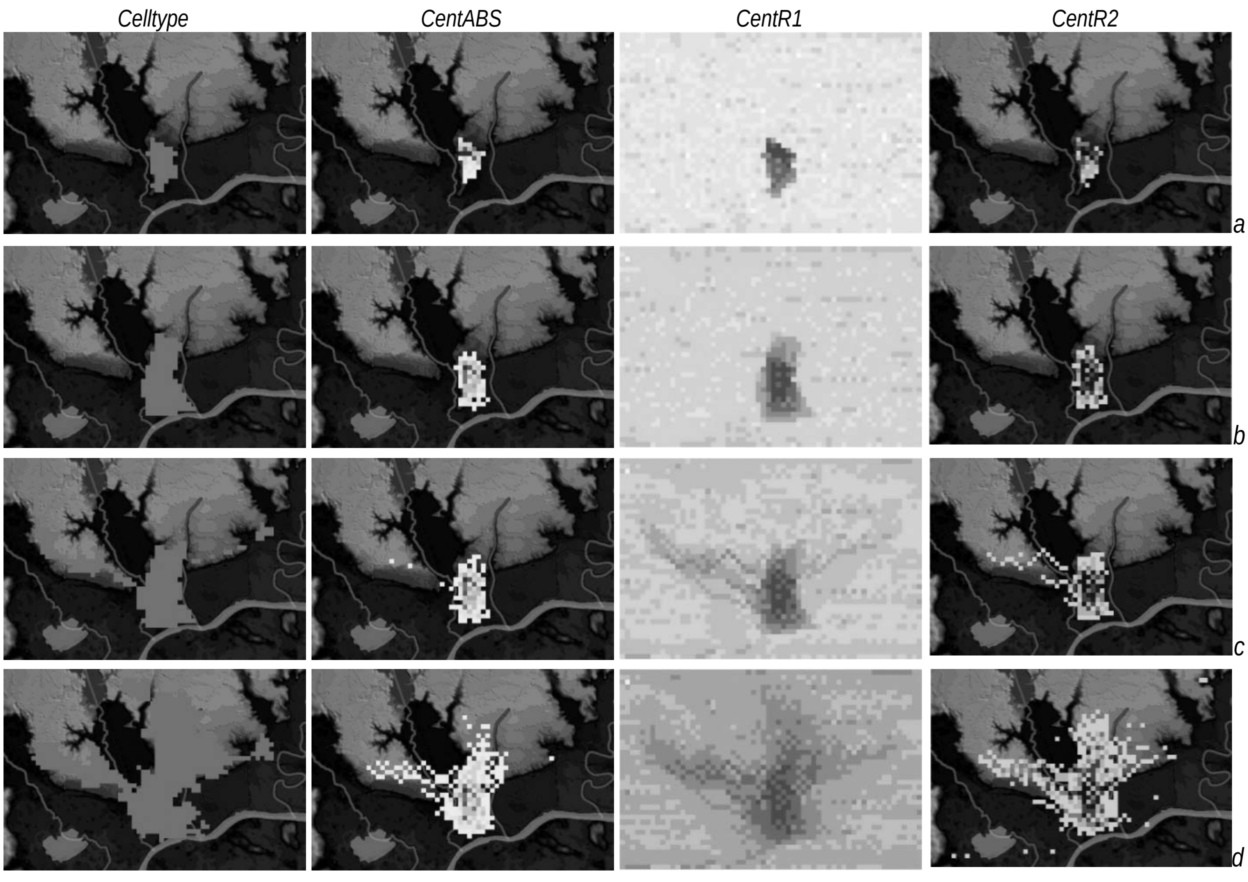

Figure 3: outputs of Celltype, CentABS, and CentR1 CentR2; grids control for years: a) 1835 b) 1916 c) 1926 d) 1965.

In figure 4 below is presented model outputs (grids) phenotype urban; centrality type 1; growth potential and natural resistance (Celltype, CentR1, Potential and ResistE, respectively), represented 8 in a total of 50 iterations (iterations 1, 8, 15, 22, 29, 36, 43 and 50).

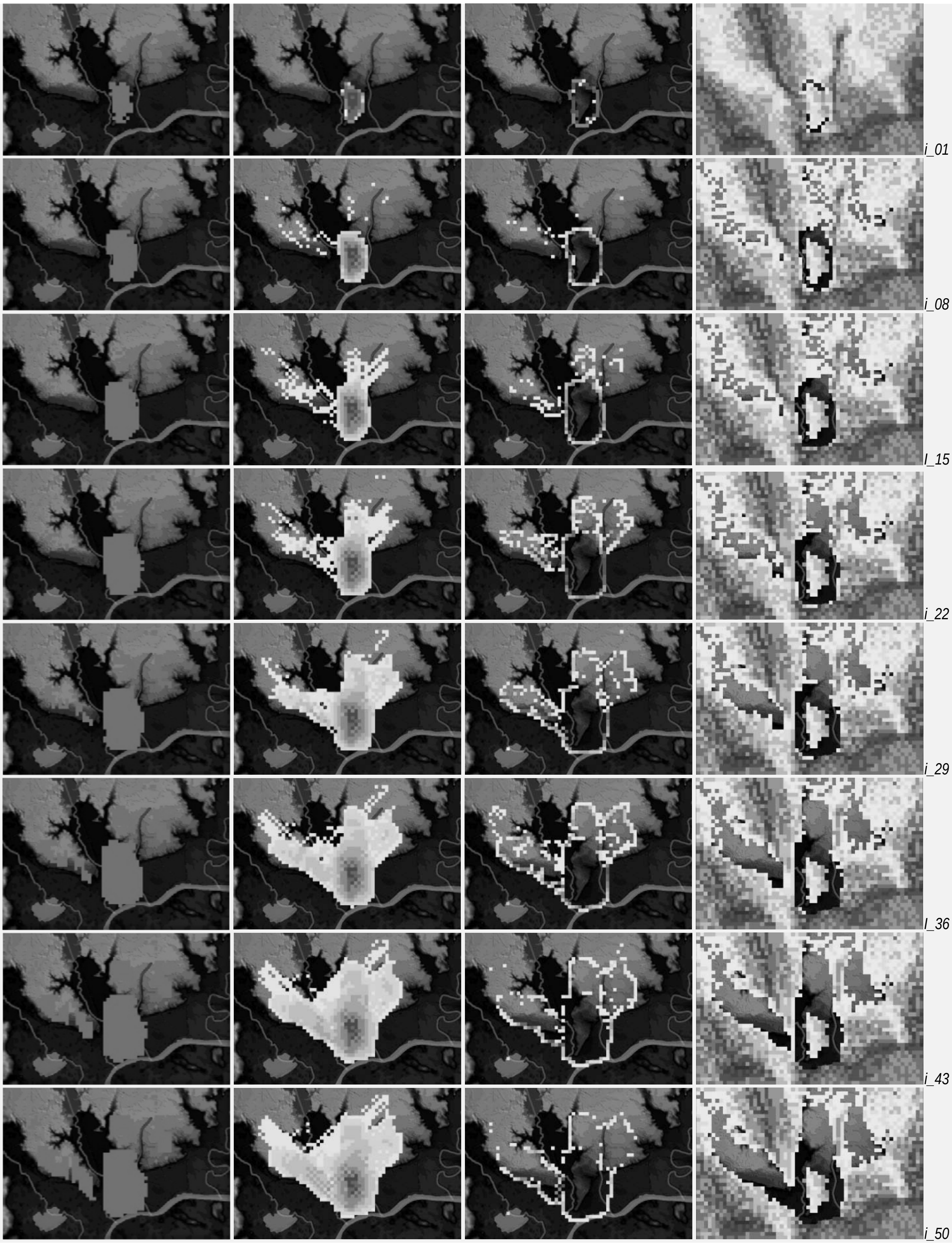

Figure 4: Simulation outputs showing eight stages of 50 iterations: a) Celltype b) CentrR1 c) Potential d) resists.

With the simulation procedure that captures morphologies of urban growth and achieve visual similarities with the real urban growth of Pelotas [1815-1965], the routing of urban modeling process is the numerical correlation results and the validation of urban modeling mechanism.

To do the numerical correlation of results of output grids, the association between control scenarios and simulated iterations occurs by cell count in each case. That is, to each control scenarios are indicated a simulated iteration with similar number of urban cells (CellType). Thus, the correlation for year 1835 is the iteration 01; for the scene in 1916, the 09th iteration; iteration 38 for 1926 and 1965 is correlated with iteration 50.

Below, the images represents the visual dynamics of correlations, the absolute centrality grids (CentABS, Figure 5), centrality type 1 (CentR1, figure 6), centrality type 2 (figure 7) and urban phenotype (CellType, figure 8).

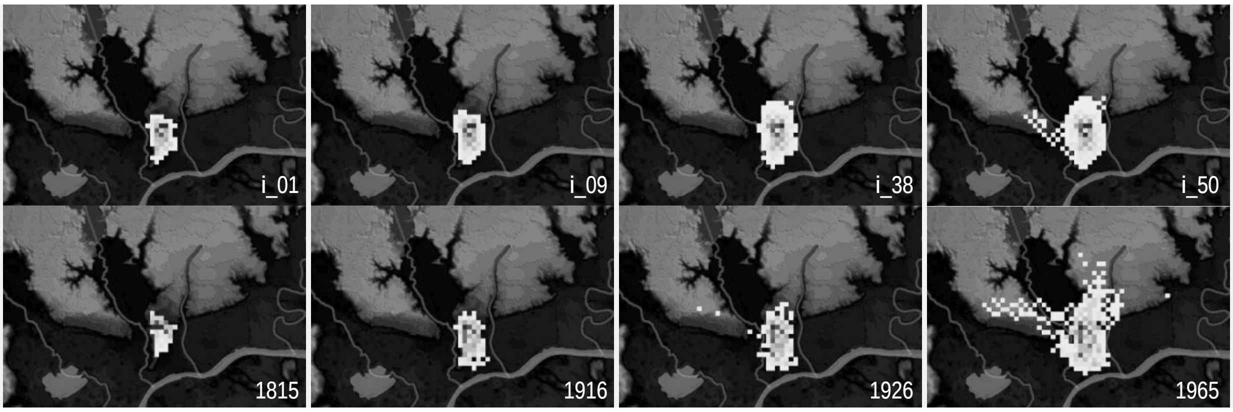

Figure 5: Dynamic correlations of absolute centrality output grid (CentABS).

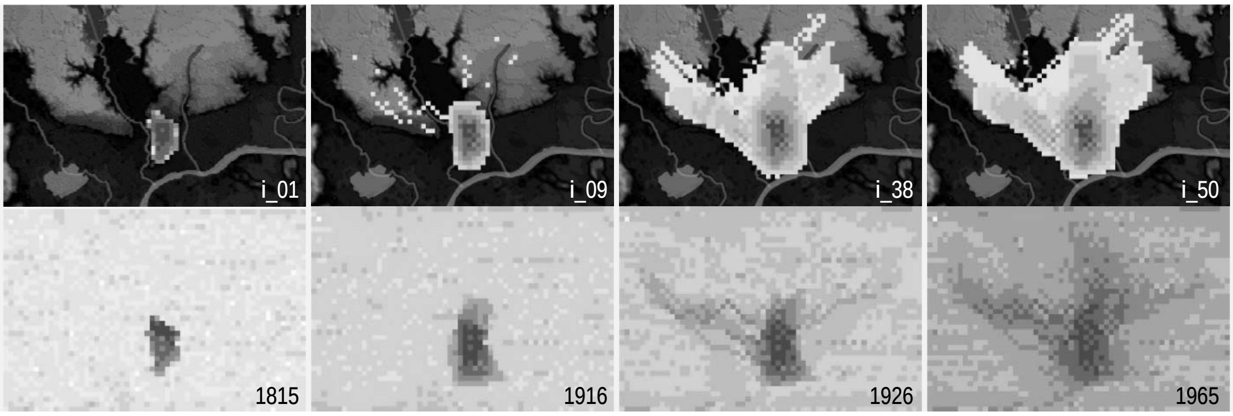

Figure 6: Dynamic correlations of centrality type 1 output grid (CentR1).

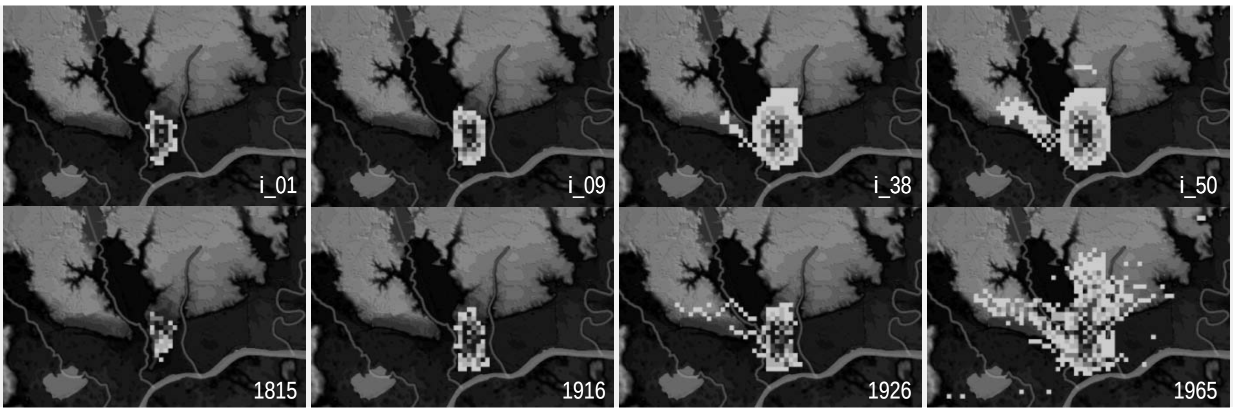

Figure 7: Dynamic correlations of centrality type 2 output grid (CentR2).

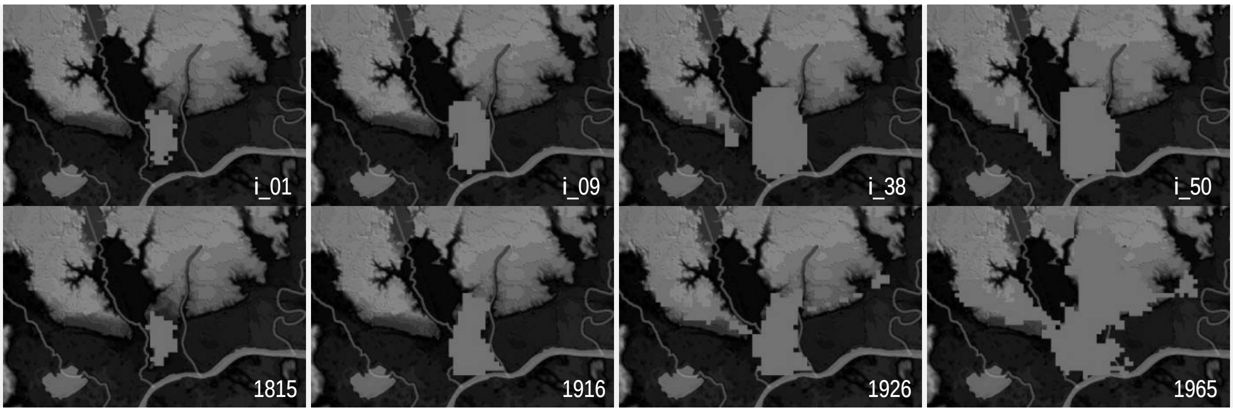

Figure 8: Dynamic correlations of urban phenotype output grid (CellType).

Besides the visual graphic correlations, grids contain numerical data that can be calculated linear correlations (R^2) and constructed scatter diagrams. In graphic of figure 9 are plotted the dispersion points of the centrality type 1 results, for four scenarios of control overlaid in blue color scale. In scatter diagrams, the proximity between points and trend line indicates best results. The correlation results average 0.79 can be considered a significant value.

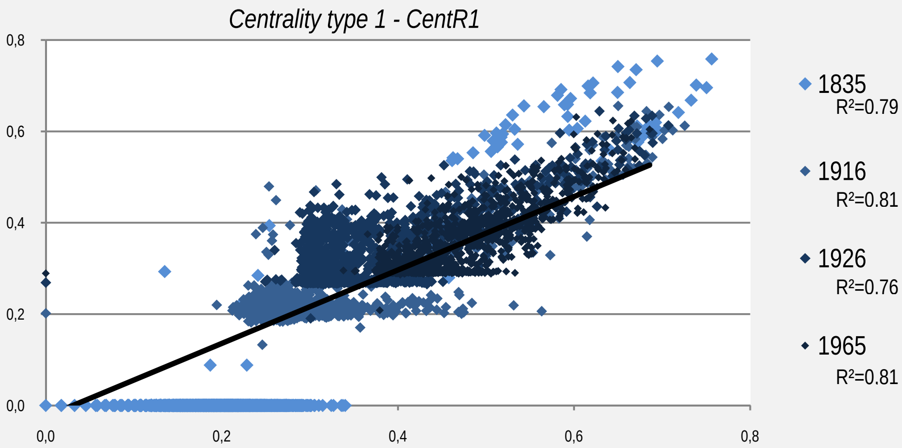

Figure 9: scatter diagrams of centrality type 1, overlaid scenarios of 1835, 1916, 1926 e 1965.

Table 1 below shows all results to four stages, allowing a dynamic understanding and compared the results for absolute centrality (CentABS), centrality type 1 (CentR1), centrality type 2 (CentR2) and urban phenotype (Celltype). Note that high correlation values occur in absolute centrality (CentABS, average 0.85) and lower results occur for urban phenotype (Celltype, average 0.66).

R²	1835 x i_01	1916 x i_09	1926 x i_38	1965 x i_50	Média
CentABS	0,81	0,90	0,87	0,82	0,85
CentR1	0,79	0,81	0,76	0,81	0,79
CentR2	0,86	0,90	0,84	0,80	0,85
Celltype	0,90	0,53	0,52	0,48	0,66
máximo	0,90	0,90	0,87	0,82	0,85

Table 1: numerical values of correlation between simulated results and control scenarios.

6. Conclusions.

This work highlights are in three distinct scientific bases: theoretical, empirical and methodological. The results achieved from these approaches converge to a common result, which reinforce the claims and conclusions made throughout the paper. Another highlight is in the relationships between the urban morphologies and landscape influences. From systems approach, the water resources influences on urban growth morphologies overcame direct relations, cause-effect based, of landscape irregularities and urban configuration. In this work the landscape attributes are not simple resistances or attributes that only constrain the urban form. In fact, what is shown is spatial discontinuity of urban form as a movement inherent in growth, but a discreet and not evident dynamic; one way to preserve the ecological water properties on dynamics of urban sprawl.

In this way, as conclusions about this paper can be indicated:

a) urban fragmentation and coincidence with natural landscape.

The fragmented urban form allows open spaces coincide spatially with sites of natural environment interest. The dynamics of urban growth and the spatial discontinuity in fact can be a way to coexists natural ecosystems and urban systems. However, to happens cities and natural landscape linked it's required to indicate a spatial unit to induce the urban fragmentation, in this way the open urban spaces can coincide with preservation of landscape ecology.

Some authors have indicated the transports systems and natural watersheds approaches, as a possibility to reduce infrastructure costs and reduce the urban growth impacts on natural landscape. From this perspective and spatial scale that is associated this paper.

b) urban spatial discontinuity and water resources influence.

The urban theory has been trying to understand from spatial viewpoint, the urban form discontinuity emergence. The discontinuity of the urban space is indicated as an emerging dynamics associated with phase transitions, similar to other complex systems. Thus, in urban science is no more necessary to investigate which attributes characterize the city as a complex system. In fact, it's necessary to indicate what are tipping points where the system converges to promoting the spatial discontinuity (Batty, 2009).

In this paper, the water resources are indicated as spaces where the urban system converges to urban morphologies discontinuity. Tipping points for phase transitions in morphologies of urban growth, places where multiple subsystems converges to “catastrophic cascades” in spatial urban discontinuity.

c) statements: locational patterns and urban expansion.

On sub-basins scale, the water properties are initially attractors to urbanizations. However, the landscape around natural streams configures wetlands and urban restrictions. In contrast, the landscape on terraces watersheds is favorable to urbanization. From sub-basins scale, original urban cores occur both due to proximity and distance from drainage lines, looking for places that most resemble the isotopic plans.

Original urban cores emerging in isotropic formations, on terraces watersheds, promoting spatial growth without natural resistances, the urban expansion is predominantly concentric until interfaces with landscape restrictions, such as occurs along drainage lines. From these interfaces, urban expansion in concentric logic is hindered. To continue urban fabric production, urban systems overcome the landscape restrictions, promoting diffusible beyond water body growths, in remote areas not adjacent to drainage lines. At this moment, the city tends to repeat the locational patterns, statics, of origin urban core, looking for landscape patterns similar to isotropic formations. After repeating the static locational pattern, urban system repeats the growth morphology, defining a dynamic and iterative process.

d) morphology, sustainability and urban performance.

The results indicate the fragmentation of urban form as an intrinsic phenomenon into the city, by the convergence of many factors. However, the fragmentation of urban form does not nullify the natural tendency of cities to occur in compact and concentric forms. Rather, it indicates that cities grow by compression and fragmentation movements, synchronously, featuring a dynamic that defines as a complex system. If complex systems characteristics are responsible for systems perpetuation over time, this work supports the thesis that alternations of compact and fragmented forms, a morphologic growth dynamic, can be assumed how a mechanism for resilience and urban sustainability. However, to really occur, the urban resilience also depends on efficiency of its own operation internal and constraints that the structure imposes to social and environmental performance.

There is no doubt that concentric city has facilitated performance, by enabling innumerous interactions internally, promoting accessibility to all spaces and straight relationships between agents inside compact urban form. However, the compact city pursuit by urban theory has not been able for reduce the social costs inside the city, not solving the problems of exclusion and urban socio-spatial segregation. Moreover, concentric models do not allow morphological articulation with the natural landscape, urbanizing natural attributes and occurring urban environmental problems.

On the other hand, the urban fragmentation can reduce the indiscriminate conversion of natural landscape attributes, if induced a way to preserve the attributes and ecological interest spaces.

However, the fragmented urban model, in the way that intrinsically occurs tends to maintain concentric distribution of urban facilities and to promote socio-spatial segregation. In fact, like the tendency to promote diffuse urban growth, the spatial inequality is intrinsic to urban phenomenon and needs to be better understood by urban theory. If in the contemporary city coexists: the segregation and socio-spatial interaction, artificial urban environment and nature; fragmentation and concentration morphological. It's necessary to urban theory involves in a new urban model, efficiency, equity and environmental quality. Only by this new science paradigm, urban theory can reach the intrinsic factors of urban sustainability, permanence and resilience.

Overall, this work helps to overcome pessimist visions about the urban phenomenon and the future of cities. This traditional viewpoint has been summarized to highlight the negative impacts of cities on natural resources. Rather, the results of this paper permit help visions of the city as a richest human artifact, with intrinsic expansion dynamics associated with resilience and permanence properties over time.

7. References.

ALLEN, Peter (1997). Cities and regions as self-organizing systems: models of complexity. Amsterdam: Gordon and Breach Science Publishers. 275 p.

ALBERTI, M; Marzluff J. M; SHULENBERGER, E; BRADLEY, G; RYAN, C; ZUMBRUNNEN, C. (2003) Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. BioScience 53(12), 2003:1169–1179

BATTY, Michael (2007) Complexity in City Systems: Understanding, Evolution, and Design. CASA Working Paper 117. 36 p.

BATTY, Michael (2009) Catastrophic cascades: extending our understanding of urban change and dynamics. Editorial Environment and Planning B: Planning and Design 36

BENGUIGUI, Lucien; CZAMANSKI, D.; MARINO, M.; (2001) City Growth as a Leapfrogging Process: An Application to the Tel Aviv Metropolis. Urban Studies 38(10): 1819–1839.

BUZAI, Gustavo D. (2003) Mapas Sociales Urbanos. Buenos Aires: Lugar Editorial 384.p.

CHRISTOFOLETTI, A. (1999) Modelagem de Sistemas Ambientais. São Paulo: Ed. Edgard Blücher Ltda.

CZAMANSKI, Daniel; BENENSON, I.; MALKINSON, D.; MARINOV, M.; ROTH, R.; WITTENBERG, L. (2008) Urban Sprawl and Ecosystems - Can Nature Survive? International Review of Environmental and Resource Economics, 2008, 2: 321–366

ECHENIQUE, M. (1975) Modelos: una discussion. In. Martin, L.; March, L.; Echenique, M. La Estructura del Espacio Urbano. Barcelona: Ed. GG.

FORRESTER, Jay W. (1968) Principles of Systems. Cambridge, Massachusetts.

HARVEY, David. (1985) The urbanization of capital. Oxford: Blackwells.

JENKS, Mike; BURGESS, Rod (2000) Compact Cities: Sustainable Urban Forms for Developing Countries. London, Spon Press.

KRAFTA, Romulo (1999). Spatial self-organization and the production of the city. Urbana 24. Caracas: IFA/LUZ. p. 49-62.

KRAFTA, Romulo (1994). Modelling Intraurban configurational development. Environment and Planning B: Planning and Design, v. 21. London: Pion. p. 67-82.

KRAFTA, Romulo (2008) Numerópolis: Mapeamento do Desempenho Urbano. Research Project Configurational Urban Systems Group. UFRGS-PROPUR. not published 14p.

LIU, Jianguo *et al* (2007) Complexity of Coupled Human and Natural Systems. Science 317, pag.1513-1516

NYSTUEN, J. (1968) Identification of some fundamental spatial concepts. In: BERRY J (ed) Spatial analysis. N Jersey, Prentice Hall

POLIDORI, Maurício C. (2004) Crescimento urbano e ambiente: um estudo exploratório sobre as transformações e o futuro da cidade. PhD Thesis UFRGS PPGECO. 352p.

PORTUGALI, Juval (2000) Self-organization and the city. Berlin: Springer. 352 p.

SOJA, Edward (1989) Post-modern Geographies. London, Vers.

VALE, L. J.; CAMPANELLA, T. J. (2005) The Resilient City: How Modern Cities Recover from Disaster. Nova York: Oxford University Press.

VIGANÒ, Paola (2008) Water and Asphalt: the project of isotropy in the metropolitan region of Venice. In. Architectural Design Vol 78 John Wiley & Sons Ltd. England.