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ORIGINAL RESEARCH PAPER

Explanation of Morphological Approach to Urban Form in Resilience Thinking[1]

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ABSTRACT: Cities are continually shifting. Sometimes change will affect growth, whereas at other times it will lead to decay. Development and decline are reflected in the built environment through the dynamics of evolution (including renovation and renewal) and decay, the difficulty of this project turns out from the increasing complexity of urban environments and from the unpredictability of external changes, two styles that have promoted environmental awareness and, consequently, contributed to a growing debate on the relationship between city and nature. By looking at urban resilience through the lens of urban variety. It can be touched on to urban form as a product of the continuous tension between recovery and adaptation on several spatial and temporal scales of transformation.

Although recent resilience approaches, such as spatial resilience, general resilience, and urban resilience, have dealt with urban form indirectly, and, conversely, some works in urban morphology have tried to comprehend the complexity of urban-natural environments, an explicit morphological perspective on urban resilience is still lacking in research. The paper is divided in three main parts: formal thinking of resilience, resilience of urban form (fitness, performance, and sustainability), and an urban network perspective on the two concepts. It closes with a discourse on the possibility of a space morphological approach to general urban resilience.

Keywords: Urban environments, urban resilience, morphology, urban form, urban network

INTRODUCTION

About half of the Earth population is living in urbanized areas, and that bit is about to get up in the following ten. Thus, improving our knowledge on urban form and its dynamics at multiple spatial scales is a substantial challenge for research especially in achieving resilience in urban administration. The understanding of urban growth and interpretation of urban morphology can be a key challenge to the rapid urbanization of the settlements (Cheng, 2011). From the view of classic concepts that develop by M.R.G Conzen which known as pioneer in urban morphology, he divided urban form into three part which are first, town plan, secondly is building fabric and thirdly is land and building utilization (Whitehand,2007).

This concept has become important as a process of urban development and provide an understanding on urban morphology moreover, urban morphology can change over time as new urban fabric is added and as the existing fabric is internally modified. The changes of internal components are major concerns that represent the interrelation of physical evolution such as economic, cultural, and political

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dimensions that are associated with urban dynamics (Rashed et al., 2005). Morphological analysis makes it possible to summarize the changes and trends of urban spatial structure and urban form. As a result, urban morphology analysis requires multi temporal datasets covering the whole urban area across a long period. Stimulated by rapid advances in geospatial technologies, high resolution remotely sensed imagery has become widely available and at a low cost. These advances have made monitoring urban growth possible, and the availability of multiple temporal datasets has very much been improved recently.

Urban resilience adds lessons from Complexity Theories of Cities to this integration (Portugali, 2012) a view according to which urban systems are often regarded as complex networks (Batty, 2013). Moreover, as ecologists Brian Walker and David Salt suggest, every ecosystem has specific features, but also some inherent general characteristics, such as diversity, openness, modularity, or tightness of feedback. These characteristics are part of general resilience and represent systems' capacity to face change that is unpredictable both in nature and occurrence (Walker and Salt, 2012). Resilience is a term which was first theorized within ecology but which has received a great deal of attention in Urban Studies, Planning and Urban Design in recent years. It is said to be one of the most important topics within wider contemporary discourses of sustainable development (Brand & Jax, 2007; Folke et al., 2002). Since the start of the project in 2011, urban resilience has been the focus of three international conferences – the 4th International Urban Design Conference, the 3rd Global Forum on Urban Resilience and Adaptation (Bonn, 2012) and the 1st International Conference on Urban Sustainability and Resilience (London, 2012) – as well as numerous other smaller and more localized events. However, arguably, its increasing popularization has resulted in a loss of meaning, as its original uses, connotations and implications have been increasingly diffused across fields, subject areas and sites of instrumentation (Pickett, Jones, & Kolasa, 1994). It is therefore important to consider carefully what we mean by resilience in the context of this project, given its focus on urban form and long-term urban management.

Therefore, this paper proposes a combination of space-morphology with the nature-ecological approach to resilience that is already employed in urban design (Moudon, 1992). and claims that this combination may improve our understanding of, and reaction to, disruptive change. Urban form and urban resilience are the concepts chosen to correlate the two perspectives. As shown in Figure 1, the two concepts structure the theoretical framework in two parts: formal treatments of resilience and resilience of urban form. The former identifies three spatial approaches from the resilience literature and the latter explores different interpretations of resilience in urban morphology. The structure of the paper follows the same division. First, spatial, urban and general resilience are briefly introduced and synthesized in the combined concept of general urban resilience. The second part provides a summary of the recent history of urban environmental performance research, from the 1960s until the present. The paper then discusses

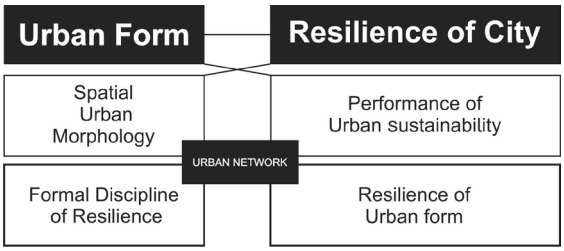

Fig 1: A theoretical framework for a space-morphological approach to general urban resilience

possible interdependencies between urban resilience and form, the current state of research on the topic, and concludes with recommendations for future investigations. (Fig. 1)

Urban resilience embraces a wide range of ways in which cities absorb and then adapt to change. Change unfolds over radically different time spans - from one moment to the next, to over a lifetime to over centuries and millennia. Studies on urban resilience tend to be divided between those which focus on drastic change in the form of sudden shocks - such as earthquakes, hurricanes, or terrorist attacks and those which explore slower processes of transformation in economic, social, and environmental fields (Müller, 2010). Authors concentrating on how cities recover from traumatic events (Vale and Campanella, 2005; Prasad et al., 2009; Clark, Evans, & Nemecek, 2010) typically seek to identify the properties of urban systems which show least 'vulnerability'. Their aim is often to use this research to highlight lessons on how cities can survive future shocks and plan within contexts of present uncertainty. Authors concentrating

on more gradual transformations consider properties that enable cities to maintain or (re)gain stability over the long term (for example, Müller, 2010). Their aim, in contrast, tends to be to identify how cities manage the relation between change and stability as a dynamic process.

Change can create impacts across a variety of spatial scales and social organizations. It can affect neighborhoods, cities, regions and/ or the world (Müller, 2010). Whilst the impacts of change can be concentrated at a particular scale, they often extend over a number of scales because of the existence of complex relationships and interpenetrations between them.

Müller (2010, p. 5) argues that the 'extremely complex and open character of urban and regional social, economic, cultural, and political systems' can make it difficult to pin point qualities of resilience that pertain to different scales. It is important to develop robust methodologies for analyzing the forms of resilience that relate to different scales and those that run across scales. emphasizes the importance of the following four aspects of the life and functioning of cities (2007, p. 10):

• **Metabolic flows:** the production, supply and consumption chains that cities need to sustain urban functions, human well-being and quality of life
• **Governance networks:** institutions which show abilities to learn, adapt and reorganize in response to urban challenges
• **Social dynamics:** demographics, human capital and inequity of citizens, communities, and consumers
• **Built environment:** the physical patterns of urban form and their spatial relations and interconnections

It is clear that urban resilience may be defined as a property of the relationships between the spatial, physical, social and cultural, environmental and economic aspects of the city, in the varied ways in which these are classified and described. It denotes, further, the abilities inscribed within these relationships to learn, adapt and stabilize the city more broadly in response to change. Notwithstanding, it has become possible to speak of 'economic resilience', 'social resilience' or 'environmental resilience' as relatively discreet categories, which allow for focused explorations of the persistence, durability and adaptability of certain aspects of the city which may or may not be a reflection of the city as a whole.

With these issues in mind, this study seeks to develop an historical approach to the study of urban resilience. It does so by exploring first the potential to speak of a resilient urban form, and second the role of governance networks in shaping how designs and built fabric become amenable and/or adaptable to changes which unfold and affect them over time. These changes may have been quite complex and diverse, composed of a mixture of dramatic and humdrum events, and have been more or less anticipated. It does not, in these terms, set out to specify a type or duration of change, but rather a period of time over which to conduct research. We begin the study by developing a framework for evaluating and assessing resilience in urban form – and in this, seeking to hold fast to notions of resilience as the property of living processes. We will go on, as highlighted above, to apply this method to the study of eight historic urban developments. These case studies reveal not only different types of urban form, but also different strategies for dealing with change through the managed development of these types over time. Such an historical empirical approach is innovative and is intended not only to contribute critically to the growing resilience literature, but to provide lessons for the future practice of building and managing resilient cities. It is widely recognized that urban resilience unfolds in the context of complex and dynamic webs of interaction. For Pickett et al, these interactions may be classified under the principle headings of 'landscapes' of 'process', 'choice' and 'outcome'. In contrast, the research organization Resilience Alliance

MATERIALS AND METHODS

URBAN RESILIENCE THINKING

Resilience has been increasingly used to describe social, ecological, and social-ecological systems (SESs). A resilient city is "a sustainable network of physical systems (the constructed and natural environmental components of the city) and human communities" (Van Timmeren, 2013) Based on this definition and in light of the trends described in the introduction, we investigate how the physical form and the social fabric of urban regions will cope with future instability, while maintaining a reciprocal relationship and a dynamic equilibrium between city and hinterland.

To describe ecological systems, Holling (Holling, 1973) associates resilience with adaptability and transformability. Adaptability is the capacity of the actors in the system to influence resilience. It is "characterized by the ability of a system to move thresholds, change the resistance to external inputs, move the current state of the system and to manage the cross-scale interaction". Transformability is of even more interest. It is defined as "the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable" (Walker et al., 2004) Transformability means defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale that define the system. It also refers to concepts such as 'city of short distances' (Rayan et al., 2009) and the 'city of small cycles' (Van Timmeren, 2006) within a larger interconnected context.

Vulnerability, already mentioned in Section 1, is a concept that is strongly related to resilience.
Vulnerability generally has a human- or society-centered perspective, for instance, in relation to climate change. In this context the Intergovernmental Panel on Climate Change (IPCC) states that "vulnerability to climate change is a function both of the sensitivity of a system to changes in climate, and the ability to adapt the system to such changes" (Schoon, 2005) The perspectives of resilience and vulnerability imply far-reaching consequences for how communities are organized, infrastructures are designed and integrated, and especially on how change is handled. It is important to realize that the stability or resilience of networks is directly related to their complexity. It is not the components of the various structures that matter, but how they are organized together as intelligent structures. In this context, Hollnagel (Hollnagel, 2006) introduced Resilience Engineering with the premise that, due to a concept called 'tight coupling', the interdependence between the components of a system, be it social or technological, might become dangerously high. Thus, amongst other factors, the level of interdependency plays an important role in determining the resilience of the system. However, resilience can be difficult to apply to systems in which some components are consciously designed [15]. The concept of general urban resilience proposed here is a synthesis of the current knowledge on spatial, urban and general resilience, discussed below.

C. S. Holling (1973) introduced the concept of resilience as a way to understand nonlinear dynamics in natural systems, such as the processes by which ecosystems maintain themselves in the face of natural disturbance, e.g., fires, droughts, floods, etc. Resilience, as applied to integrated systems of people and the natural environment, has three interrelated characteristics:
(1) the amount of change the system can undergo and still retain the same controls on function and structure;
(2) the degree to which the system is capable of self-organization; and (3) the ability to build and increase the capacity for learning and adaptation Holling developed a resilience management approach for ecosystems as a reaction to the "command and control" management that characterizes conventional resource management (Holling and Meffe 1996). Such systems have a strong sector-based focus, often aimed at managing a few target resources, e.g., timber, monoculture crops, a few target fish species, or livestock that are primarily managed for economic output without consideration of the consequences such management has on ecosystem functioning (Regier and Baskerville 1986). A frequent result has been the reduction of the range of natural variation, e.g., diversity, in such systems (Holling and Meffe 1996), leading to increasingly brittle ecosystems that over time lose their capacity to maintain biodiversity and buffer and incorporate natural perturbations (see, e.g., Gunderson et al. 1995, Kasperson et al. 1995, Finlayson and McCay 1998, Gunderson and Holling 2002).

Resilience and Urban Morphology and Form

Urban morphology refers to the form of human settlements and the process of their formation and transformation. This morphology occurs based on certain characteristics such as urban fabrics, natural and man-made structures, street layout, architectural complexity, urban materials, and human activities (Sharifah et al., 2013). These characteristics influence the changes in environment, economy, and social activities of the urban settlement. Besides that, urban morphology analysis can help identify the

transformation of urban form development and the evolutionary of urban form and structure (Cheng, 2011). Moreover, urban morphology plays a fundamental role in the resilience of urban system. In recent years, the challenge facing most of urban areas is how to accommodate future population and development growth in a sustainable manner. Any of transformation in urban patterns and forms should be taken seriously so that it will minimize the negative impacts towards the environment. In some countries such as Granada, the environment of the city becomes physically degraded, damaged, or even destroyed by the impact of the urban development that follows modernization. The main issues on urban morphology and planning are still poorly developed. Thus, the significance of urban morphological study has yet to be realized amongst urbanists (Whitehand, 2004). Therefore, urban morphology study provides important knowledge to the planner in order to develop any
area in a city or even for fringe belt. Lack of interest and awareness in history among the planners and others have prevented them from developing the settlements with systematic urban dynamics. Hence, the responsibility for the built environment is not taken seriously towards realization of sustainable urban development. Therefore, urban planners need information to allow them to respond to the expectations and needs of the urban growth. The information can help forecast future model of urban settlements (Kalyani & Govindarajulu, 2013). Urban morphology study can help in design control through policy. Due to deficiency in policy for design control, urban morphology study can be an important issue and can be considered in developing a method for expressing detailed design policies (Hall, 1997). The phenomenon of urban morphology on urban system can affect the economy, environment, climate, technology, and others of the entire city or even region. This urban morphology process can be a force that drives demand and change in the policies or strategies in order to shape sustainable and resilient urban form and structure. From this process, all agencies involved in city planning can structure the urban form into a systematic arrangement (Gillen, 2006).

As cities grow in complexity their spatial morphology, infrastructures and services must adapt to the needs of present and future urban dwellers and shifts in environmental baseline conditions. Interestingly enough, while urban regions produce two-thirds of global emissions, urban dwellers on average use 40 percent less energy than suburbanites (Steffen, 2012)(Glaeser, 2012) From this perspective, the agglomeration effect that allows urban regions to have high population densities and economic activity could serve as a potential asset in the development of adaptive strategies towards mitigating the effects of disruptive anthropogenic change (e.g. climate change) relative to energy generation and much more. The question is, however, to what extent urban form should be adapted to better cope with disruptive change.

During the last five decades, several studies have sought to understand the impact of urban form on the environment. Environmental fitness, sustainable urban form and the environmental performance of urban patterns are three approaches that have not explicitly (or centrally) used the term ‘resilience’, yet their scope has considerably overlapped with resilience thinking. Therefore, this section introduces the environmental fitness discourse of the late 1960s (Institution, 1968) with a special emphasis on Ian McHarg’s work (McHarg, 1994) Then, it outlines the current descriptions of sustainable urban form given by Burton et al. (Burton et al., 2013) and Jabareen (Jabareen, 2006) and it introduces Alberti’s (Alberti, 1999) investigation of urban patterns in relation to environmental performance.

The Form of Urban Environment

In 1968, the Smithsonian Institution published the papers delivered at its Annual Symposium under a title that was very representative to the concerns of that time: The Fitness of Man’s Environment (Institution, 1968) The fifteen contributors – biologists, anthropologists, architects, and planners – acknowledged that the environmental changes caused by urbanization had led to undesirable consequences and that a future vision on the performance of urban environments was needed. Environmental fitness – just as resilience is today being the common denominator in their writings. In parallel, and very shortly after the Symposium, Ian L. McHarg – one of the participants – published Design with Nature [30], a book that, since then, has received considerable attention in the field of urban design and landscape architecture. Strongly influenced by one of

his precursors Lawrence J. Henderson, author of The Fitness of the Environment (Henderson, 2010) McHarg disqualifies "the old canard 'form follows function'. Form follows nothing", he says, "– it is integral with all processes. Then form is indivisibly meaningful form, but it can reveal ill fit, unfit, fit and most fitting. Fitness is then by definition creative and will be revealed in the form of fitness that is life-enhancing"

This worldview had increasingly dominated the discourse in urbanism at that time, most certainly because scientists were becoming aware of the environmental consequences of the unleashed urban growth of the previous decades. The separation of city and nature had reached a point in time when it could not be sustained anymore. That dichotomy was not just the consequence of urban development, but more than that: the cause of environmental degradation. As a result, it became an acknowledged threat to human wellbeing. The concept of fitness, together with subsequent applications, came as a possible solution to this crisis.

As many planners and designers of that time were fascinated by the image of blues, greens and greys of Earth seen from space, McHarg applied the concept of fitness with a careful regard for land cover and land use. In his view, natural-process values are inversely proportional to urban use suitability. For instance, land covers that are richest in biodiversity – surface water or marshes – are the less hospitable for urbanization, while flatland, the less likely to host abundant biodiversity, is the most suitable for urban development. Yet, as we have observed throughout history, these two extremes tend to pair up; urban environments have grown as close as possible to rich natural areas, such as floodplains and deltas. Recently, their relationship has become conflicting: urbanization has ended up damaging its environments, rather than shaping it in a synergistic way. In addressing the spatial dimension of this conflict, McHarg claims that open-space distribution in urban environments must respond to natural processes. In other words, urban form – as a result of the spatial distribution of open and occupied land – was (and is) considered highly relevant to the study of the relationship between city and nature. According to him, "it is essential to understand the city as a form derived in the first instance from geological and biological evolution, existing as a sum of natural processes and adapted by man. This enquiry is described as an investigation into the given form –the natural identity – and the made form – the created city".

His concern for the separation between given form and made form is obvious. Yet he, together with his contemporaries, still seems to look at city and nature separately. Even though they offer valuable solutions, in essence they praise nature and blame the city. As the relationship between given and made form has suffered considerable changes in the years that followed, an increasing number of researchers have shared McHarg's concern. Not the character, but the spatial extent of this relationship has changed. Today's urban reality is different from that of the 1960s in the sense that man-made networks – as pointed out in the introduction – have grown into the main driving forces of urbanization, leading to a complex, dense and globally interconnected web of urbanization. Urban environments (rather than 'free-standing' cities) are intertwined with natural processes, thus increasing our environmental impact at an accelerated pace. The problems anticipated by McHarg's generation have grown into a harsh reality today, but the clarity of his observations is still valuable for current research.

Sustainable Urban Form

Recent studies have continued to show interest in the environmental performance of cities under the umbrella of sustainability (Burton and et al., 2006) (Jabareen, 2006), (Jenks and Jones, 2010)These studies have focused on the relation between land-use and transport systems and, accordingly, aimed for assessing these two features based on "archetypal urban geometries" (Newton, 2000) It is commonly agreed that urban concentration, in contrast to dispersion, is a feature that makes urban form more sustainable, as it reduces travel distances and, correspondingly, environmental impact. Jabareen, for instance, identifies seven design concepts – compactness, sustainable transport, density, mixed land uses, diversity, passive solar design, and greening – and four models of sustainable urban forms neotraditional development, urban containment, the compact city, and the eco-city. Based on these two dimensions he proposes a matrix to assess the sustainability of the four types of urban form. Although the compact city has received extensive support it

has been acknowledged that a wider understanding of urban diversity is needed.

DISCCUSION AND CONCLUSION

Urban Patterns and Resilience Performance

In an earlier paper, Alberti summarizes the state of research conducted on interactions between environmental performance and urban patterns in a matrix of four environmental variables – sources, sinks, support systems, and human well-being – and four structural variables – centralization, density, grain, and connectivity. Following this 'synoptic review of existing studies', she highlights four major implications for urban theory:

- Environmental processes are drivers of change;
- Consideration of scale;
- Including uncertainty into our enquiries;
- Consideration of thresholds.

Although she only briefly mentions resilience in relation to environmental response to change, the implications outlined above clearly resonate with the features of resilience. Yet sustainable urban form research has remained parallel, almost as an alternative to the emerging field of resilience.

Urban Networks

One of the main challenges of any research dealing with the resilience (fitness, sustainability, or performance) of a system is the factor of uncertainty and complexity. Such a context requires tools that are fit to grasp and analyze the patterns and processes at hand. Network thinking in urban design, an approach that has emerged under the umbrella of Complexity Theories of Cities has gained popularity among morphologists interested in complex urban adaptive systems as we show in this section, this perspective is useful not just for describing the form of complex systems, but it may, ultimately, serve to draw inferences about processes and system performance, i.e. resilience, too.

Generally, the study of networks is part of a broader field of science called complexity theory. Complexity theory aims to understand the rules of interaction between parts, such as atoms, amoeba, and biota in natural ecosystems, cars moving in traffic, or trades within the stock market, through the use of computer modelling. While a computer model can never truly represent the fidelity of the real world, there are some very useful ideas within complexity theory that can be used to better understand and potentially strengthen the basic principles of interaction within urban systems in the face of looming disruptive changes (Henriquez, 2014)

One essential concept to complexity theory is the complex adaptive system (CAS) and its characteristics of emergence and self-organization. Emergence refers to patterns and meaningful order that emerge spontaneously out of the interaction of parts within a complex system. These patterns are identified by accumulative change over time and can occur at different scales, for various reasons, and are usually difficult to predict (e.g. the shape of a flock of birds moving in the sky versus the collective will of the global economy). Self-organization refers to how complex order arises from the interaction of agents or components in an initially disordered system. A key element of CASs is that they have multiple potential equilibriums. From this perspective, the city serves as the perfect example of a CAS, where humans fulfil the role of agents, expressing behavior based on internal rules (desires, actions, beliefs) and external rules imposed by both society (laws, culture) and the physical environment (streets, parks, rivers, etc.). But these emergent features (i.e. bottom-up initiatives and community building) of CASs are equally relevant to the description of urban form or formation, be it on neighborhood, district or even city level of scale. As cities are the hubs of wealth, innovation, creativity and heterogeneous populations, they are also simultaneously hotspots for disease, crime and environmental pollution (Montenegro, 2014) Additionally, similar to the historical findings of Diamond (Diamond, 2005) network theory has shown that the world's most important networks (economics, politics and ecosystems) are perpetually on the brink of instability and collapse (Buchanan, 2003) As a result, there is almost a universal law within nature in which history is frequently marked by sudden and overwhelming events that completely shift system dynamics (i.e. dynamic equilibrium).

Strogatz and Watts (Watts and Strogatz, 1998) studied the distinction between social networks and other networks and found that whether a network

is created by man (power lines, social network, the world wide web) or by nature (neural net in the brain, nervous system of a worm) there is a distinct underlying "small-world structure". Small-world networks (Milgram, 1967) are characterized by having a few degrees of separation between dispersed interacting parts due to weak, bridging links and being highly clustered around particular important hubs. At some base level, regardless of the conditions in which networks developed there is an identical architecture.

Further, it can be argued that the ultimate goal, when elaborating on resilient responses to city growth and continuing complexity of cities, is to introduce the principles of fitness and 'economies of scale'. The idea is to create a complex, adaptive aristocratic structure of separate networks, or preferably of the whole that they form together. It implies 'scale invariance' and 'self-organization', with change as a precondition.
According to Barabási et al. (Barabasi and et al., 1999) city and networks than should grow (change) continuously, e.g. through new links and (decentralized) clusters. However, new links also need to be connected to the whole following the power law, with so-called "multi-connected" links following the principle of 'preferential attachment'. This principle implies the process that, in case of growing systems or networks, they expand because of new vertices being added that are connected with the vertices already present in the system. For most of the networks, this happens according to preferential attachment, dependent on the extent of connectivity of the vertices that are already there, the so-called 'effective attachment': the bigger the connectivity the bigger the chance of a new link. So the existing city form and layout of networks, and their interconnections define growth, and therefore indirectly the resilience of the whole system.

Eventually, this combination of growth and "preferential attachment" is responsible for the scale-free distribution and the possibility of 'power law' scaling as observed in real (e.g., natural) networks. In order to understand the necessary process of clustering within this process, for the sake of resilience, it is of importance to know the underlying powers of the principle of 'preferential attachment', the 'richget richer' principle. Regarding this principle, Bianconi and Barabási (Bianconi and Barabasi, 2001) argue that the aspect of fitness, similar to that to which McHarg referred regarding natural systems, plays a role in competitive networks. This is referred to as the principle of the 'fitter-get-richer', where the aspect of competitiveness implies competition within networks rather than competition between networks. The aspect of fitness must be defined differently for the various networks. In this type of system, a node (e.g. an urban sub-center) can only link further at the cost of other nodes: the (theoretically) competitive character of this type of network is the result of the fact that already existing nodes in a system have to compete (linearly, as demonstrated) with a increasing number of other nodes in the continuous growing process of the system.
It is expected that the scale-free character is a principle, generic or universal for complex networks such as cities irrespective of their dynamics, geometry or structure. The scale-free heterogeneity of transforming and competitive complex networks is a direct consequence of the principle of self-organization by local decisions made by individual 'vertices' and based on information that was led through the communication systems to the more visible, 'richer', heavier- linked vertices, irrespective of the nature and the source of this visibility.

Morphological Approach to Urban Resilience

In summary, we explored the reciprocal relationship between urban form and resilience, first from an ecological, and then from a mostly morphological point of view. We introduced the concept of general urban resilience and three chronologically consecutive interpretations of urban form in the context of environmental fitness. Then network thinking was introduced as a promising and overarching approach capable of describing the complexity of urban form and resilience. The reason for this exploration stems from our general hypothesis that the form of urban environments may be used to assess or build their resilience. Hence, this paper intended to discuss the potential of combining the knowledge of space-morphology and general urban resilience.

In our exploration, we identified four challenges in correlating urban resilience and urban form. First, the literature dealing with urban resilience does not

have its own instruments; it still uses concepts from other fields, in which resilience is more consolidated. Urban environments are dual complex systems, as Portugali warns us (Portugali, 2011) meaning that both the city and its agents – humans, communities, organizations – are complex systems in a dynamic equilibrium. The linkage to natural systems has been challenged by certain social scientists because it neglects the sociological fact that humans are malleable and conditioned by their social environment, not the natural environment (McDonald and Patterson, 2007) Human behavior is primarily influenced by societal norms rather than immutable natural laws. From this perspective, planning cities as a metaphor for a large biological entity is naïve because human relationships with the environment and other humans are more complicated. In this sense, the frameworks used in ecology, for instance, cannot be directly applied to urban environments, as they will not fit the character and extents of urban processes. Second, the inconsistent terminology of research dealing with the relationship between environment and city seems to create confusion. Environmental fitness, sustainability, and environmental performance presented here are concepts developed with the same incentive as resilience: the causes and the consequences of environmental impact. Third, as Alberti pointed out in 1999 already. the literature still lacks a conceptual framework that integrates urban patterns and environmental performance. And fourth, current research in urban design is taking a nature-ecological approach to urban resilience, leading to methodologies adapted from ecological research that do not integrate existing (and consolidated) urban design research methods. Therefore, we propose the following:

1.The concept of general urban resilience provides a coordinated knowledge of spatial, urban and general resilience. Additionally, research on general urban resilience requires a framework capable of assessing the complexity of urban environments. Networks offer a framework that is already applied in Complexity Theories of Cities and that is compatible with pattern-process descriptions characteristic of (landscape) ecology.

2.We extend our knowledge base on urban resilience and form to include studies that do not explicitly refer to resilience, but which have the same focus. There are similarities between studies concerned with resilience assessment and those dealing with the measurement of urban form in relation with environmental performance. These studies need to be correlated before a reliable theoretical framework and an integrated method of assessment can be developed.

3.The theoretical framework illustrated in Figure 1 contributes to a common body of knowledge for nature-ecology and space-morphology.

4.Space-morphology brings methods of analysis already familiar to urban design research, such as urban network analysis. This paper contains the preliminary findings of an eight-month research; therefore, results on resilience and urban form cannot be claimed yet. However, the conceptual framework provides a good starting point for future research. A correlational research of spatial patterns and urban resilience indicators is essential for a reliable integration of nature-ecology and space-morphology. In addition, there is still need for research on how networks can be applied to assess urban form. Finally, both correlational research and network analysis of urban form have to be applied to case studies.

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