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Metaphors from the Resilience Literature: Guidance for Planners

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1 ABSTRACT

The notion of resilience is gaining traction in the academic and professional urban development and planning literatures. But, what is it? It is clearly more than a public administrator (or planner) saying that their place is "resilient". As a "newer term" in the emergent lexicon, it suffers from too many definitions. In this paper, we briefly trace how the original concept of resilience has morphed from its original use in ecological science to the climate change adaptation literature and to its possible ascendancy into the spatial analysis and design literatures. Then, we describe two dominant metaphors in resilience thinking – Per Bak's "Sand Pile" and "Controlled Burning". The urban development (characterization) and planning (policy responses) analogies that could incorporate these metaphors are then explored and include tipping points or thresholds of change, dynamics at one scale affecting outcomes at another scale, and overall inefficiencies of public administration to insure "resilience".

2 INTRODUCTION

The focus in this paper is primarily on the concept of resilience and secondarily on its use as an adjective in word phrases such as "resilient city". The concept of resilience is gaining traction in the academic and professional urban planning literature, but its meaning remains difficult to pin down. Part of the ambiguity lies in very basic definitions, of which two are pertinent – simple "resilience" and psychological "resilience". The first definition is that the concept or idea is a property of science and of systems. In these terms, resilience is the property of a material to absorb energy when it is deformed elastically and then, upon unloading to have this energy recovered. It is the maximum energy per unit volume that can be elastically stored (much like a balloon). On the other hand, psychological resilience is the positive (note that this is value judgement) capacity of people to cope with stress and adversity. A resilient personality copes with stress and bounces back to a previous state of normal functioning. And, if we can define resilience, what is a resilient city? Is it the city's leadership who might have the psychological trait of fighting back or adapting to changing priorities?; the city's economy that might have internal structural rules that allows its aggregate descriptors such as GDP or wealth appear stable or at least well defined in terms of their path and direction; and/or the city or region's social structure which might exhibit some characteristics of stability in terms of composition or wealth distributions. Moreover, we will intermittengly challenge the value of stability as a vision for planning activity.

The "resilient city" is a cosmopolitan phrase. But, who or what is resilient? In the hazards and adaptation to climate change literature, it seems to be the city administration, who adopts policies and procedures in anticipation of the worst case scenario. Less likely is some administrative understanding of the "socio-ecological" system, from a scientific (ecological, economic or social) point of view. Planners and administrators focus on place versus behavioral processes fosters Portugali's assertion of "misappreciation" of managing dynamics (2006, 1999). Less focus has been placed on deeply analyzing the theories behind the ideas of resilience, shifting the attention to developing ways to apply it to the physical environment.

The purpose of this paper is to examine some metaphors that make up the constellation of "resilience/resilient" thinking. Here, we use the first definition of resilience – as a property of scientifically defined systems. Furthermore, we argue that "resilience" is not a unitary concept and that it is probably better to think of it as a collection of metaphors – each with specific time-space-scale dimensions.

This paper is organized as follows. The next section presents a short history of the resilience concept from its inception in ecology, through its adoption by the adaptation to climate change research community and to its initial foray into spatial planning. We define "economic" and "social" structures of contemporary cities and regions. Then, we articulate the two resilience metaphors – sand piles and controlled burnings. This is followed by examples of how these concepts help understand dynamics and guide planning efforts. The final part of the paper suggests future research avenues.

3 A SHORT HISTORY OF THE RESILIENCE CONCEPT

In this section, we briefly trace the concept of resilience in three phases – from its original use in ecological science through its appropriation by the adaptation to climate change research community, including its usage by theorists interested in social resilience and vulnerability of cities, migration patterns, etc. and finally to its potential use in spatial analysis, planning and design.

3.1 Resilience in Ecology

Ecology is the study of the relation of living organisms to each other and their surroundings. The key primitive concept is that of ecosystems, which are defined by a web, community or network of individuals that arrange into a self-organized and complex hierarchy of process (drivers) and pattern (result). Ecosystems create a biophysical feedback between living (biotic) and nonliving (abiotic) components of an environment that generate and regulate the biogeochemical cycles of the planet. Ecosystems are sustained by biodiversity within them, which is often presented as the full-scale of life and its processes, including genes, species and ecosystems forming lineages that integrate into complex and regenerative spatial arrangement of types, forms, and interaction. These ecosystems provide goods and services that sustain human societies and general well-being. There are a number of seminal references, including Odum (1953).

3.1.1 Resilience as an Ecological Concept

Thus, there is a structure to ecosystems, which is in itself dynamic. These structures are subject to both internal and external threats. For example, human activities that could potentially adversely affect ecosystem resilience include exploitation of natural resources, pollution, land use (sprawl), and anthropogenic climate change. The ecosystem response to these "disturbances" is normally couched in terms of ecological stability. Ecological stability is normally classified in terms of three outcomes: resilience, (returning quickly to a previous state), constancy (remaining unchanged), and persistence (resistance and inertia). Resilience is the ability to recover quickly from disturbances such as fires, flooding, windstorms, insect population explosions, and human activities such as deforestation and/or the introduction of exotic plant or animal species. Constancy or resistance means that the ecosystem is non-responsive to a disturbance.

However, there are some instances where the dynamics of the ecosystem and/or the ecosystem itself cannot respond to internal or external changes. In this case, when disturbances are of sufficient magnitude or duration as to profoundly affect the ecosystem processes and structure, it is transformed, usually but not necessarily, to a less desirable and degraded regime. This alternative response to a disturbance becomes part of our discussion below.

The identification of the attribute of resilience and the beginning of scientific study of it is due to C.S. Holling (b. 1930, 1973) who defined and illustrated "stability" and its relationship to random disturbances in the environment. He introduced resilience in terms of capacity measures, as the capacity to persist relationship in nature even when disturbances occur. The literature on ecological resilience is enormous, with seminal studies on predator-prey relationships (Morris, 1963, Lewontin, 1969), vulnerability (Smit & Wandel, 2006), and biodiversity (Peterson et al., 1997)

Advances in human-ecological thinking seem to be focused on the work at five research nodes: Marina Alberti's at the University of Washington, Nancy Grimm at Arizona State (e.g., 2000), Stewart Pickett and colleagues at the Cary Institute of Ecoystem Studies in New York (e.g., 2001) and Herbert Sukopp in Germany (e.g., 1996). In this body of work, much emphasis is placed on the twin notions of cities and systems and the value of complexity theories. For example, Pickett et al. (2004) have argued that the metaphor of "cities of resilience" can bring together the disciplines of urban design, ecologists and social scientists. After distinguishing between equilibrium resilience (the ability of stystems to return to their stable equilibrium point after disruption) from non-equilibrium resilience (the ability of a system to adapt and adjust to changing internal or external processes – after Holling, 1973; Gunderson et al., 1995), Pickett et al. (2004) focus on the value of the role of spatial heterogeneity in both social and ecological functioning. They conclude with identifying the potential usefulness of "learning loops", the value of "experiments", and the potency of dialogue among professionals and citizens, communities, and institutions to support both research and design.

3.1.2 Measures

In measuring resilience, constancy, and persistence, ecological researchers focus on measures of elasticity and amplitude. Elasticity is the speed with which a system returns. Amplitude is a measure of how far a a system can be moved from the previous state and still return. Peterson et al. (1998) shows a number of graphic representations of these phenomena.

The field of ecology has also borrowed the idea of neighborhood stability and "domain of attraction" from dynamical systems theory. In dynamical systems, a fixed rule regulates the time-dependency of a point in space (for example, number of fish in a lake in the spring time). Dynamical systems theory focuses on the flexible behavior in changing states through long-term, observed periods. Its relevance lies in the attempt to answer such questions as "will the system settle down to a steady state in the long term, and if so, what are the possible steady states?", or "does the long-term behavior of the system depend on its initial condition?" It is particularly focused on analyzing fixed points at which the state of the system changes, and holds that certain points occur with a domain of attraction, meaning that any nearby point will adapt to this fixed point.

Measurements of ecosystems (subject to resilience or transformation) often fall into one of four types: species diversity, idiosyncratic, rivets, and drivers and passengers (Peterson et al, 1998). Often, such studies are couched in terms of "spatial" units of observation. The spatial arrangement of ecosystem has an influence on the adaptability and resilience of its components. Their planned distribution over the landscape is intended for a certain kind of function, and cannot be qualified as either random or homogenous (Legendre & Fortin, 1989) Organisms form patches and/or gradients to group together and a vast number of relationships between components of the ecosystem exist through this self-organization in the spatial and temporal scale. Gradients are associated with observed trends over a certain period of time and distance. Patches are increasingly uniform formations with demarcated division between the patches themselves. However, in this spatially uniform arrangement of patches and gradients occur random fluctuations and changes over time, deemed as noise, which renders a slightly different landscape while remaining in the arrangement of gradients and patches.

3.1.3 The Special Place of "Feedback"

Throughout the exploration of the metaphors, one overarching element exists within the analysis of each of them. Feedback is the mechanism arising from the interactions and patterns of a system.

Poitive feedback in systems acts to exacerbate the changes and responses to emergent patterns. It can enhance or negatively affect the system's stability and state (Cinquin & Demongeot, 2002). It strengthens the emergent process or patterns. An example of this is the continued streghtening of a hurricance through positive feedback in the form of temperatures and atmospheric pressure. Negative feedback is the opposite in that it deters the potential continuity of the occurrence. It serves as the weakening force to the emergent pattern. It will try to revert the system back in to the input state. A mountain existing in the path of a hurricane is the weakening agent or negative feedback to the hurricane. Climate change could experience negative feedback, if expulsion of carbon is minimized.

In either case, the function of positive or negative feeback on the system may not be optimal for the resilience of the system as it may cause instability within. Feedback is a feature of management in the system that either enhances or reduces resilience. It is another component of the resilience concept, but less predictable when applied to systems outside of nature (Whiteman et al., 2004).

Possible application of feedback mechanisms can only be performed with a clear understanding of the functionality and responses stemming from feedback paterns. Until then, the term "resilience" is more successfully applied to identifiable instances within ecological interactions.

3.1.4 Ecological Stability

The enormous literature on ecological stability (ecological economics, ecosystem services, etc.) presents a compelling picture of the need for scientific conceptualization and measurement. It also presents a general finding that stability of ecosystems is generally a result of functional specialization, not necessarily diversity of species. Furthermore, research has demonstrated that there is considerable functional redunancy in natural ecosystems (agents doing more than one job). Resilience may be the result of functional redunancy.

3.2 Resilience in the Adaptation to Hazard Mitigation and Climate Change Literature

Resilience has emerged as a major buzzword in the literature dealing with hazards and/or adaptation to climate change. Presumably, the desire is to be able to withstand short term or long term shocks and be able to return to pre-shock or pre-trauma conditions.

3.2.1 Resilience as a Desirable Attribute in Hazard Occurrences: Natural

Most of the literature has focused on natural hazards such as hurricanes or earthquakes. The key references here are numerous, from Paton & Johnston (2001) dealing with risk management and emergency planning, to more focused research on specific natural occurrences such as volcanos (e.g., Johnston, Millar & Paton, 2001); coastal disasters (e.g., Adger, 2005) to community response to disasters such as New Orleans (e.g., Colten & Sumpter, 2009). More complex formulations include the study of microbial communities, demonstrating how larger ecological systems have an important role in sustaining the system and its processes (Allison & Martiny, 2008).

Godschalk's (2003) seminal piece on the resilient city describes "disaster resilience principles" including that resilient systems tend to be: redundant with a number of similar components, diverse as in functionally different attributes, efficient in the ratio of energy suppied to energy delivered, autonomous to operate independently, strong, interdependent, adaptable and collaborative (p. 139). Each of these are loaded and contextualized words, as we will atempt to explore later in this paper.

Berke's (2003) momumental book, **Navigating Social-Ecological Systems**, includes contributions by a variety of authors in a number of disciplines, including the work of political scientists (e.g. Low et al., 2003), but focusing on the contributions of complexity theory. Walker et al. (2004) provide a useful discussion of the relationships between resilience, adaptability, and transformation in social-ecological systems.

3.2.2 Resilience as a Desirable Attribute in Hazard Occurrences: Terrorism

There is a less visible literature on dealing with man-made shocks such as terrorism and/or spills, de-railment or truck emergencies. These studies, including terrorism resilience, have continued to expand since the attacks of September 2011, and deal heavily with the securization of the city. The need for urban resilience stems from vulnerability (mostly material and technological), insecurity and overall changes that are occurring in cities. Research arround urban resilience as a preparedness method to security threats focuses on dealing with social and economic policies to ensure resilience in cities, which have become "threat-rich" as a result of density and concentration of wealth (Coaffee & Rogers, 2008; Coaffee, Wood & Rogers, 2009).

3.2.3 Resilience as a Adaptation to Climate Change Concept

Within the adoption to climate change discourse, the resilience concept has been used to explain a form of adaptation of environments. Among the earliest references to the term "resilience" in the climate change literature are studies that emanate out of the emergency management literature, particularly in regards to hurricane events. These events (hurricanes) are viewed as "shocks" to the existing physical ecosystem primarily but also to the social ecosystem as well. Most of the attention has been paid to the human consequences.

From these rootes grew a cottage industry that used the phrase "resilient" and "cities" together. Aside from that reference, non-governmental organizations – particularly UN Habitat – have adopted the phrase and concept for their purposes. In most cases, the focus is on natural disasters. The other major NGO involved in climate-related resilience thinking is ICLEI (International Council for Local Environmental Initiatives, founded in 1990, now ICLEI-Local Governments for Sustainability). Among their current initiatives is the upcoming Resilient Cities 2011: 2nd World Congress on Cities and Adaptation to Climate Change (Bonn, Germany, June 3-5, 2011).

Berkes et al. (2003) also give insight to the resilience concept in terms of climate change. Holding that current communities lack an element of resilience, they suggest that our low levels of adaptation to existing climatic variation can be obseved by the high impact and high costs associated with recovering from events like floods, ice storms, and hurricanes. In this version, resilience is painted as adaptive capacity to any response that can increase the probability of survival, using strategies to change the productive activities of humans to ensure livelihood in reponse to climate change.

So, resilience here means adaptation – perhaps foresighted actions meant to anticipate effects of catastropic shocks from the environmental realm. One can take this a number of ways. Using Pickett et al (2004) as a benchmark, we could ask, for example, whether New Orleans is a resilient city? Some (Campanella, 2006) would argue that it is. Clearly, the French Quarter has shown resilience – the ability to return to its prior state as a premier destination for conventions and vacations; but the 9th ward has not recovered and the overall population of the metropolitan region is down approximately 30% (http://abcnews.go.com/Politics/orleans-populations-shrinks-10-years/story?id=12856256, retrieved Feb 14, 2011). Clearly, the social and economic dynamics of the city proper and the metropolitan region have changed – that is, it is not resilient.

3.3 Resilience in Spatial Planning Analysis and Design (Urban and Regional Studies)

The New Orleans example is a perfect entre to how we might consider "resilience" as a concept or attribute of city or regional spatial structure. Much of the emphasis of the existing literature in on planning processes and institutions – almost a psychological response. But, cities and regions have characteristic properties much like an ecosystem has characteristic properties. For example, Bourne (1981) identifies properties including *form* (spatial patterns), *interaction* (relationships, linkage, flows), and *structure* (rules) of urban places. The idea that it is possible to describe cities and city regions in terms of their spatial properties stems from urban geography and regional science (e.g., Haggett et al., 1965).

To describe, evaluate, and/or analyze spatially defined system in terms of resilience requires a formal theoretical structure. Complexity theory offers a way to think about these relationships. But first, we need to know something about the properties of spatial structure overall, and then in terms of basic economic and social descriptions.

3.3.1 Notions of Spatial Structure

This question of stability or resilience of spatial structures is in its formative stage, as researchers try to move beyond the "natural disturbance" catalyst for their research put forth. Are these properties stable? Among the inuendos "out there" are questions such as, going from large to small scale: is the Blue Banana structure stable?; is the historic core stable?; how, specifically, do mega infrastuructre projects alter or transform existing properties of spatial structure?; is the current polycentric structure of our cities and regions stable?; is the city or regions employment structure stable?; is the existing social spatial structure stable?; is a particular district or neighborhood stable?; etc. Our focus here is on the city-region or overall urban agglomeration. We focus on two specific areas: the economic and social structure of the place. But prior to this, we ask a very simple question: What is a metropolitan region?

Bogart (2006) relunctantly attempts a definition metropolitan area. He describes a number of "criteria" and "benchmarks" of both place-specific and process-specific elements. Among the place-specific attributes is the presence of employment centers, in which 30 to 40% of employment is dispersed throughout. Also identified is the presence of a major univerisity attracting students from outside of the region, and at least one major stadium for professional sports, whether built or in the planning stage. Among the process-specific are rates of commuting, rates of segretation by race and income, rates of disparity, and rates of congestion. So, the current state of a place may be that its transit system accounts for 40% of trips. Or, that the suburbs contain 50% of all residents with incomes over $60,000 annually. These are its current "properties".

3.3.2 Resilience in the Spatial Economic Realm?

The spatial economy is describable in terms of uses and hierarchies. At any point in time, there is a known distribution of a number of economic variables: at the non-spatial level, there is the distribution of employment across classes of workers, normally defined by industry. There is a similar distribution of wealth among those classes. Economic base and/or input-output models demand a set of classes and proportions among them.

We also know that there are certain parameters – say of interaction. Among the process-specific are rates of commuting, rates of segretation, rates of disparity, etc. So, the current state of a place may be that its transit system accounts for a certain percetange of trips. The major point is that some of these we would like to remain stable (the size of the middle class, for example), while there are others that we would like not to remain stable.

3.3.3 Resilience in the Spatial Social Realm?

There is a known spatial social structure in contemporary city and regions. We know that our cities and regions remain segregated according to income and class and that this property is resistant to change. We know that our cities and regions remain segregated according to race and ethnic characteristics and that this property has increasingly become overcome – that is, it is changeable. We know from Burgess and the Chicago School that immigration causes stress in a neighborhood, but that the stress is eventually worked out and that the "neighborhood" reverts to its functionality.

Most of the literature to be found focuses on individuals or communities (Gotham and Campanella, 2010), or cities that have undergone stress. Most of these studies focus primarily (exclusively) on the psychological definition of resilience. There is little in the way of measuring elasticity or amplitude.

4 RESEARCH PROBLEM

The major research task herein is to explore resilience metaphors and identify their potential usage as guidance for planners. Two tasks are performed. The first is the articulation or description of two resilience metaphors: Sand Piles (specifically, articulation of the concept of self-criticality) and Controlled Burns (specifically, articulation of the concept of multiscalarity. After this, the second task is to use these concepts in examples of planning situations, defined in terms of spatial economic or social structures. We illustrate how resilience concepts can improve understanding of typical planning situtations like transit, employment, housing and migration. The choice of metaphors is completely arbitrary (i.e., we could have, space permitting, explored a number of other metaphors).

5 TWO RESILIENCE METAPHORS

Complexity theory will force us to think in terms of open systems, non-equilbrium solutions, self-organization, multiscalarity and other mechanisms and resulting patterns. In this section, we describe two resilience metaphors – ideas that contain elements of complexity concepts. These are: Per Bak's sand piles and the ecological idea of controlled burns. Each is discussed in turn.

5.1 Sand Piles

Bak et al. (1988) are credited with discovering self-organized criticality in natural systems. Criticality is understood within a dimension of boundaries between the stable and the unstable, where a natural system finds itself dwindling between a critical state, driven to the edge of instability.

In Bak's sand pile model, the resilience-disturbance relationships understood through the characteristics of self-organized criticality are exhibited. The fate of a pile of sand is explored as continous, but slow changes are made through the addition of grains of sand, one at a time. As grains of sand continue to be dribbled from the top, eventually the pile reaches a critical state, challenging the stability of the pile and leading to a modification of the state of the sand pile, an avalanche of the sand grains (Bak et al., 1988). Smaller avalanches occur more frequently, while intermediate or catastrophic avalanches (which affect the entire system) are infrequent occurrences (Dhar, 2006)

Note the above explanation brings forth a number of characteristics associated with self-organized criticality. First, it occurs in slow moving but constantly changing and non-equilibrium systems. Note also the build up of pressure within the system progressing to a critical state. Through this characteristic, this system has intrinsic thresholds and identifiable tipping points. Since smaller avalanches are said to happen more frequently than catastrophic ones, there also exists a basic power law within the system.

5.1.1 Thresholds and Tipping Points in General

In complexity theory, the threshold is called the "edge of chaos". It is the point at which the current structure morphs into some else. It is the point of where the previous structure becomes unresilient.

Within the discussion of Bak's sand pile and criticality, thresholds and tipping point are the amount of variation allowed and the precise moment when that variation is no longer tolerated. The tipping point is the moment at which the state begins to change in a dramatic manner. Gladwell's (2000) one "dramatic moment in an epidemic" where everything can potentially change is the tipping point. Quercia and Galster contend that thresholds are the dynamic process at which the feeback from the state of a system is altered and some critical value is reached. Take the example of neighborhood change. The threshold and tipping point is the critical point past which neighborhood dynamics begin to escalate and change rapidly (Quercia & Galster, 2000). Schelling's tipping point is another example of the concept in neighborhood change, in which neighborhoods often "tip" and become predominantly white or black depending on some level of self-organization in the preference of the residents (Schelling, 1978).

5.1.2 Agent Based Models in Complexity Theories

Batty's **Cities and Complexity** (2006) contains a review of several agent based models that result in "changed" states. These include Pedestrian Modeling, in which studies are performed to observe how individuals respond to local patterns (street and congestion, shopping centers, street festivals).

He is not alone. Krugman's **The Self-Organizing Economy** (1996) describes in some detail the very simple model of City Formation, which shows how small biases in agents leads to segregation (an altered or second state). This model illustrates self-organization in spatial economics by exploring the emergence of office districts in a polycentric metropolitan area (ex. Los Angeles). The model studies self-organization of space based on independent location decisions by individual firms. It shows that practically any intial distribution of business across the area, will instinctively arrange itself into a spatial form with multiple, clearly separated business centers, and these edge cities are roughly evenly spaced.

5.2 Controlled Burnings

The significance offered by the metaphor of controlled burning to the resilience concept is in the view of regeneration. Forest management provides the idea that proper care of a forest enables it to remain healthy and provide the products needed. Included in this maintenance are controlled or prescribed fires. This technique is used to reduce the potential harms in the forest (fuel buildup) that may results in larger, serious fires. It also stimulates regeneration of the forest environment.

When translated into city or metropolitan regions and their reslience attributes, the metaphor may apply when considering certain actions taken to regenerate the spatial structure (specifically and more commonly in economic terms). For example, the demolition of an abandoned public housing project for a newer, multi-purpose structure in its place is a useful way of depicting the forms of controlled burning exercised, that in turn affect the resilience of the area.

5.2.1 Multiscalar Implications

Controlled burnings illustrate the complexity principle of multiscalarity. In multiscalarity, the "whole" system is viewed as a series of hierarchical relationships among agents acting at different scales. Properties of the "whole" are really made up of agents carrying out their business at other scales.

The example above is ecological. In order for the forest to survive (in terms of ecological attributes suchas biodiversity), individual interactions at lower levels of resolution are carried out. Sometimes, these lower level activities present a threat to the overall system. In this case, it is debri (dead leaves). Controlled burning is a way of eliminating this problem.

6 WHAT DOES IT MEAN FOR PLANNING?

6.1 Resilience in Economic Spatial Structure

6.1.1 A Transportation Example

The City of Fort Lauderdale, Florida is actively involved in developing "The Wave" -- a fixed-rail tram system for its downtown. The system is internal to the downtown, and does not connect to other transportation options outside of the downtown except by other modes, like buses. The Wave is a "**disturbance**" to the existing mobility patterns and transportation infrastructure.

What Per Bak would say.

In this example, the sand pile is the collection of trips of individuals on a given network of links. The "Wave" is a new link that causes the collection of trips to possibly be accomplished on the trolley. The change in distribution of trips from car to trolley is equivalent to a "minor" avalanche, but the overall sand pile remains fairly constant. The size of the avalanche is directly equal to the success of the trolley in diverting trips from the old system structure which included only roads and automobile travel to a new mixed system of transportation.

The notion of self-criticality could be associated with a top-down force such as the introduction of a fixed transport infrastructure. If the size of it is sufficient enough to change the mobility dynamic, the "disturbance" could create a new dynamic thus increasing the number of trips accomplished by the trolley system. If the new force is of sufficient size, the internal structure of sand pile becomes unstable, the old sand pile (transportation through roads only) collapses and regenerated sand pile containing mixed transportation options emerges.

Should It be Burned?

The "ecosystem" in this case is human desire and material transportation network. The "Wave" is a small-scale transport alternative introduced into the overall transport ecosystem. As such, its ability to alter the system-wide trip patterns is limited, but it could alter trip patterns within its spatially limited scale.

Second, it could-- if effective – pare out inefficient transport opportunities within the overall system. For example, a fixed rail on a road with limited amounts of right of way will in turn force that limitation to be used by the rail system and thus not usable by cars. For cars, these spaces are functionally "burned", enabling better overall mobility options.

6.1.2 Pattern of Employment Centers

It is well known that our cities and regions may be characterized by a set of employment centers, each arguably specialized. The total economic well-being of the city or region is depdendent on the processes that create this polycentric picture and on the pattern itself. The current pattern of employment centers can be "**disturbed**" by the introduction of a new sector of activity – for example, biomedical research. Where and how much activity related to the new sector yields a question of how resilient the former pattern of employment centers is.

What Per Bak would say.

The sand pile in this example is the pattern of employment centers governed by self-organization principles that result in such pattern. Each employment center will have minor avalanches corresponding to general trends of the business cycle. The disturbance is how to find space within the sand pile for the new biomedical activity to occur. If within an existing employment node, the introduction of new activity will cause "mid-range" avalanches. If the new activity is located in a new area of the sand pile, this might be of sufficient size to cause the original sand pile (pattern of employment centers) to change to accommodate a new and diversified center.

Should It be Burned?

The "ecosystem" in this case is the pattern of employment centers. Employment centers have internal dynamics that are specific to the mode of clustering and/or production. From time to time, certain companies or locations may become obstacles to the overall functioning of the employment center. Either market adjustments or governmental leadership may lead to a streamlining of the internal dynamics of the employment center.

The disturbance created by the need to accommodate a new sector will create the need to provide additional space or "make roomwhich entails some form of redirection or "burning" of previous land-use patterns.

6.2 Resilience in Spatial Social Structures

6.2.1 A Housing Example

Penn & Zalesne (2007) identified LAT couples, those people "living apart together". This form of interpersonal relationship creates a need for additional housing units viz. couples living together. The "**disturbance**" to the housing market is the creation of excess demand for a given population size.

What Per Bak would say.

The sand pile in this case is the housing market, more specifically, the supply of housing units. There is a generally stable relationship between the size of a population and the number of households. The demand stemming from LAT couples to occupy twice as many housing units stresses the sand pile. If their numbers are small enough, the sand pile will only experience minor avalanches. However, should the LATs grow in size and/or concentrate in certain parts of the housing market (sand pile), there could be spatial consequences and/or partial destruction of the sand pile.

The disturbance to the system is the new pattern of housing and the new people moving into the neighborhoods appropriate for absorbing them. This shock exists not only for those already in the community but also for others looking for real estate in area. These in turn might go elsewhere, reorganizing the market at elsewhere's location. The housing market would need to respond with more stock to accommodate the individuals, thereby altering its state.

Should It be Burned?

The ecosystem is the human need for housing and the housing stock. The housing stock is always under development as new houses are built and older ones are revitalized. The same is true for spaces. Rural land is converted to subdivisions; underutilized urban areas are revitalized.

The revitalization of urban areas – likely to be desired by the LATs – means either revitalizing existing structures and/or the removal of these to enable the creation of new structures.

6.2.2 A Migration Example

There is a known spatial distribution of social residential patterns. Communities often form as a result of human desire to surround ourselves with similar people. Any given city or region typically can accommodate growth. However, mass migrations caused by war or climate often stress local housing markets and spatial aspects of social residential patterns. For example, the 2010 Haiti earthquake spawned a **"disturbance"** as massive immigration to South Florida. Where did they go, what did they do, how did they influence existing the spatial social structure of the metropolitan region?

What Per Bak would say.

The sand pile in this case is the social residential pattern, composed of both specific intensities and spatial relationships. Per Bak would look at self-organization positive feedback which would assume that communities with an established number of Haitians would receive the most migrants. Self-organized criticality offers the suggestion that smaller communities of Haitian immigrants will receive some of those migrants, therefore holding more Haitian population than before, but not as much as the main communities. There is also the possibility of reorganization (of the sand pile) after a major avalanche occurs in the form of spill-over of migrants from a saturated community that does not have the capacity to absorb the outmigration, these in turn settling in areas formerly absent of any Haitian population. The existing community that absorbed the shock of new migration is transformed through this build-up of pressure in the form of new residents. This system (neighborhood) was driven to the tipping point and can be assumed to change states in that it must expand outwards or spill into other neighborhoods. It will not revert to previously experienced stability.

Should It be Burned?

The ecosystem here is community ecology. Large immigration demands place stress on the community. This stress is likely to be exhibited as overcrowding, lack of public services, and insufficient housing stock to accommodate new immigration

In this case, it is the addition of more rivets and drivers to satiate new demand for services needed by the community ecology. Instead of control in the form of "burning," the mechanism is better envisioned as control by addition of nutritents to the ecosystem, which in turn ensure its health and survival.

7 CONCLUSION AND DISCUSSION

The concept of resilience initially is understood through a dimension of scientific purpose. Its existence and components are ones found primarily in nature/ecological systems. The functionality of ecological systems contains elements that are arranged for optimal survival and optimal utilization of resources. The metaphors described are best identified in natural systems, as self-organized criticality and multiscalarity are essential characteristics of these systems. However, the resilience concept is also found in human interactions. The metaphors apply in varying degrees to complex systems outside of ecology. Knowing this, resilience, its components and associated metaphors are present within the systems that comprise urban development and planning principles. The idea involves certain processes that if understood, could aid the direction of future management and growth while contributing to the understanding of complex systems of human scale.

Transit, employment, housing and migration are systems present in planning practice continously evolving and challenging the capacity to adapt to the changes experienced within them and the overall urban landscape. This paper provides a theoretical structure by which to guide in the understanding and presence of resilience in systems. Proper and sufficient understanding of the theories behind the sand pile and the controlled burn is needed to be able to successfully develop resilience indicators and measures that may aid in the development of regional planning efforts. Application of these principles requires careful measurement of the elements present in individual cases, as a generalist approach will not result in optimal ability to ensure resilience within the city.

8 REFERENCES

ADGER, W.N. Social and Ecological Resilience: Are They Related? Progress in Human Geography, 24(3): 347-64, 2000.

ALBERTI, M. Advances in Urban Ecology. New York: Springer Science+Business Media, LLC. 2008.

ALLISON, S. & MARTINY, J. Resistance, Resilience, and Redundancy in Microbial Communities. Proceedings of the National Academy of Science, 105: 11512 – 11519, 2008.

BAK, P. K. CHEN & K. WIESENFELD. Self-Organized Criticality. Physical Review A, 38, pp. 364-374. 1988

BATTY, M. Cities and Complexity. MIT Press, Cambridge, MA. 2005

BERKES, F., J. COLDING & C. FOLKES (eds.). Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge, UK: Cambridge University Press, 2003.

BOGART, T. Don't Call It Sprawl. Cambridge, UK: Cambridge University Press, 2006.

BOURNE, L. The Geography of Housing. New York: Haslted Press, 1981.

CAMPANELLA, T. Urban Resilience and the Recovery of New Orleans. Journal of the American Planning Association, 72(2), 141-146.

COAFFEE J. & ROGERS, P. Rebordering the City for New Security Challenges: From Counter-terrorism to Community Resilience. Space and Polity 12(1), 101-118, 2008.

COAFEE J., WOOD D.M. & ROGERS, P. The Everyday Resilience of the City: How Cities Respond to Terrorism and Disaster. Hampshire, UK: Palgrave Macmillan, 2009.

COLTEN, C. & SUMPTON, A. Social Memory and Resilience in New Orleans. Natural Hazards, 48: 355-364, 2009.

CINQUIN, O. & DEMONGEOT, J. Positive and Negative Feedback: Striking a Balance between Necessary Antagonists. Journal of Theoretical Biology 216(2), 229-241, 2002.

DHAR, D. Theoretical Studies of Self-Organized Criticality. Physica 369: 29–70, 2006.

GLADWELL, M. The Tipping Point: How Little Things Can Make a Big Difference. New York: Little, Brown and Company. 2000

GODSCHALK, D.R. Urban Hazard Mitigation: Creating Resilient Cities. Natural Hazards Review, 4(3), pp. 136-143,

GOTHAM, K.F. & R. CAMPANELLA. Toward A Research Agenda on Transformative Resilience: Challenges and Opportunities for Post-Trauma Urban Ecosystems. Critical Planning, 17: 9-23, 2010.

GRIMM, N.B. J.M. GROVE, S.T.A. PICKETT & C.L. REDMAN. Integrated Approaches to Long-Term Studies of Urban Ecological Systems. BioScience, 50: 571-584, 2000

GUNDERSON, L.H., C.S. HOLLING & S.S. LIGHT. Barriers Broken and Bridges Built: A Synthesis. In. L.H. Gunderson (ed.) Barriers and Bridges to the Renewal of Ecosystems and Institutions. NY: Columbia University Press, 489-532. 1995.

HAGGETT, P. A. D. CLIFF & A. FREY. Locational Analysis in Human Geography. Bristol, UK: Edward Arnold. 1965 (1977).

HOLLING, C.S. Resilience and Stability of Ecological Systems. Annual Review of Ecological Systems, 4:1-23, 1973.

KREMEN, C. Managing Ecosystem Services: What do we need to know about their Ecology? Ecology Letters 8: 468-479, 2005.

KRUGMAN, P.R. The Self-Organizing Economy. Blackwell, Cambridge, MA. 1996.

LEWONTIN, R.C. The Bases of Conflict in Biological Explanation, Journal of the History of Biology 2: 34-45, 1969.

LOW, B., E. OSTROM, C. SIMON & J. WILSON. Redundancy and Diversity: Do They Influence Optimal Management? In F. Berkes, et al. (eds). Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge, UK: Cambridge University Press, 2003

MORRIS, R. F. The Dynamics of Epidemic Spruce Budworm Populations, Memoirs of the Entomological Society of Canada 31: 116-129, 1963.

PATON D. & JOHNSTON D. Disasters and Communities: Vulnerability, Resilience and Preparedness. Disaster Prevention and Management 10: 270-277, 2001.

PATON, D., MILLAR, M. & JOHNSTON, D. Community Resilience to Volcanic Hazard Consequences. Natural Hazards, 24: 157-169, 2001.

PICKETT, S.T.A., M.L. CADENASSO & J.M. GROVE. Resilient Cities: Meanings, Models, and Metaphors for Integrating the Ecological, Socio-Economic, and Planning Realms. Landscape and Urban Planning, 69, 236-84. 2004.

PICKETT, S.T.A., M.L. CADENASSO, et al. Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socio-Economic Components of Metropolitan Areas. Annual Review of Ecology and Systematics, 32: 127-157, 2001.

PENN, M. Micro-Trends: The Small Forces behind Tomorrow's Big Changes. New York: Hachette Book Group, 2007.

PETERSON, G., C.R. ALLEN & C.S. HOLLING. Ecological Resilience, Biodiversity, and Scale. Ecosystems, 1:6-18, 1998.

PORTUGALI, J. Complexity Theory as a Link Between Space and Place. Environment and Planning A. 38: 647-664, 2006.

PORTUGALI, J. Self-Organization and the City. Heidelberg, GE: Springer, 1999.

QUERCIA, R. & GALSTER, G. Threshold Effects and Neighborhood Change. Journal of Planning Education and Research. 20: 146, 2000.

SCHELLING, T. Micromotives and Macrobehavior. New York, W.W. Norton & Company, Inc. 1978.

SMIT, B., WANDEL, J. Adaptation, Adaptive Capacity and Vulnerability. Global Environmental Change. 16,3: 282-292, 2006.

SUKOPP, H., M. NUMATA & A. HUBER (eds). Urban Ecology as the Basis for Urban Planning. The Hague: SPB Academic, 1996.
WALKER, B., C.S. HOLLING, S.R. CARPENTER & A. KINZIA. Resilience, Adaptability and Transformability in Social-Ecological Systems. Ecology and Society, 9(2): 5-13, 2004.
WHITEMAN, G. ET AL. Bringing Feedback and Resilience of High-Latitude Ecosystems into the Corporate Boardroom. Ambio 33(6): 371-376, 2004.