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From fail-safe to safe-to-fail: sustainability and resilience in the new urban world

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Abstract: The extent to which the 21st Century world will be "sustainable" depends in large part on the sustainability of cities. Early ideas on implementing sustainability focused on concepts of achieving stability, practicing effective management and the control of change and growth-- a "fail-safe" mentality. More recent thinking about change, disturbance, uncertainty, and adaptability is fundamental to the emerging science of resilience, the capacity of systems to reorganize and recover from change and disturbance without changing to other states-- in other words, systems that are "safe to fail." While the concept of resilience is intellectually intriguing, it remains largely unpracticed in contemporary urban planning and design. This essay discusses the theory of resilience as it applies to urban conditions, and offers a suite of strategies intended to build urban resilience capacity: multi-functionality, redundancy and modularization, (bio and social) diversity, multi-scale networks and connectivity, and adaptive planning and design. The strategies are discussed in the context of resilience theory and sustainability science, and are illustrated with innovative policies, projects, and programs selected from international examples.

Paul,

thanks for your patience.
The reviewer's comments were particularly helpful and challenging. Please pass on my gratitude.
I've attempted to respond to the comments without overly-expanding the length of the essay.

best,

Jack

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Complete Title Page

From *fail-safe* to *safe-to-fail*: sustainability and resilience in the new urban world

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1. The new urban world

Sometime in the year 2007, demographers estimated that global population became predominately urban for the first time in history. Estimates from multiple sources including the United Nations predict this trend to continue throughout this century, with the world's population reaching 70% urban by 2050. These global data mask significant differences in urban population trends between the developed and the developing world – where much of the increase in urban inhabitants will occur. Despite these regional differences, the world is undeniably becoming more urban – with profound impacts on land use, human welfare, social equity and sustainability, broadly defined. Therefore, the challenge for sustainability in the 21st Century will, arguably, be won or lost in cities and their larger urban regions.

2. Sustainability, equilibrium and resilience

"Expect the best, plan for the worst, and prepare to be surprised" --*Denis Waitley*

The modern era of the 20th century was arguably associated with an equilibrium, or deterministic conception of nature, science and ecology. Developed societies embraced a "fail-safe" mentality based on the promise of science and technology to meet social and economic needs, cure disease, and undo the environmental mistakes of previous generations.

In the latter half of the 20th century, more-or-less coincident with the advent of sustainability, an alternative, non-equilibrium paradigm of science, of systems, and of the understanding of the natural and built environment emerged (Botkin, 1990). This view, known as chaos or non-equilibrium theory, argued that natural and cultural systems are inherently variable, uncertain, and prone to unexpected change.

The fields of ecology and resource management were early adopters and practitioners of the non-equilibrium view. Landscape ecology evolved as an interdisciplinary field that defines landscapes as heterogeneous spatial entities, with inherent disturbance regimes in terms of type, frequency, and intensity of disturbance(s). With its focus on landscape pattern-process relationships, landscape ecology explicitly and systematically brought the non-equilibrium view to landscape planning, particularly in terms of landscape form, pattern, and change (Turner, 1990). Concurrently, resource management adopted the concept of adaptive management through which managers could address uncertainty and "learn-by-doing" through the conception and design of management actions as "experimental probes" that could "adapt" if the results were not as expected, or to learn new methods when the actions were proven to be effective.

In landscape and urban planning, early thinking about sustainability, however, tended towards a static conception – where sustainability was envisioned as a durable, stable, sometimes formulaic "fail-safe" urban form or condition that – once achieved - could persist for generations, for example through "smart growth" or "new urbanism". From a non-equilibrium perspective this conflated view of sustainability and stability is paradoxical. How can a static landscape condition be sustainable in a context of unpredictable disturbance and change? A more relevant position "safe-to-fail" anticipates failures and designs systems strategically so that failure is contained and minimized (Steiner 2006). Resilience theory offers a new perspective, or possibly a solution to this paradox of sustainability.

Resilience is defined as the capacity of system to respond to change or disturbance without changing its basic state (Walker and Salt, 2006). Building resilience capacity through landscape and urban planning requires that planners and designers identify the stochastic processes and disturbances that a particular landscape or city is likely to face, the frequency and intensity of these events, and how cities can build the adaptive capacity to respond to these disturbances while remaining in a functional state of resilience (Vale et al., 2005). Resilience capacity also requires building an adaptable social infrastructure to assure meaningful participation and achieve equity in the face of socio-economic change and disturbance, and meaningful participation by stakeholders in planning and policy decisions. Resilience demands a new way of thinking about sustainability. Resilience is a more strategic than normative concept, because, to be effective, resilience must be explicitly based on, and informed by, the environmental, ecological, social, and economic drivers and dynamics of a particular place, and it must be integrated across a range of linked scales (Pickett et al., 2004). In addition, by definition, resilience depends on being able to adapt to unprecedented and unexpected changes.

Resilience capacity can be strengthened by biodiversity, modularity, tight feedbacks, social capital, acknowledging slow variables and thresholds, and innovation (Walker and Salt, 2007). Resilience capacity is well-suited to an adaptive approach to planning and design, in which innovation is pursued through responsible experimentation, developing a culture of monitoring, and learning from modest failures.

Sustainability science (SS) is an emerging interdisciplinary field that shares principles, goals, knowledge and operating methods with sustainability and resilience theory. SS also shares many fundaments of landscape ecology including the many approaches to study nature-society interactions in heterogeneous and dynamic landscapes at multiple scales (Wu, 2006). SS is problem-solving focused. It addresses the dynamic interactions between nature and society, considering both how social change influences the environment and how environmental change shapes society. SS aims to provide knowledge “co-produced” by scholars and practitioners to inform decision making for sustainable development (Clark and Dickson, 2003). SS also addresses the behavior of complex self-organizing systems (e.g. cities) supporting social “actors” to engage sustainability and resilience challenges in the face of uncertainty and limited information (Kates et al., 2001).

3. Strategies for building urban resilience capacity

A proposed suite of five urban planning and design strategies for building urban resilience includes: multifunctionality, redundancy and modularization, (bio and social) diversity, multi-scale networks and connectivity, and adaptive planning and design. These strategies are discussed below and further explained in (Ahern, 2010).

3.1. Multifunctionality

In the new urban world, planners and designers will be challenged to find new ways to provide for sustainable ecosystem services in the increasingly limited spaces within compact cities. Multifunctionality can be achieved through intertwining/combining functions, stacking or time-shifting. It is inherently efficient spatially and economically, and benefits by support from the social constituents and stakeholders associated with the multiple functions provided. Multifunctionality supports response diversity in the functions provided. Examples include the Green Streets program in Portland, Oregon, urban stormwater wetlands as at Potsdammer Platz in Berlin, Germany, wildlife highway crossings as in Banff National Park, Alberta,, and floodplain parks as in Buffalo Bayou, Houston Texas.

3.2. Redundancy and modularization

Redundancy and modularization are achieved when multiple elements or components provide the same, similar, or backup functions. Redundancy and modularization spread risks - across time, across geographical areas, and across multiple systems. When a major urban function or service is provided by a centralized entity or infrastructure, it is more vulnerable to failure. When the same function is provided by a distributed or decentralized system, it is more resilient to disturbance. Redundancy and modularization are strategies to avoid putting "all your eggs in one basket," and for preparing and pre-planning for when (not if) a system fails. Examples include site or sub-watershed based sewerage or stormwater systems as in the Chicago, Illinois Green Alleys program, or the Augustenborg Housing Project retrofit in Mälmo, Sweden.

3.3. (Bio and social) diversity

Biodiversity along with social, physical, and economic diversity, are important and effective strategies to support urban resilience. Biodiversity has been described metaphorically as a "library of knowledge," some of which is familiar and valued, while some remains "unread, but on the library shelves" waiting for its value or function to be discovered (Lister, 2007). Response diversity in biological systems refers to the diversity of species within functional groups that have different responses to disturbance and stress (e.g., temperature, pollution, disease). Thus with a greater number of species performing a similar function, the ecosystem services provided by any functional group—for example, the decomposers - are more likely to be sustained over a wider range of conditions, and the system will have a greater capacity to recover from disturbance. An example of response diversity applied to urban bio-physical systems includes low impact development practices such as permeable pavement and bioswales, and urban tree canopy managed to intercept rainfall before it reaches the ground. Each feature adds to the response diversity of the urban stormwater system, reducing the amount of storm drainage infrastructure that a city needs to build and maintain, and enhancing the overall resilience capacity of that system. Likewise, cities with higher levels of economic and social diversity have a more complex response diversity by which they are better positioned to adapt to change and socio-economic disturbance. For example, an economically and socially diverse city can support social services and cultural programs that keep it economically vibrant, equitable, and attractive place for people to live and work , despite economic and social disturbances. In contrast, less socially-diverse communities often struggle to recover from disturbances and show characteristics of non-resilience, by “flipping” to other conditions.

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3.4. Multi-scale networks and connectivity

Networks are systems that support functions by way of connectivity. When an urban landscape is understood as a system that performs functions, connectivity is often the critical parameter - and the lack of connectivity is often a prime cause of malfunction or failure of particular functions. Multi-scale connectivity is important when planning for functions that operate at multiple scales: for example walking trails that link with bus routes, or urban drainage swales that connect to non-channelized low-order streams, that, in turn, link with higher-order streams. In urban environments, connectivity of built systems is generally robust but in natural systems is typically greatly reduced, often resulting in fragmentation—the separation and isolation of urban landscape elements with significant impacts on specific ecological processes that require connectivity (e.g., species dispersal and movement). Complex networks build resilience capacity through redundant circuitry that maintains functional connectivity after network disturbance(s). Connectivity is arguably a primary generator of sustainable urban form - built around blue-green networks that support biodiversity, hydrological processes, pedestrian transportation, climatic modification, neighborhood identity and aesthetic enhancements. Examples of multi-scale networks include many greenways and ecological networks, and the Staten Island Bluebelt that supports urban drainage, wildlife habitat and recreational functions in New York City.

3.5. Adaptive planning and design

Adaptive planning and design conceives the “problem” of making decisions with imperfect knowledge about change and uncertain disturbances as an “opportunity” to “learn-by-doing” (Holling, 1978). Under an adaptive model, urban plans and designs can be understood as hypotheses of how a policy or project will influence particular landscape processes or functions and implemented planning policies or designs become “experiments” from which experts, professionals, and decision makers may gain new knowledge through monitoring and analysis. While adaptive management has been practiced successfully in natural resource management for decades, its application to urban planning and design is rare. If urban planning and design is truly innovative and adaptive in its pursuit of sustainability and resilience, it has an inherent potential to fail. To reduce the risk of failure, innovations can be “piloted” as “safe-to-fail” design experiments (Lister, 2007). The Sustainable Sites initiative is explicitly recognizing monitoring activities in support of an adaptive approach in sustainable site design. Examples of adaptive planning and design include the unprecedented restoration and remediation at the Emscher Landscape Park in Germany, and the SEA Street project in Seattle, Washington.

4. Discussion and research needs

Resilience is a complex, multi-dimensional challenge for urban sustainability planning and design. The strategies proposed above will require a new culture of innovation, monitoring and assessment of plans and built works – from which plan and project-specific data can be obtained to "test" the hypotheses that innovative plans and designs inherently represent. Assessment of ecosystem services is gaining acceptance as a universal and explicit approach to the measurement of sustainability, and has proven useful to spatially associate urban form with multiple social, and biophysical functions. Recent sustainability initiatives including LEED and Sustainable Sites offer protocols for more rigorous assessment of built works, in specific terms, but could be expanded to monitor performance and impacts over time.

Achieving a resilient sustainability will depend on significant innovations. In the 21st century, much of the infrastructure of the developed world will be replaced or rebuilt, and even more infrastructure will be needed to service the rapidly expanding cities of the developing world. Ironically, when viewed as an opportunity, the magnitude of global infrastructure (re)development represents an unprecedented opportunity to redirect and (re)conceive the process of urbanization from one that is inherently destructive to one that is sustainable and resilient in specific terms. This is the promise and challenge of green infrastructure as a key idea to build resilience capacity.

Finally, these challenges will demand a higher level of inter- or transdisciplinary collaboration in both research and practice than presently exists. Both the established U.S.

National Science Foundation's Urban Long Term Ecological Research Program (LTER) and the newer U.S. National Science Foundation - U.S. Forest Service' Urban Long Term Research Area program (ULTRA) are models for the type of long term, interdisciplinary research on complex urban systems needed to build resilience capacity that is a prerequisite of sustainability.

Addressing the challenges of sustainability and resilience arguably will require a transdisciplinary, integrative sustainability science that differs from science as we know it in terms of the structure, methods and content of the questions we ask. In addition to adaptive design focused on physical urban systems, and urban biodiversity, research is needed on how to achieve greater social learning and meaningful social engagement and participation in decision-making and policy setting. Research is needed to learn what makes knowledge about nature-society interactions useful within both science and society to build resilience capacity and to guide society on a sustainable trajectory (Kates et al. 2001). Solutions for sustainability and resilience therefore are more likely to evolve from such inter- and transdisciplinary research and project-based collaborations involving an increasing number of overlapping and complimentary disciplines.

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***Short Author Biographies**

Jack Ahern

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Jack Ahern is a landscape architect who focuses his research on the application of landscape ecological theories, principles and methods on landscape planning and design projects. Earlier, he worked on broad-scale integrated systems of protected lands known as greenways – linking their spatial configuration and resource base with ecosystem services and human use(s). This work led him to the Netherlands for cross-cultutural research on landscape planning and ecology, leading to his Ph.D. from Wageningen University (2002). His books address multiple aspects of his applied research including: Water-Centric Sustainable Communitis (2010) (Co-author), Measuring Landscapes: A Planner's Handbook (2006) (Co-author), Biodiversity Planning and Design: Sustainable Practices (2006) (Lead co-author), Greenways as Strategic Landscape Planning: Theory and Application (2002); A Guide to the Landscape Architecture of Boston (1999); Greenways: the Beginning of an International Movement (1995) (Co-author).

Ahern's current research has shifted to applied ecologically-based planning and design of urban environments for sustainability and resilience. This work continues to engage landscape ecology as a theoretical platform to integrate the emerging, fine-scaled professional practices of green infrastructure and landscape urbanism across scales to form green urban networks linked with ecosystem services, sustainability and to build resilience capacity.