Refining the Resilience Narrative:
A critical reflective review of the current discourse

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Contents

Introduction

The winds of change blow across the world making branches sway. Like leaves on a tree, people live in an ever more complex world supported by a branching network of systems. As the winds blow, some leaves dance on the breeze while others flutter through the air, losing their attachment and life. At times branches and trunks break. Gaps appear in the spider web of systems that form the canopy, and more leaves fall.

Also like the leaves, many people live with uncertainty and the fear of falling. The complex web of systems on which our survival depends is poorly understood and often beyond ability to control as individuals or even communities and nations. Seen from above, the mosaic pattern of leaves that form the forest canopy is resilient. The diverse colors of different species, each adapted to the land hidden below, combine to form a kaleidoscope of patterns that wave in the wind and evolve as the seasons slowly change: dynamic, alive and ever shifting. The mosaic of life supported by branches is a metaphor and parallels the mosaic of society supported by systems. New leaves emerge while older ones fall becoming mulch on the forest floor. Occasionally large fires sweep through, opening spaces in the canopy for grasses and a whole new, and at times different, generation of trees and species.

The complex web of systems on which our survival depends is poorly understood and often beyond our ability to control as individuals or even communities and nations.

Below the ground, roots reach out tapping water and nutrients. A hidden inverse tree linked upward to the canopy by trunks through which flow the building blocks of life: water, energy, nutrients and, most hidden of all, information. News of the changes in season, the daily cycle of sun and shadow, the needs for water and nutrients, all these pass as hidden communications from leaf to branch to trunk to root and back again in an endless cycle. The roots of each tree intertwine with others in patterns of symbiosis and competition. Collaboration and competition co-exist. The flows of nutrients, water and energy are modulated by the forest as a whole but are also subject to capture by the most deeply rooted and healthy trees.

The tree is only one element in a forest, and the forest is renewed through cycles of dynamic change: fires, senescence, disease and pests—all are essential to let the light in, release the nutrients locked in aged wood, and allow new trees to access the sun and grow. Even with individual trees, leaves age with the seasons and fall before new leaves can grow. Lower branches age and wither and must be pruned. Removal of the deadwood is key to a longer life. Dynamic change in the forest opens space for diverse species of plants and animals: each with their own population dynamics and predator-prey relationships. Resilience of the forest is a balancing act with long-term damage to all when individual species dominate, and the forest loses its dynamic diversity or predators disappear and populations explode.

A resilient ecosystem reflects the dynamic cycles of its constituent species. At multiple levels both these species and the ecosystem itself cycle through phases of growth, disruption, reorganization and renewal: or, to put it another way, birth, growth, maturation, death and rebirth. Resilience is lost when these cycles are blocked and the ecosystem becomes increasingly structured and rigid. In such situations, diversity and flexibility decline and ecosystems can become trapped in low productivity states that are highly resilient to change. A strong but brittle tree may resist the wind for a while, but when it blows too hard the roots give way or the trunk breaks. Forests where the trees are all the same age or species remain green until contagion strikes and a disease, a pest, a storm, or a drought sweeps through, following a common strand of vulnerability. Then the ecosystem collapse is far more dramatic, fundamentally altering the structure and function of the forest and tipping it to grassland or some other form of ecosystem with new patterns of productivity, resilience, and vulnerability.

This is the foundational analogy increasingly being used to describe complex socio-ecological systems. It guides much thinking on the dynamics of human society as well as natural ecosystems. In some ways it may be more than an analogy. People are, after all, animals and a central part of the global ecosystem. There is little reason that the principles we have observed that underlie natural ecosystem dynamics should not apply to humans as well as other species within ecosystems.

What is the meaning of resilience? What is its purpose and who does it benefit? On what time, institutional, or geographic scale? Toward what ultimate objective? What are the tradeoffs, who chooses, who loses, and who gains? Can resilience be for everyone?

But here many loud voices say, "*What about agency, governance, and the institutions we create?*" Humans have the ability to act and shape their environment. Complex political dynamics shape relationships and together with institutional rules govern the approaches we develop to manage and shape the world we live in. The point is a good one: agency, political relationships, and institutions have a huge influence. Whether or not they really free us from the basic principles applying to all other ecosystem elements is, however, far from certain. We're an adaptive species, but some other species are as well. At the same time, it's clear that unlike the leaves on the tree, individuals, families, and higher-level organizations have spaces in which they can and do act to shape their environment, lives, and livelihoods. Furthermore, the complex interactions of culture, law, politics and economics produce patterns of competition and symbiotic collaboration that shape both the broad mosaic of society and the action space of agents at different levels from the individual upward. Do the consequences of agency and institutions trump the underlying drivers of ecosystem dynamics in determining social outcomes?

The purpose of this paper is to explore this question and the implications our understanding of complex systems dynamics have for efforts to address some of the real challenges we now face in the context of globalization, rapid urbanization, and climate change. We follow the analogy, explore the questions it poses and, along with the role of agency, ask: *What is the meaning of resilience? What is the purpose of resilience and who does it benefit; on what time, institutional, or geographic scale; toward what ultimate objective? What are the tradeoffs, who chooses, who loses, and who gains? Can resilience be for everyone?*

Core Arguments

The purpose of this working paper is to present a critical reflective review of the current academic and applied policy discourse on resilience with the dual goal of:

1. Strengthening the ability to apply systems approaches and associated resilience concepts to the very real challenges global society faces in the context of climate, urbanization, globalization and other change processes.

2. Identifying points of tension between the underlying scientific understanding of system dynamics, human agency, and the social or policy objectives disaster mangers, development organizations and other such entities seek to achieve.

Using results of our review, the working paper makes five core arguments:

- **First**: We argue that, particularly in policy and application contexts, the focus on resilience per se can be misleading.
- **Second**: We argue that resilience is not always desirable.
- **Third**: We argue that, at least in an applied sense, resilience depends heavily on context.
- **Fourth**: We argue that where resilience is an appropriate goal, it is likely to emerge as a consequence of numerous small "solutions," often ones that build off or enable existing social responses rather than as a consequence of large-scale planned or proactively designed interventions.
- **Fifth**: We argue that, rather than resilience, transformation may be a more powerful concept in some contexts.

Understanding factors that affect the resilience and dynamics of a system underpins the ability to enhance or support socially desirable outcomes and, equally, the ability to unpack and change less desirable situations.

First: we argue that, particularly in policy and application contexts, the focus on resilience *per se* can be misleading.

While resilience as a term has clear advantages due to the way it resonates across many social and political divides, the underlying understanding of system dynamics is ultimately of greater importance. Resilience is a property of systems. It emerges as a consequence of factors within systems, such as their diversity, flexibility, ability to learn, responsiveness, and how those factors affect dynamics. Understanding these factors underpins the ability to enhance or support socially desired outcomes

and, equally, the ability to unpack and change less desirable situations. As a result, rather than focusing on resilience *per se*, a more appropriate question might be: *What factors contribute to the resilience of what systems, for what purpose, for whom*?

Tradeoffs between resilience at one level within systems or between system components can result in tensions between the benefits of resilience to society as a whole and the impacts of disruption or change for those who depend on specific subsystems.

Furthermore, the general resilience of an ecosystem, economy, or urban area (all of which are "systems of systems") may be different from the specific resilience of the many subsystems of which it is composed. Tradeoffs may exist between resilience at one level within systems or between system components. In fact, patterns of dynamic and relatively rapid change or collapse within subsystems may be of fundamental importance to the resilience of the larger system as a whole. This is akin to the notion of robustness trade-offs in engineered systems (Csete & Doyle, 2002). It raises the issue of general resilience versus specific resilience (see Box 1). From a social or policy perspective, this suggests inherent tensions between the benefits of resilience that may accrue to society as a whole and the impacts of disruption and change for those who depend on or are part of specific subsystems. This tension between general and specific resilience is poorly recognized in policy and applied debates. The benefits of resilience are real, but so are the costs.

BOX 1

General versus specific resilience

General resilience is commonly thought of as a generic property of systems. It has to do with the system's ability to retain structure and function when subject to diverse shocks and stresses including those that have never been identified, are considered unlikely, or may only occur in the future. Specific resilience, on the other hand, refers to the resilience of specific systems to specific stresses. That is to say, the question of "resilience of what, to what?" (Folke et al, 2010). While general resilience has strong conceptual appeal, it is difficult to define or implement in practice because:

1. Contexts can experience fundamentally different types of disturbances where resilience depends on different and sometimes conflicting factors;

2. Different scales of disruption require different forms of resilience—the factors that contribute to resilience at one level of stress may undermine it if stress levels pass critical thresholds; and

3. Human processes generally respond to specific identified problems and opportunities rather than more abstract conceptual challenges.

Second: We argue that resilience is not always desirable.

States that have high resilience can be undesirable. According to the Resilience Alliance, resilience "has three defining characteristics: The amount of change the system can undergo and still retain the same controls on function and structure; the degree to which the system is capable of self-organization; and the ability to build and increase the capacity for learning and adaptation" (as cited in Allison & Hobbs, 2012, p. 184). These characteristics can, however, be present in, for example, social, economic and land-tenure systems where poverty dominates and is entrenched due to systemic features that ensure replication in the face of dynamic economic or other change processes. They can also be present in water, energy, transportation, land-use, or other critical environmental and infrastructure systems that are either ultimately unsustainable or have major undesirable aspects such as pollution or species loss.

States that have high resilience can be undesirable.

Third: We argue that, at least in an applied sense, resilience depends heavily on context.

Even at the level of meta-systems, such as urban areas or economies, as opposed to within individual sub-systems, context matters. Substantial research has focused on the degree to which characteristics of a system, such as diversity, contribute to resilience in relation to a broad range of potential sources of disruption (Ahern, 2011; Carpenter et al., 2012; Fiksel, 2003; Walker et al., 2014; Walker & Salt, 2012b; Youn et al., 2014). Our review suggests, however, that in many cases the factors discussed as contributing to general resilience actually address a specific set of known or projected sources of disruption. If evaluated against either different forms or levels of stress, those very interventions would often increase the likelihood of system collapse (see examples in Box 2). The idea of resilience as a "general property" that responds to uncertainty by protecting against multiple hazards and widely varying levels of stress could easily be taken too far. Doing so would create a false sense of security and potentially open the door to larger disasters.

Resilience depends on the nature of the stress and the context.

BOX 2

Contexts where attempts to build 'general' resilience could lead to system collapse

1. While attempts to strengthen networked relationships within communities, between organizations, and with economies can contribute to climate and disaster resilience, those same sets of relationships can increase the potential of contagion from diseases, panic, or other viral forms of disruption that spread via networks.

2. Increasing the resilience of flood defenses to extreme storms may contribute to the overall resilience of the urban area but it only does so if climate extremes do not exceed the buffering capacity of the system. If flood responses fail, the effects on an urban system can be catastrophic. It is, as a result, important to understand both the potential threshold storm or flood levels where failure might occur and to design in ways that allow safe failure.

Given that an extremely broad array of factors contribute to the resilience of the aggregate "system-of-systems" that comprise an urban area, building resilience can require numerous, generally small, interventions within sub-systems.

Fourth: We argue that where resilience is an appropriate goal, it is likely to emerge as a consequence of numerous small "solutions," often ones that build off or enable existing social responses rather than as a consequence of large-scale planned or proactively designed interventions.

Resilience is an emergent property of systems. It emerges as a consequence of a fairly diverse array of factors at different scales within systems (see Box 4).

Resilience frameworks, such as those represented in Box 3, represent attempts to categorize and, in a highly simplified manner, represent the extremely broad array of factors that contribute to the resilience of the aggregate "system-of-systems" that comprise an urban area. Resilience of this meta-urban system emerges as a consequence of many, many factors within each of the sub-systems. Building resilience, as a result, can require numerous, generally small, interventions within each of these sub-systems. Like a mosaic, the portrait of urban resilience is assembled out of many small individual elements that on their own represent little, but taken together create a broader pattern.

BOX 3

Examples of climate resilience frameworks

1. The Climate Resilience Framework (CRF) developed by the Institute for Social and Environmental Transition (ISET)-International identifies 12 broad characteristics that contribute to resilience of physical systems, the human agents associated with systems, and institutions (Friend & MacClune, 2012; Tyler & Moench, 2012). These characteristics are aggregates that relate to a much more diverse array of specific physical, social, and institutional features.

2. The "City Resilience Framework" developed by Arup and the Rockefeller Foundation contains numerous measures that serve as indicators for a much more diverse array of actual conditions on the ground within urban areas. This framework attempts to measure resilience on the basis of four categories with 12 key indicators, 48-54 Sub-indicators, and 130-150 variables (Da Silva & Morera, 2014).

BOX 4

Urban areas as 'systems-of-systems'

The urban ecosystem is amorphous. It is made up of many other systems including, but not limited to, electricity, water, sewage, health, and institutional systems. In order to look at these systems in isolation and pinpoint the area in which resilience needs to be built, it is necessary to understand existing system dependencies. The water system, for example, is dependent on water sources in the external ecosystem to provide water and on electricity to treat the water before it is distributed. It is also dependent on management and regulatory systems, which are parts of wider social and political organization systems, and so on. The water system and the other systems it depends on to function aggregate to make up what we know as a part of the urbanscape.

When someone is talking about building resilience in the water system, for example, they could be referring to a number of different things. They could mean how to diversify water supply or change the organizations that provide water. Alternatively they could focus on how the ecosystems that provide water are managed. What they are referring to depends heavily on historical patterns of development and the highly contextual nature of interactions. Ultimately, what will make a water system resilient depends on where the fragility is in a particular context.

Fifth and finally: We argue that, rather than resilience, transformation may be a more powerful concept in some contexts.

Systems often fluctuate within a distinct array of conditions, or in resilience terminology "basin of attraction," where self-reinforcing feedback loops serve to maintain a particular status (Walker, Holling, Carpenter, & Kinzig, 2004). They can "tip" out of that basin and move to a new meta-stable state when feedback loops are disrupted to the extent that they no longer reinforce and reproduce the existing system configuration. Conditions can shift from a positive, desirable state to one that is undesirable or vice versa (Allison & Hobbs, 2004; Carpenter & Brock, 2008; Holling, 2001; Maru, Fletcher, & Chewings, 2012). In either case, the initial status of the system may be highly resilient, reinforced by multiple feedback loops and persistent over time despite widely changing conditions. The change between states occurs during events where the basic structure and function of the self-reinforcing feedback loops are altered and the system "tips" or transforms into a different state.

Addressing issues such as the decarbonization of energy systems in response to climate change requires fundamental and relatively rapid "transformative" changes in the structure and function of key systems.

Most strategies to build resilience involve incremental changes over an extended period of time; as wider conditions evolve, the system adapts, yet retains the same feedback loops and controls on function and structure. The changes do not fundamentally reshape society or the systems on which we depend. They also occur gradually rather than as a relatively abrupt shift in system characteristics. Such strategies, therefore, make far less sense in relation to needs that are more transformative such as the need to shift global energy systems away from fossil fuels or the basic socio-political conditions that keep large populations locked in poverty. Addressing these issues would require fundamental and relatively rapid "transformative" changes in the structure and function of infrastructure, economic, or political systems rather than incremental changes that retain pre-existing structure, function and feedback loops.

Overall, the above core arguments shift attention away from "resilience" *per se* and toward the need for a deeper and more nuanced understanding of system dynamics and their implications for real world problems. Basic questions need to be asked regarding resilience *of what, to what, through what process, for what purpose, and for whose benefit*? Distinctions also need to be made between resilience at an aggregate level and that at the level of specific sub-systems, groups, or individuals. In many, if not most, cases *this may involve real tradeoffs* where the benefits of resilience do not accrue directly to those who bear the costs. Finally, the arguments suggest that resilience is not always an appropriate goal. Building resilience can reinforce the entrenched feedback loops within society that maintain undesirable elements of the status quo. In such contexts, understanding of system concepts may be useful for driving more transformative change processes: "tipping" systems rather than reinforcing resilience.

Context

Recognition of the unavoidable implications of climate change for society underpins the increasing attention devoted to resilience among those working on adaptation. In addition, resilience concepts have widespread relevance in relation to other sources of disruption, whether those are related to economic change, conflict, health or other factors. Resilience—in popular terms connoting flexibility, elasticity and the ability to resist, spring back, and do well in the face of disruption (Resilience, 2015)—has meanings that span many political and social divides while also suggesting practical courses of action in response to diverse threats. As a rallying cry, it's hard to be against. It is, however, equally difficult to define what resilience really is, or more accurately, what the factors that contribute to resilience really are.

Scientifically, resilience concepts have emerged primarily from research in ecological system dynamics, engineering, and psychology (Bonanno, 2004; Holling, 1973; Hollnagel, Paries, David, & Wreathall, 2010; Hollnagel, Woods, & Leveson, 2007). In ecological system dynamics it refers to "the amount of change a system can undergo (its capacity to absorb disturbance) and remain within the same regime—essentially retaining the same function, structure, and feedbacks" (Walker & Salt, 2012a p. 215). In engineering, resilience has generally been used to describe the ability and speed with which a material or system can absorb energy or another stress and then return to its original state (Holling, 1996). The emphasis here is on steady state conditions and the speed of return to those conditions following disturbance. Finally, in psychology, resilience generally refers to the ability of people to "maintain relatively stable, healthy levels of psychological and physical functioning" following trauma or in relation to the "protective factors that foster the development of positive outcomes and healthy personality characteristics among children exposed to unfavorable or aversive life circumstances" (Bonanno, 2004, p. 20). Beyond this, there are tens if not hundreds of definitions of resilience put forth by different authors in a wide array of fields and applications that attempt to capture nuances in the concept (CARRI, 2013). All the definitions contain basic connotations of "recovery" or "continuity" in the face of disruptions. Beyond that, they vary with respect to, for example, whether recovery and continuity imply a return to pre-existing conditions, relate to structure and function of a system, contain notions of adaptation or change, or relate to the continuity of conditions such as human wellbeing.

While it is hard to be against resilience, it is equally difficult to define what resilience really is, or more accurately, what the factors that contribute to resilience really are.

Despite the wide variety of definitions, resilience concepts have clear relevance in relation to the impacts anticipated as a consequence of climate change. These impacts are, in any given location, difficult to predict. In addition, the changes anticipated often relate to increases in variability and the occurrence of extreme events. Resilience in the broad sense of the ability to respond to surprises and the unpredictable impacts of change processes (climate, economic globalization, urbanization) is clearly important. This relevance is enhanced by increased reliance on complex food, water, energy, communication, economic, and socially networked systems to meet essential needs. Disruptions in such systems can cascade across systems and regions. Because very few people, particularly in urban areas, now

depend primarily on local resources, the wellbeing and indeed survival of large human populations depends on the resilience and sustainability of global systems.

Given the above, there has been a flowering of use of resilience terminology. In 2013 it was suggested as the "buzzword" of the year in Time Magazine (Walsh, 2013). Academically, the home for most research on the resilience of social-ecological systems is the Resilience Alliance and its associated journal, *Ecology and Society*[1]. At the same time, organizations such as the Rockefeller Foundation have adopted resilience concepts as the basis for major programs with urban governments, development organizations and a wide array of other entities as a core applied approach for "managing disruption, avoiding disaster, and growing stronger in an unpredictable world" (Rodin, 2015). Similarly, USAID has now adopted resilience as a core organizing principle across its programs and has established the Global Resilience Partnership (USAID, 2015). Resilience has become, some argue, a core development goal in its own right (Béné, Wood, Newsham, & Davies, 2012; Davoudi et al., 2012; Friend & Moench, 2013; Leach et al., 2007).

Though resilience is becoming an increasingly important goal globally, tensions are emerging regarding resilience of what, for what purpose, and for whose benefit. Who decides such issues is also a point of tension.

As the use of resilience terminology has grown, so have tensions regarding its meaning and the real value it adds in development debates. Questions of equity and purpose are now increasingly being asked: the resilience *of what, for what purpose, and for whose benefit* has become a point of debate and along with questions concerning *who decides* (Béné et al., 2012; Friend & Moench, 2013; Leach et al., 2007). Conceptual tensions are also emerging regarding the universality of resilience characteristics and whether or not the ethical goals that are at the center of many global development debates, such as equity and good governance, are among those characteristics or are inherently separate considerations. The inherently positive connotations of resilience are also being challenged. There is growing recognition that systems and contexts can be highly resilient with respect to retaining the same structure, function and feedbacks following disturbance but also highly undesirable (Walker & Salt, 2012a). There is also a growing literature on "resilience traps" where strong feedback loops serve to impede change and maintain systems that have key undesirable features (Allison & Hobbs, 2004; Carpenter & Brock, 2008; Holling, 2001; Maru et al., 2012). Overall, as a result, while the use of resilience terminology has exploded, debate is growing apace.

Road map

The purpose of this paper is to outline key elements in the broad emerging narrative of resilience as applied to the nexus of urbanization and climate change. A key point is to bring different thought silos together in ways that increase understanding of the factors that contribute to resilience and the points of entry for action and the growth of effective responses to critical stresses. Key elements of the diverging discourses around resilience are presented first, followed by a deeper exploration of the conceptual foundations regarding the nature of cities and how that relates to the foundational concepts of resilience. This largely conceptual section is followed by a series of illustrative case studies drawn both from ISET-International's applied work in urban areas across South and South East Asia and from other sources. These cases are intended to illustrate both the utility of and issues inherent in the application of resilience concepts to the very tangible challenges facing rapidly developing cities and regions in the context of climate and other forms of disruption. The concluding sections of the paper synthesize critical tensions and points where the application of resilience concepts adds value to approaches for responding to the combined challenges emerging as a consequence of urbanization, climate and related change processes.

The concluding sections of the paper synthesize critical tensions and points where the application of resilience concepts adds value to approaches for responding to the combined challenges emerging as a consequence of urbanization, climate and related change processes.

Diverging discourses

There is a growing divergence between the use of resilience as a term in academic or policy contexts and among the general public. Furthermore, while the word is common in the English language, the English usage has only partial parallels in many other languages. In German, for example, rather than flexibility and elasticity, the term resilience is often translated in a way that connotes stability, indestructability, tension, strength and resistance while other words contain meanings closer to those in English (dict.cc, 2015). In Hindi, at least four separate words with differing connotations of flexibility and "returning to" a prior state are used as translations for the set of concepts captured by the one English term[2]. Similar divergences are common in other languages. As a result, we have found that the interpretation of resilience terminology itself is challenging across cultural contexts.

Broad distinctions are emerging between the discourse over resilience in academic and scientific circles, policy circles, and the public.

Beyond this, while any characterization of the manner in which resilience is used as a term will miss nuances or the elements emphasized by different groups, broad distinctions are emerging between the discourse in academic and scientific circles, the policy discourse, and the public discourse:

- **The academic discourse:** In the academic and scientific literature on complex systems, resilience is increasingly discussed as a multi-faceted attribute of complex social-ecological system dynamics (Adger, 2000; Gunderson & Holling, 2002; Walker & Salt, 2012a). Drawing on insights from a wide range of natural and social science disciplines, a wide range of factors thought to contribute to resilience has been identified. These factors are perhaps most well documented where physical systems are concerned and factors such as the diversity, redundancy, flexibility and safe-failure are commonly noted (Gunderson & Holling, 2002; Moench, 2014; Moench, Tyler, & Lage, 2011; Walker et al., 2004). The social science dialogue is also advancing although the factors that contribute to resilience are perhaps more widely debated. Key elements mentioned in the literature include responsiveness, ability to learn, resourcefulness, collective identity, social security, empowerment and leadership (Da Silva & Morera, 2014; Tyler & Moench, 2012). Overall, from both social and physical science perspectives, resilience is described as including the ability to learn from events and to adapt, evolve, and ultimately transform (Resilience Alliance, 2015c). It also involves recognition of the non-linear dynamics of social-ecological systems, the existence of alternative stability domains within such systems, and the presence of thresholds where systems can "tip" between different relatively stable states. Conceptually, shifts between alternative stability domains involve changes in the function, structure, and feedback loops that maintain conditions within a given domain. Conditions that push the system from one to another domain exceed the resilience of the original domain. Although the academic literature diverges somewhat on this, it is increasingly recognized that some stability domains are much less

desirable than others, regardless of their capacity to absorb disturbance and reorganize. As a result, resilience is not inherently positive. Undesirable states can also be highly resilient (Anderies, Walker, & Kinzig, 2006; Carpenter, Walker, Anderies, & Abel, 2001; Gunderson & Light, 2006; Maru et al., 2012). Furthermore, there is increasing recognition that the resilience of urban areas, economic systems or other aspects of human society does not inherently imply that the benefits of such systems will be equitably distributed or, more specifically, address the real needs of poor or marginalized groups (Béné, Newsham, Davies, Ulrichs, & Godfrey-Wood, 2014; Béné et al., 2012; Friend & Moench, 2013).

- **The policy discourse:** In contrast to the increasingly nuanced academic discourse, the policy discourse frames resilience as inherently positive. Judith Rodin's recent book, "The Resilience Dividend," captures some of the policy elements well (Rodin, 2014). Rodin argues forcefully, and to a large extent convincingly, that areas need to invest broadly in activities to build social, physical, and institutional forms of resilience in order to "survive and thrive" in a dynamic and uncertain world where the threat of disaster is increasing. The "resilience dividend" accrues because investments in resilience: (1) enable "individuals, communities, and organizations to better withstand a disruption"; and (2) "also enables them to build new relationships, take on new endeavors and initiatives, and reach out for new opportunities" (Rodin, 2014, 316). Rodin's book builds off a stream of policy related work over the last decade that views resilience of critical human livelihood, economic, and infrastructure systems as central components in any response to disaster, the increasing risks associated with climate change, and the ever-growing complexity of global socio-economic systems (DFID, 2011; Moench et al., 2011; www.PopTech.org). Resilience, defined as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies," was identified as a core part of the United States National Security Strategy in 2010 and as central in the 2014 Quadrennial National Security Review (Department of Homeland Security, 2014, para. 1). Similar statements can be found in documents from many international and national organizations (The World Bank, 2013). Overall, the policy discourse focuses heavily on resilience in the context of disaster and climate change with an additional emphasis on other sources of disruption, such as terrorism and social unrest. In practice, the emphasis is primarily on government led strategies, particularly projects, for proactive risk management and, when events occur, a slightly broader approach to supporting recovery than has historically been the case. Increasingly, resilience is seen as more than simply the ability to recover from events. It is framed as "bouncing forward" to improve conditions, or as changing systems in ways that fundamentally reduce interconnected risks. Elements of the policy discourse are increasingly criticized for their lack of attention to the distributional effects of resilience strategies, how they are governed, and whether or not they actually benefit some of the most vulnerable sections of society (Béné, 2013; Davoudi et al., 2012).

The academic discourse on resilience is more nuanced than the policy discourse with increasing recognition that resilience is not inherently positive.

The policy discourse often glosses over the distributional effects of resilience strategies, how they are governed, and whether they actually benefit the most vulnerable.

- **The public discourse:** Public discussions on resilience lack the nuances present in either the policy or academic discourse. In most of ISET-International's discussions with individuals and the general public, resilience is described primarily in terms of the ability to recover and return to the conditions that existed prior to a disaster or other event. It is also often equated with the personal or regional ability to withstand misfortune, personal trauma, or economic hardship. Although this may be slowly changing, most of those talking about resilience in this context rarely reference systems concepts or see resilience as involving the capacity to avoid risk or "bounce forward" to conditions that are substantially different and better than those existing prior to a disaster. Interestingly, in contrast to much of the policy discourse, individuals who are poor or in an otherwise disadvantaged position but are coping with it relatively well are often characterized as highly resilient. This is often the case with disasters or with individuals who have gone through a trauma such as loss of a job, a family death, or an illness. This represents a more psychological perspective on resilience. Resilience in the public discourse might best be defined as "the ability, particularly of the poor, to cope with adversity."

Resilience in the public discourse might best be defined as "the ability, particularly of the poor, to cope with adversity."

While the above discourses may have been described in overly simplistic terms, it is clear that the meaning of resilience differs greatly between those using it to describe the dynamics of social-ecological systems, those using it as a basis for public policy, and those using the word as part of every-day conversations. Because of this divergence, the next section focuses on some of the core conceptual issues related to resilience in the context of urbanization and climate change, the core focus of this paper.

Core conceptual issues

The structure of the city

This section makes two core arguments:

1. Cities are Complex Adaptive Systems (CAS) that are dynamic and responsive to change as a result of (1) agent behavioral drivers (economic, power, political); (2) networked relationships in critical systems; and (3) the invisible institutional "rules" that mediate both agent interactions and the growth of network structure.

2. Existing approaches to planning and building urban resilience using either broad-based stakeholder processes or more centralized strategies face inherent limitations.

There are inherent limitations to using either broad-based stakeholder processes or more centralized strategies for planning and building resilience.

Globally, cities are increasingly seen as Complex Adaptive Systems (CAS) in which a diverse array of agents, from individuals and households up to major businesses and governmental entities, interact to create and manage the equally diverse array of environmental, infrastructure and other systems that serve as the constituent elements defining city's physical form. CAS formulations emphasize self-organization and see system structures as emergent[3], or spontaneously and incrementally growing as a consequence of underlying dynamic interactions between agents (Holland, 1999). The interactions among diverse sets of agents lead to hierarchically structured, or nested, forms of organization across scales. Interactions both within and across system scales are dominated by non-linear dynamics and reflect multiple feedback loops and diverse information flows. The resulting system is dynamic, non-equilibrium, and responsive to change rather than static or directed toward a uniform development trajectory (Sanders, 2008).

While much of the thinking on Complex Adaptive Systems has emerged as a consequence of research in natural science fields such as biology and ecology, there is also a deep observational basis for it in economics and studies of urbanization. Von Thünen's model, which was originally developed and published in 1826, interpreted the land-use patterns associated with urbanization primarily as a function of transport economics (Von Thünen, 1966)—that is to say, as an emergent pattern arising from interactions between different agents in relation to the transportation time required to enable that interaction. This formulation remains an influential part of urban studies (Von Thünen, trans. 1966). More recent research on large urban data sets has documented remarkably regular scaling patterns in cities globally (Bettencourt, 2013b, 2014; Bettencourt, Lobo, & West, 2009). Infrastructure and basic system services typically scale sub-linearly with population, reflecting economies of scale and a relatively consistent population-based requirement for critical food, water and similar services. Other features of a city such as innovation (as indicated by the number of patents issued or the diversity of business types) and

crime, however, scale super-linearly (Bettencourt, 2013b; Bettencourt, Lobo, & Strumsky, 2007). Per capita, larger cities show greater evidence of innovation and contain more specialized niches within the urban economic ecosystem. Larger, denser urban environments create more opportunities for agents to interact. The higher the density of interactions, the greater the opportunities for information exchange, collaboration, innovation, and other behavioral responses involving different agents. Cities, as a result, become engines of innovation and economic diversification, a dynamic which may well explain their "pull" for rural populations and the very large proportion of the global economy they generate.

Cities can, therefore, be conceptualized as "integrated social networks imbedded in space and time," a specific form of CAS (Bettencourt, 2013a, p.176). Their physical form is a functional outcome of the value opportunities to initiate and sustain social interactions brings to people. Factors that constrain connectivity such as segregation or time lost in travel due to inefficient transportation networks constrain the productivity and dynamism of the urban area. Based on extensive analysis of cities as social networks, Bettencourt argues:

Cities are Complex Adaptive Systems that display strong emergent characteristics. These are influenced and mediated by the pre-existing cultural, economic, and political relationships among agents that comprise the wider society.

> *Cities are natural systems that evolve spontaneously in human societies under very general circumstances, whenever there are open-ended advantages to human sociality across scales. In this sense they are as natural as beehives or coral reefs, and should not be thought of as arbitrary human artifacts to be redesigned at will* (Bettencourt, 2013a, p.184).

The formulation of cities as CAS reflecting the value of social interactions contrasts strongly with more anthropological, social-constructionist, and political ecology perspectives such as those of Harvey, Lefebrve and others who see the city more as a reflection of capitalist forms of production, power relations, and politics (Harvey, 2008; Lefebvre, 1996). Harvey argues that:

> *the question of what kind of city we want cannot be divorced from the question of what kind of people we want to be, what kinds of social relations we seek, what relations to nature we cherish, what style of daily life we desire, what kinds of technologies we deem appropriate, what aesthetic values we hold* (Harvey, 2008).

This formulation views the city as something that is actively created and contested rather than as an emergent feature that reflects more neutral behavioral and less politically influenced drivers. While Harvey's approach draws heavily on Marxist notions of class struggle, the arguments around urban design and whose voices and interests are represented in the decision-making processes surrounding urban development are more universal. Planned cities such as Chandigarh, New Delhi, Gandhinagar, and the ancient Fathepur Sikri in India, or their parallels in Europe and the Americas, originally reflected the design ideas of a small and elite group of sponsors and urban planners. Other cities have been shaped or reshaped more incrementally with different levels of active design input, again mostly delivered through urban elites and the design communities that service them. Those who are involved "early in the game" can build their fortunes by investing in low cost rural

lands and, as development opportunities emerge and land values skyrocket along the new transit lines, watch that initial investment multiply. The same can be said for urban renewal programs or other major investments that shape the character of cities. Throughout this, the voices of economically or socially marginalized communities, and often even middle class residents, are rarely represented in the decision making process. The role of capital and the incentives of wealthy or powerful entities in shaping urban futures are difficult to deny.

While the CAS and social constructionist perspectives spring from very different roots, they are not inherently contradictory. Cities are Complex Adaptive Systems that display strong emergent characteristics influenced and mediated by the pre-existing cultural, economic, and political relationships among agents that comprise the wider society. The concept of *agency* represents one key bridge between the CAS and social constructionist perspective. Agent behavior in the formation of cities can be conceptualized as a function of basic behavioral drivers interacting with pre-existing and emergent elements of geographical, organizational, socio-political, and institutional structures. A second bridging element relates to *networks*. Networks include the physical geographical (rivers, hills, valleys, lakes, oceans), infrastructure (roads, energy, communication infrastructure) and social (institutional, relationship, market, etc.) features that enable, shape and provide a foundation for the growth of urban structure. There are powerful invariants in urban structure across different regions of the world that relate to basic spatial laws (Hillier, 2002). The growth of urban structure reflects a balance between locally defined socio-cultural and more globally uniform micro-economic forces (Hillier, 2002, 2009, 2012). The initial local spatial geometry reflects local socio-cultural and geographical factors. With growth, however, more universal micro-economic processes reflecting spatial laws come to dominate (Hillier, 2002). Movement seeking uses, such as retail shops, are attracted to locations on transport networks that enable high mobility, while non-movement seeking functions, such as residential housing, emerge in less high flow locations. To put this in another way, networks interact with agent incentives as critical factors shaping the growth and continuity of urban structure. As individuals and businesses, for example, agents seek locations within networks that address specific business or transport needs; as hierarchically structured government entities they proactively add new elements to extend the networks under their control; and as members of self-defined communities, individual agents seek locations with others who share similar identities.

A unified theory of urban dynamics needs to recognize the interaction between the different drivers of agency and elements of structure, including social networks, the geographical form of environmental and infrastructure systems, and institutions.

Overall, a unified theory of urban dynamics needs to recognize the interaction between the different drivers of agency and elements of structure, including social networks, the geographical form of environmental and infrastructure systems, and institutions. The drivers of agent behavior combine the micro-economic factors (such as location and flow) that influence businesses and livelihood opportunities *along with* the cultural, power, and socio-political relationships that influence proactive decision making processes and the ability of different groups to capture or create value. Agent behavior reflects the nature of pre-existing frameworks (whether natural, institutional, or infrastructural) while playing a major role in the creation of new networks. The complex adaptive urban systems that result consequently display dynamics that emerge from three core sources: (1) agent behavioral drivers

(economic, power, political); (2) networked relationships in critical energy, transport, communication and other systems; and (3) the invisible "rules" such as the spatial laws Hiller documents, that mediate both agent interactions and the growth of network structure. These relationships are captured in ISET-International's Climate Resilience Framework (CRF) (Moench et al., 2011; Tyler & Moench, 2012).

Why is the above important? It is important because it suggests fundamentally different avenues for influencing the nature of cities in the face of rapid global urbanization, climate and other change processes. Many analysts looking at cities from both the social constructionist/political-economic and Complex Adaptive System perspectives advocate a greater role for democratic processes and community voices in urban planning and decision making. They emphasize the critical importance of process and voice, particularly for marginalized groups, in shaping the city and counteracting the influence of established sources of political and economic power (Harvey, 2008; Lefebvre, 1996). This is often framed as central to the creation of a city that is resilient and "owned" by the inhabitants. Resolving subsequent questions of *resilience of what, for what purpose, for whom and by whom* depends on processes that enable voice and provide opportunities for political input by many diverse communities—in effect a restructuring of governance relationships (Friend & Moench, 2013). At the same time, *in practice* many approaches to urban planning and the management of complex urban systems emphasize strategies that are much more centrally driven. This perspective sees process-based approaches as messy, time consuming, and difficult to sustain or replicate at scale. This view underpins the elite role now emerging at the heart of many current approaches to urban planning. The 100 Resilient Cities initiative of the Rockefeller Foundation, for example, hinges on the placement of "Chief Resilience Officers" with direct access to mayors and the highest levels of city governments in order to insert resilience thinking and planning into the processes shaping urban systems[4]. While processes for engaging communities are advocated as part of this, the core approach relies on shaping cities by providing direct access to centralized sources of political and economic power.

Greater attention to the fundamental drivers of agent behavior and how those interact with the emergence of network structure could help those seeking to build resilience to identify critical areas where process and voice are essential to address questions of community ownership, equity and wider vision while also recognizing the importance of more centralized strategies.

The conceptual issues outlined above suggest that hybrid strategies based on a much deeper understanding of urban evolution are likely to be essential in order to address the massive challenges facing urban areas as a consequence of climate change, growth, and related stresses. In specific, greater attention to the fundamental drivers of agent behavior and how those interact with the emergence of network structure could help those seeking to build resilience to identify critical areas where process and voice are essential to address questions of community ownership, equity and wider vision while also recognizing the importance of more centralized strategies. This could open opportunities for, in addition to planning, shaping incentives in ways that influence the behavior of different groups of actors. With the goal of identifying effective and equitable strategies for responding to the impacts of climate change on urban areas, the sections that follow explore questions of agency and the dynamics of complex adaptive urban social-ecological systems.

Agent relationships, networks and identity

This section makes four core arguments:

- **First**: Agent characteristics and behavioral drivers are of fundamental importance in the development of a more scientific basis for understanding urban areas;
- **Second**: Scientific understanding is, in turn, essential for the development of strategies to build resilience or transform key systems in ways that respond to climate and other challenges;
- **Third**: Even with improved scientific understanding, most urban structure is emergent, and planning or management strategies will necessarily have large reactive elements; and
- **Fourth**: Understanding of urban agent structure and behavioral incentives can provide deep insights into the factors generating both the highly resilient desirable and the equally highly resilient undesirable dimensions of urban areas.

If you can't explain it, you can't manage or predictably transform it.

Therefore, the goal of building resilience and supporting the transformation of urban systems in ways that respond to climate change probably depends on scientific understanding of the behavioral drivers of urban agents, rather than narrative explanations alone.

Cities, whether they are analyzed as social networks or as a reflection of class, power and economic relations in society, are socially constructed. Historically, most explanations regarding the evolution of cities and the social divisions or other structures they contain, have been largely narrative descriptions that attempt to explain the causal basis of observed patterns. Some, such as Von Thünen's urban land use model, although developed long before the emergence of agent-based modeling techniques, make fairly explicit assumptions regarding the economic drivers of individual agents (Von Thünen, trans. 1966). Others, such as the work of Harvey and Lefebvre, focus less on the individual agent characteristics and, instead, develop narratives derived on the basis of class, power or other relationships at a societal level (Harvey, 2008; Lefebvre, 1996).

While historically it was impossible to demonstrate that observed patterns in urban areas could emerge as a consequence of the basic behavioral drivers of individual agents, agent-based modeling techniques have provided a mechanism, however partial, for doing so. Epstein comments, "to explain a pattern, one must show how a population of cognitively plausible agents, interacting under plausible rules, could actually arrive at the pattern on time scales of interest." For example, if a city displays a clear pattern of segregation along wealth, cultural, racial or other lines, models based on agent incentives would need to be able to reproduce that pattern over the time scale in which it emerged in order to prove such incentives could be sufficient to explain pattern development. Epstein's motto, in short, is: "*If you didn't grow it, you didn't explain it*" (Epstein, 1999, p. 67). Taking Epstein's argument one step further, we argue here that *if you can't explain it, you can't manage or predictably transform it*. Therefore, the goal of building resilience and supporting the transformation of urban systems in ways that respond to climate change probably depends on scientific

understanding that derives explanations using testable approaches reflecting the behavioral drivers of urban agents, rather than narrative explanations alone.

The above argument points toward critical areas where additional basic research could contribute substantively to the frameworks and indicators currently being used for developing urban resilience. Some frameworks, such as ISET-International's CRF, derive notions of vulnerability and resilience from basic principles regarding the role of urban agents and system dynamics operating according to the prevailing institutional "rules in use," (Tyler & Moench, 2012). Such a framework could be used to generate and test many of the assumptions that underlie current strategies. This may seem theoretical, but the practical relevance is essential to recognize. It is, for example, widely assumed that social equity, cohesion, and broad-based engagement contributes directly to the resilience of urban areas (Da Silva & Morera, 2014; Rodin, 2014). Similarly, the role of communities and local organizations in resilience is very widely cited in the literature on disaster management (Berke, Kartez, & Wenger, 1993; Davidson, Johnson, Lizarralde, Dikmen, & Sliwinski, 2007; Kreimer, Arnold, & Carlin, 2003; Patterson, Weil, & Patel, 2010; Pelling & Wisner, 2012; Wisner, 2003; Wisner, Gaillard, & Kelman, 2012). As Rodin (2014, p. 63-64) states on social cohesion:

> *This is the glue that bonds people to one another, in families, groups, organizations, and communities. It consists of genuine commitment and caring, shared values and beliefs, engagement, common purpose, and sense of identity, and it makes all the difference in building resilience.*

It is unclear that social cohesion and equity are directly related to the ability of a system to absorb disturbances and still retain its basic function and structure.

Based on this and other similar findings, many urban areas are being encouraged *for resilience purposes* to invest heavily in social engagement and work directly with marginalized communities.

Many inequitable systems have, over centuries, maintained their structure and function despite massive and highly disruptive changes.

While the above is more than justified as important from an ethical perspective and clearly contributes to the ability to absorb the impacts of disaster and other forms of disruption, it is less clear that social cohesion and equity are directly related to the ability of a system to absorb disturbances and still retain its basic function and structure (Walker & Salt, 2006). Highly inequitable systems where social cohesion is maintained through extractive power relations can also be highly resilient. Many such systems have, over centuries to millennia, maintained their structure and function despite massive and highly disruptive changes. Semi-feudal landlord systems where small groups of wealthy individuals have effective control over the livelihoods of many much poorer individuals have persisted in locations such as South Asia despite the disruptive changes that have occurred in governance systems, technology, and connectedness over recent centuries. In fact, the San Francisco earthquake example Rodin uses to describe the role of social cohesion (Rodin, 2014, p.64-67) reflects a common finding—even highly divided communities often come together in the context of a disaster. Unfortunately, they often fragment again once the crisis has passed. Similarly, the processes driving environmental degradation could be seen as themselves highly resilient. For example, groundwater over-extraction is difficult to control or create common pool management systems precisely because of highly individualized control over the modular, diversified and

flexible structures (wells) through which the resource base is accessed (Blomquist, 1992; Burke & Moench, 2000; Moench, 1992). The core argument here is that the way humans organize in groups or as individual agents and the incentives that it creates can lead to highly resilient states (in complex adaptive system terminology "basins of attraction") that aren't necessarily socially or environmentally desirable. Changing that requires deep understanding of those organizational principles and the driving behavioral incentives.

Studies of racial segregation in urban areas illustrate the above point clearly. Research conducted in the late 1970s using early agent-based modeling techniques demonstrated very clearly that only slight differences in preference could rapidly result in complete segregation (Schelling, 1971; Zhang, 2004). Researchers demonstrated that the desire to have "one other" similar individual on a street or in a neighborhood rapidly generated highly segregated patterns of urban settlement. This clearly demonstrated the self-reinforcing or, to put it another way, highly resilient systemic feedback loops that underlie patterns of segregation. Efforts to address negative stereotypes or encourage more interaction would, on their own, be insufficient to alter entrenched patterns of segregation. Deeper analysis using this approach might also have suggested different avenues, based on urban structure, which could potentially support integration (Axelrod & Hamilton, 1981; Epstein, 1999; Schelling, 1971; Zhang, 2004).

Changing highly resilient states that aren't socially or environmentally desirable requires deep understanding of the organizational principles humans and societies follow and the driving behavioral incentives.

Work in the field of Cultural Theory (also known as Grid-Group theory) suggests there are three basic forms of organization in society, each of which is associated with broad behavioral incentives (Dake, 1992; Douglas, 1997; Douglas & Wildavsky, 1983; Lima & Castro, 2005; O'Riordan & Jordan, 1999; Ostrom, 1991, 1998, 2014; Thompson, Ellis, & Wildavsky, 1990; Wildavsky, 1987):

1. **Hierarchical**: This form, which is commonly associated with large governments, the formal structure of religious institutions, and the internal structure of many corporations, is organized with lower units in some manner reporting to and depending for direction on higher units and ultimately some centralized command structure.

2. **Individualist**: This form, which characterizes the behavior of individual workers in the labor market, corporations in relation to each other, and relations between nation-states, creates the emergent structure of markets and other exchange or competition-based networked relationships.

3. **Identity group (or egalitarian)**: This form of organization is based primarily around shared forms of identity, whether based on place, political affiliation, belief systems, or culture. It grows out of the human search for identity in relation to others and, as a result, lies at the heart of on-going processes of cultural differentiation. To be me, I must differentiate myself from you; for every "us" there must be some "other."

These forms of organization as agents have clear behavioral incentives associated with them. *Hierarchies* are typically supported by some form of revenue generation (taxes, tithes, corporate profits) that then enables the people within the organization to "do" something. Their legitimacy (or survival) as an organization depends on their ability to maintain a flow of revenues. This, in turn, depends on the services they deliver. Overall, the strong incentive is to "do something" to utilize revenues and maintain the support that justifies existence and provides organizational power. *Individualist* forms of organization, in contrast, typically depend on exchange as a major factor underpinning their survival. Whether as an individual or as a corporation in a global marketplace, you have to "produce something" in order to "receive something." The reality of competition, exchange, and comparative advantage is, as a result, a key behavioral driver. *Identity-group or egalitarian* forms of organization lack both the command and control structures of hierarchies and the exchange based incentives of individualist structures. In addition, although they may develop forms of revenue generation to support a common objective, they are not associated with a core mechanism for large-scale revenue generation. As a result, they tend to exercise action primarily through voice (advocacy for ideas, political action, etc.) while also using that action to maintain group identity and differentiate themselves from others; they need the "other" to exist.

The incentives generated by differing modes of organization may well underpin a wide variety of the dynamics observed in urban areas.

The incentives generated by differing modes of organization may well underpin a wide variety of the dynamics observed in urban areas. Individualist modes of organization, for example, are likely to thrive in locations that provide numerous opportunities for exchange. The growth and density of interactions in emerging urban areas would thus contribute to the emergence, growth, and diversification of market networks. This would tend to create the super-linear scaling observed with increases in the scale of urban areas (Bettencourt, 2013b; Bettencourt & West, 2010). The competitive nature of individualist modes of organization would also tend to generate some of the wealth and power dynamics others have used to explain the growth of urban structure (Harvey, 2008). Early actors and those with initially better resource endowments are likely to have a comparative advantage over those entering later or with fewer resources, and are likely to be in a better position to capture and structure the resources of urbanizing areas. Where individualist market actors are concerned, early entrants will tend to enjoy comparative advantages for diversification and be positioned to take advantage of self-reinforcing feedback loops as market networks develop. Logically, this type of dynamic would contribute to the development of highly resilient but also fairly stratified, or economically differentiated, market structures. Where the more hierarchical structures typical of government organizations are concerned, capacities will be added as revenues grow and infrastructure or service requirements increase. The logical consequence of this is likely to be the growth of sector-specific capacities within governments to meet those infrastructure and service needs. This is likely to contribute to the growth of self-reinforcing feedback loops, path dependent development trajectories, and deeply embedded and resilient governmental structures.

Other critical urban characteristics may also emerge as a consequence of differences among forms of organization. For example, hierarchical governmental forms of organization require resources to grow and establish capacities. As a result, unless

they have access to external funding, they are likely to be of low capacity and have limited power to shape the emerging urban area until the economy grows sufficiently to establish a significant tax revenue base. This may well explain why urban planning and management efforts tend to always be "playing catch-up." Similarly, identity-based forms of organization are likely to multiply and take on structure when: (1) the economy generates sufficient resources to enable individuals to contribute resources; (2) density of opportunities for social interaction increases, creating a stronger incentive to differentiate in order to maintain identity or initiate advocacy around issues or other points of self interest. As identity within urban areas becomes increasingly diversified and related to special interests (whether work, religion, family, race, or lifestyle), there is likely to be less and less of a collective identity. Divisions such as those documented in the studies of segregation are, as a result, likely to grow. The same dynamic documented in Schelling (1971, 1978) and Zhang's (2004) pioneering work on segregation would, for example, apply to the differentiation between wealthy and poor neighborhoods and the rapid process by which gentrification or reverse processes can transform one to another. Furthermore, conceptually, these could also take the form of association with a particular set of interests, contributing to the growth of special interest groups. A slight preference, for example, to associate with musicians would rapidly generate a segregated pattern, not in geographical space but in social space. This would then generate networks based primarily based on the subtle preferences associated with identity.

Density and networked relationships appear central to agent behavior and the emergent nature of urban ecosystems. This has important implications for resilience and social equity.

The above dynamics suggest what may be some of the most important basic factors influencing agent behavior and generating the emergent network properties of complex adaptive urban ecosystems. All the forms of agent organization are likely to be heavily influenced by the super-linear effects of increases in density documented by Bettencourt (2013b). All also generate and rely on networks of relationships for their growth and continued existence.

These factors have important implications for resilience and social equity. *First,* even in the absence of strong political or power dynamics, the basic drivers of agent behavior are likely to create highly differentiated, often inequitable, elements of urban structure. While some of this may be socially neutral or positive (preferences for associating with musicians or engineers) the core dynamics are also likely to result in segregation and separation based on economic, racial, ethnic, religious and other divisions. *Second,* initiatives to design or improve the structure of urban areas are likely in all but a few conditions to be playing catch-up. Urban structure is largely emergent, and for core reasons related to resources and the timing of capacity emergence (i.e. following establishment of a population and revenue base), planning generally attempts to "fix" existing problems rather than proactively identify and address them. *Third*, many elements of urban structure are deeply embedded and likely to be resilient whether or not they are desirable. They emerge as a consequence of basic patterns of social organization and the associated networks and feedback loops those generate. As a result, despite attempts to change conditions (i.e. disrupt the causes), they tend to maintain core elements of structure and function. Such forms of "resilience lock-in" create deep basins of attraction and may explain the persistence of highly undesirable social or environmental conditions.

The broad literature on "poverty traps" is relevant here, and the same ideas could be applied to what might be called "identity traps," or the creation of institutional silos (Maru et al., 2012). These emerge as a consequence of the same dynamics that create equally resilient but more desirable elements of urban structure, such as the networks and relationships that support innovation and vibrant artistic or cultural communities. Altering these patterns or transforming less desirable conditions may require strategies that undermine, as with patterns of segregation, the very factors that make them so resilient in the first place.

Characteristics and dynamics of urban systems

This section makes three core arguments:

- **First**: As hierarchies of complex adaptive systems, urban areas display similar dynamics to those observed in other multi-layered complex systems;
- **Second**: The factors that contribute to the resilience of such systems are not inherently desirable and can have negative consequences for social equity, long-term environmental sustainability, or other broad social goals. Resilience says little about the desirability of any given system—If a system has major undesirable characteristics, its ability to maintain structure and function in the face of pressure to change is not inherently beneficial; and
- **Third**: The maintenance of system resilience involves inherent tradeoffs, suggesting a major role for broad-based political processes as a foundation for decision-making.

Transforming systems that are resilient but have major undesirable characteristics requires strategies that undermine the factors that make the systems resilient in the first place.

In order to understand the linkages between the features society value in urban systems and their dynamics, it is important to understand the characteristics and dynamics of systems in more detail, and how those relate to the cycles of adaptation described in the large literature on Complex Adaptive Systems.

Cycles of adaptation

From the perspectives of both theory and observation, most dynamic and adaptive systems go through cycles of reorganization, exploitation, conservation and release (Gunderson & Holling, 2002). Each of these phases and characteristics, including the release or "creative destruction" phase, are vital to maintaining the potential, connectedness, and resilience attributes of a system as well as its adaptive nature.

As described by Gunderson and Holling (2002), systems are characterized by:

- **Resilience:** The ability to maintain key structure and functions following disruption;

- **Potential:** The ability to accumulate resources over time, thereby increasing possible outcomes for the future; and

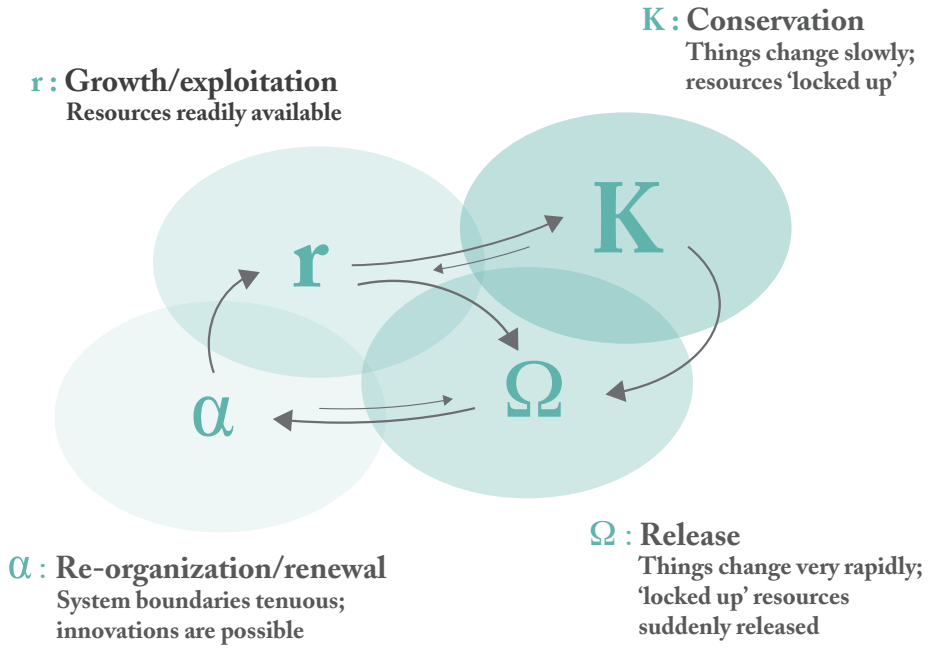
- **Connectedness:** The concentration of potential within internal system elements.

Development of these characteristics depends on adaptive cycles of growth, conservation, release, and reorganization (Holling & Gunderson, 2002). Blocking one of these phases from occurring alters the cycles and can contribute to losses of resilience and low potential. Different levels of these three characteristics ultimately determine the extent of a system's adaptability, or mal-adaptability, to internal or external disruptions. A first point to understand, therefore, relates to the nature of adaptive cycles.

The cycles that characterize CAS can be thought of in four stages: growth/exploitation (***r***), conservation (***K***), release (Ω), and re-organization (α).

Development of resilience, potential and connectedness in systems depends on adaptive cycles of growth, conservation, release, and reorganization.

Figure 1: Adaptive Cycles



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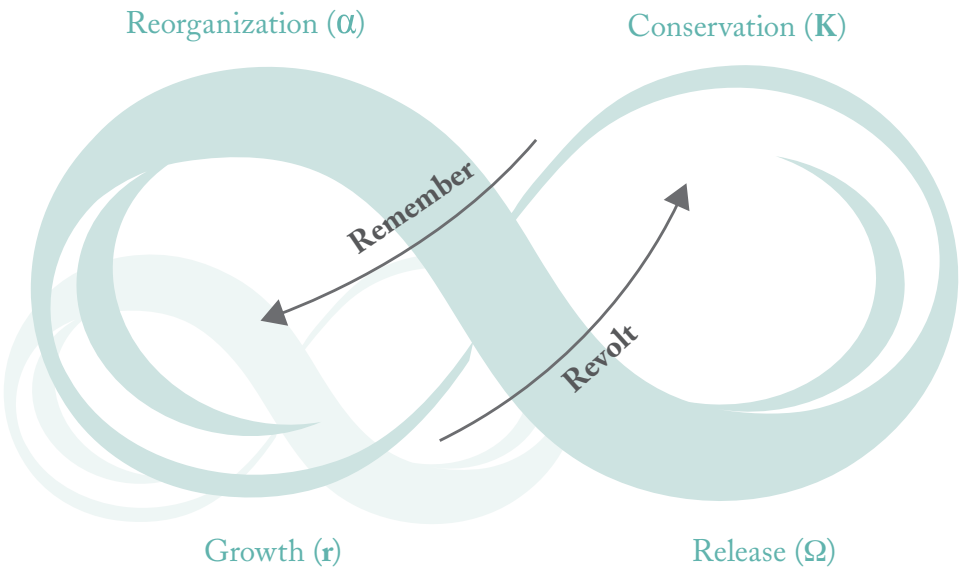
Growth and the accumulation and storage of capital and potential mark a first slow progression from exploitation to conservation (Gunderson & Holling, 2002). This front loop (***r*** to ***K)*** phase of growth is also marked by increasing connectedness, or rigidity, which results in both the potential and capital becoming locked away within the system's increasingly connected structures. The second, faster, phase from release (Ω) to reorganization (α) is instigated through either an internal or external trigger that results in the quick release of the stored capital and loss of those structures. Within this phase, the potential also drops until the system's structures are reorganized so as to take advantage of the newly available capital released into the system. Cycles can also occur where systems transition directly from an initial growth phase to collapse, or even iterate between reorganization and collapse. However, if the release or collapse phase does not occur, the system would become increasingly rigid to the point where the system itself becomes highly brittle and resistant to change (Gunderson & Holling, 2002). The longer that a system is held in place, the bigger the collapse may be. This limits the adaptive and dynamic capabilities of systems. Therefore, maintaining the dynamic adaptive nature of systems and preventing the rigidity described above requires both the slower transition and growth of the system from exploitation to conservation as well as the quicker transition from the release to the reorganization phase in the cycle.

Maintaining the dynamic adaptive nature of systems and preventing rigidity may require slow transition of the system through the exploitation and conservation phases and rapid transition from the release to the reorganization phases in the adaptive cycle.

Beyond the adaptive cycles themselves, urban areas can be thought of as "systems of systems." That is to say, urban entities as a whole are made up of numerous sub-systems (social units, elements of infrastructure, infrastructure systems) that scale upward. In the complex systems literature, such systems of systems are described as a *Panarchy*. Within a Panarchy, individual adaptive systems are connected to each other across scales through so-called "revolt" and "remember" connections (Resilience Alliance, 2002b). Revolt refers to processes by which the collapse of a system at a faster, smaller scale can influence a larger, slower system by acting as the "trigger" for that larger system's release phase. An example of this revolt process could be the impact of a decline in property values on municipal tax bases. Remember, on the other hand, occurs when the accumulated capital from a larger scale is mobilized and released into a smaller system's reorganization phase (Gunderson & Holling, 2002). FEMA's disbursement of emergency funds following the 2013 Floods in Boulder, Colorado to impacted homeowners is an example of the remember phase.

Figure 2: Panarchy



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Dynamic exposure to change and stress are central to maintaining the resilience and adaptive capacity of infrastructure and ecological systems as well as human social systems.

We see adaptive cycles in urban areas where, in the absence of large, sudden shocks, the general resilience of the urban area as a whole depends on, and probably changes much more slowly than, the much more dynamic cycles within sub-systems or components of the urban system. Individual businesses, for example, evolve and change rapidly in relation to the overall urban economy. This is also likely to be the case with environmental systems (conditions in a specific watershed versus the overall ecosystem supplying water to the urban area) and infrastructure (the development and maintenance of specific highways versus the overall transportation system). Each of these subsystems has characteristics that make it more or less resilient to general sources of disruption *and* points where it is more or less resilient to impacts from much more specific events, such as the impact of climate change on water systems. Importantly, research on complex social-ecological system dynamics suggests that the resilience of meta-systems or panarchies depends heavily on the cyclical processes involving growth, accumulation, collapse, and reorganization within the underlying sub-systems. Dynamic processes in the sub-systems serve to maintain diversity and release accumulating stresses in ways that avoid the gradual buildup of tensions or rigidity, buffer specific shocks to specific systems, and thus contribute to resilience at the meta-system and panarchy levels (Gunderson & Holling, 2002).

Overall, dynamic exposure to change and stress are central to maintaining the resilience and adaptive capacity of infrastructure and ecological systems as well as human social systems. Understanding the basic dynamics of the sub-systems of which the overall urban system is assembled is, as a result, central to understanding the factors that contribute to general urban resilience.

A few examples help to illustrate this: In urban areas, a dynamic and diversified economic ecosystem is of fundamental importance to the urban economy as a whole. Individual businesses within this urban economy, and indeed even full sectors of the economy, rise and fall with the business cycle, entry of new technologies, and a host of other factors. If the economy or elements of it are overly protected, businesses tend to become rigid and have little incentive to avoid courses of action that would otherwise entail large risks. Over time, this can build up to a level that, as happened in American cities that were heavily dependent on the automobile industry, threatens the overall urban ecosystem. Wolfsburg Germany now faces precisely this issue as Volkswagen encounters global problems as a consequence of the "defeat devices" it installed to avoid emissions control regulations (Bowley & Eddy, 2015). The overall lesson is that the resilience of the urban economy as a whole depends heavily on the factors that maintain some level of risk exposure and dynamism in the underlying businesses. New businesses need to be created, while those that are outdated need to reinvent themselves or die. Risk and competition are fundamental factors underpinning this dynamism.

Understanding the basic dynamics of the sub-systems of which the overall urban system is assembled is central to understanding the factors that contribute to general urban resilience.

Interestingly, the same types of arguments apply equally well to key elements of urban infrastructure and ecological systems. The "Integrated Water Resource Management Plan" (IRP) for the Metropolitan Water District of Southern California (a six county, multiple municipality area), for example, explicitly focuses on the identification of a highly diversified portfolio of water sources and includes significant elements of demand side management due to the high level of risks associated with any single source (2010). This emphasis on diversification grew out of a long history of experience with water supply variability in the dynamic climate of the South Western U.S (Metropolitan Water District of Southern California, 2010). That strategy is, however, now facing a severe test as California's unprecedented drought cuts into all sources of supply. Furthermore, because even the most recent (2010) update of the IRP focused on meeting the original IRP goal of "full service demands at the retail level under all foreseeable hydrologic conditions" (Metropolitan Water District of Southern California, 2010, p.ii), they may have buffered both local agencies and consumers from the growing drought in a way that is likely to amplify impacts and could cause catastrophic system collapse, should the current drought continue. Some elements of water use, such as water-intensive landscaping, are deeply embedded in culture, and while there are few technical hurdles to changing them, they face social resistance. Others, such as the design of bathroom facilities and sewer systems in ways that require specific flow levels to function, are far more technically difficult to change on short notice and may face similar cultural resistance. If populations had not been buffered from high levels of variability in water supply, both of these features would probably have evolved in ways that are more adapted to drought.

The relationship to resilience

Where does resilience fit in? In contrast to potential and connectedness, which influence the accumulation of resources and create space for innovation within the system (Resilience Alliance, 2015c), resilience emphasizes how these and other characteristics allow systems to continually recover from and adapt to disruptions (Friend & Moench, 2013; Gunderson & Holling, 2002; Maru et al., 2012). In this sense then, resilience speaks to the capacity of an ecosystem "to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes" (Resilience Alliance, 2015c, para. 2). Systems with low levels of resilience are vulnerable to disruptions that have the potential to shift the system into a different state, while more resilient systems are able to maintain their structure during these smaller disturbances (Resilience Alliance, 2015c).

It is possible to have resilience that is specific to each of the adaptive systems that constitute a city- or general resilience, which applies to the panarchy as a whole. Importantly, the resilience of sub-systems within a panarchy may influence the overall resilience of the panarchy itself. Maintaining resilience at the panarchy level may depend on rapid changes that release stress at the sub-systems level. This is, for example, the case with exposure to intermittent flooding. High levels of protection eliminate the incentives for individual households and businesses to take action and protect assets (Baldassarre et al., 2013; Bell, Green, Fisher, & Baum, 2001; Burton & Cutter, 2008; Ludy & Kondolf, 2012; Tobin, 1995; White, 1945). This results in the commonly observed phenomena of settlement behind flood levees, and the resulting large disasters, as in New Orleans, when those levees fail. Regular exposure to low levels of flooding would cause real losses but would also incentivize a broad base of the urban population to avoid high-risk areas or take action to manage risk. A similar dynamic is present, as discussed below, in relation to urban economic systems.

As a general characteristic, resilience may benefit the city as whole while negatively affecting smaller sub-systems within the city or vice versa.

As a general characteristic, resilience may benefit the city as whole while negatively impacting smaller sub-systems within the city or vice versa. We see how resilience can be context specific in Liberia, for example, where social ties that contributed to resilience during war ultimately influenced the spread of Ebola (Onishi, 2014), or in cities where the re-location of cheaper housing out of floodplains would contribute to the overall resilience of the city while also exacerbating the vulnerabilities of inhabitants by distancing them from work and others services (Friend & Moench, 2013).

The human element

Within socio-ecologic systems, humans are an integral part of ecosystems and likely to be subject to the same cycles of growth and collapse as described in the preceding section. This is, for example, present in the business cycle and the boom-bust nature of many regional economies. Maintaining economic dynamism requires competition. The growth of new industries often requires the collapse of

old ones. This is generally associated with job losses. Furthermore, as new industries emerge from the reorganization phase (Ω), people will need to learn new skills and reinvent themselves in order to participate. The dynamic generates expectations that individuals who have spent years building their careers in a specific industry will suddenly be willing and able to learn new skills according to the newest industrial trend or product. This can be extremely difficult for the people involved, particularly low-income groups, those with highly specialized industry-specific skills, or those who are at late phases in their career. While collapse is an inherent and important element in maintaining dynamic adaptive cycles, it can have very real impacts on individuals. Resilience requires collapse and reorganization, a requirement that implies patterns of loss at the individual and human level. The situation directly parallels ecological system dynamics.

The above analysis suggests that there are inherent tradeoffs between elements of social equity and the resilience of urban economies and systems at large. How should resilience at a meta-system level be balanced against inherent patterns of human loss *and vice versa* how should efforts to improve equity or protect vulnerable groups be balanced against reductions in resilience and the high costs of rigidity and some ultimate larger collapse? Is it possible to provide something else *in addition* to resilience that, while not completely ameliorating the loss, at least deals with the potentially negative consequences of the collapse phases within adaptive cycles? This raises questions of resilience *of what, for what purpose, for whom* along with questions related to how decisions are made and how the costs and benefits are distributed (Friend & Moench, 2013).

There are inherent tradeoffs between elements of social equity and the resilience of urban economies and systems at large.

Finally, it is important to emphasize that there are highly adaptive socio-ecological systems that, while resilient, have negative social or political consequences. Economic systems, for example, that depend on large pools of unskilled and easily dismissed low-wage workers can address the variations inherent in the business cycle simply by downscaling the workforce. Such economic systems cycle through phases of exploitation, conservation, release and reorganization and are able to retain the same set of functions and structures as before the disruption—i.e., they are highly resilient.

Questions often exist regarding how resilience at a meta-system level should be balanced against the human losses that may entail and, vice versa, how efforts to improve equity or protect vulnerable groups should be balanced against reductions in resilience and the high costs of rigidity and some ultimate larger collapse.

The very resilience of these structures perpetuates regimes of inequality. Similarly, the physical infrastructure systems on which urban areas depend can be highly resilient, but also generate large negative environmental costs. Fossil fuel based energy systems, for example, have many characteristics that contribute to their resilience (highly diversified sources, modularity, flexibility, strong supporting feedback loops, etc.). The carbon emissions generated by such energy systems, however, drive climate change with potentially catastrophic consequences for human society. The systems are resilient. Although energy systems are changing gradually and could, over time, shift in structure and function away from fossil fuels, far more rapid forms of transformation are essential.

Overall, resilience should be understood as an attribute of systems that can generate either desirable or undesirable results. As an attribute, it reflects the characteristics that allow systems to continually recover from and adapt to disruptions, but in

itself says nothing about whether or not the systems and their status are socially or environmentally desirable (Friend & Moench, 2013; Gunderson & Holling, 2002; Maru et al., 2012). Moreover, it is important to understand that resilience primarily describes a system's ability to absorb and recover from shocks (Friend & Moench, 2013; Holling, 1973). It does not determine the distribution of impacts from shocks on the resources or the individuals within the system (Friend & Moench, 2013). It also does not describe how and where the capital that was stored and gathered during the exploitation phase is released or re-distributed during the release and reorganization phases. Ultimately, this implies that the process of maintaining a resilient system involves tradeoffs and suggests an important role for broad-based political processes to guide decision-making.

Transformation

This section makes two core arguments:

1. Transformation needs to be recognized as a "step change." Ideally, such transformative change should be part of a managed transition that seeks to maintain desirable characteristics rather than through collapse or as a consequence of some highly disruptive event. The more resilient a system is, the less subject it is to abrupt forms of transformation.

2. Policy goals should be to: (1) reinforce the resilience of desirable situations and ensure that they do not transform in undesirable ways, while (2) catalyzing transformation away from undesirable, but resilient, states.

The process of maintaining a resilient system involves tradeoffs and suggests an important role for broad-based political processes to guide decision-making.

Major tensions exist between resilience and transformation. Resilience concepts include recognition that complex social-ecological systems will adapt and change over time as they, or their constituent sub-systems, progress through different cyclical phases. As a result, they recognize the potential for transformative change. A central goal of resilience management, however, is to avoid having the key factors underpinning complex social-ecological systems such as urban areas, develop "fragile rigidities, exposing them to turbulent transformation" (as cited in Shaw & Sharma, 2011, p. 19). The basic implication is that while transformation may occur, in the case of social-ecological systems it should be gradual and part of a socially or environmentally positive transition rather than through collapse or as a consequence of some highly disruptive event. In both incremental and more abrupt processes, transformation involves altering the basic elements of system structure and function. It represents a step change to a "new" system that is, in some way, fundamentally different from the "old" system. The more resilient a system is, the less subject it is to abrupt forms of transformation. Furthermore, even with incremental processes, the factors that create system resilience tend to keep it within preexisting basins of attraction, i.e., work to retain elements of structure and function while resisting the larger step changes that could be described as truly transformative.

While transformation may occur, in the case of social-ecological systems it should be gradual and part of a socially or environmentally positive transition rather than through collapse or as a consequence of some highly disruptive event.

The more resilient a system is, the less subject it is to abrupt forms of transformation.

The above distinction of transformation as a step change is not recognized in most policy related work that utilizes concepts related to resilience and transformation.

While theoretical work by groups such as the Resilience Alliance recognizes that systems can be in highly resilient but undesirable regimes, most discussions of resilience in policy contexts assume that resilience is inherently desirable. Rodin (2014), for example, describes the dividend, or opportunities, that building resilience can offer to communities. At the same time, the United States Department of Housing and Urban Development (HUD) is providing $1 billion to fund the National Disaster Resilience Competition with the goal of helping communities to "increase resilience to future disasters" (U.S. Department of Housing and Urban Development, 2014). As documented at numerous places in this paper, however, resilience *per se* says little about the desirability of any given system. Questions addressing how systems can be moved out of self-reinforcing but undesirable "highly resilient" situations are rarely raised.

From the perspective of the authors, rather than positing resilience as inherently positive, the policy objectives in using systems concepts to address the challenges facing complex social-ecological systems such as urban areas should be twofold:

To address challenges in complex social-ecological systems, the policy goals should be to reinforce the resilience of desirable situations, and catalyze transformation away from undesirable, but resilient, states.

1. To reinforce the resilience of desirable situations and ensure that they do not transform in undesirable ways; and

2. to catalyze transformation away from undesirable, but resilient, states.

While the question of "desirability" depends on social perspectives and requires definition through the political processes that should define policy objectives, our focus here is on the role of system concepts. Can system concepts be used to shift the rhetoric around resilience away from the current inherently positive connotation to a more scientifically informed stance that uses the insights such concepts could generate to inform strategy? The starting point may be to increase recognition that, whether or not a particular system state is desirable or undesirable, the same basic attributes are likely to influence its resilience or potential for transformation.

Urban areas, as with other meta-systems or panarchies, are emergent features that reflect the nature of their constituent sub-systems. They are large, slow moving, systems-of-systems that even in the face of major catastrophes, tend to be highly resilient and difficult to change rapidly. The sub-systems of which they are made, however, are much more dynamic, quickly changing, and potentially subject to influence. As a result, we argue that strategies for building resilience or catalyzing transformation at an urban scale need to focus primarily on factors within and between different constituent sub-systems. The attributes of these sub-systems and the nature of their connections with other systems across scales determine their resilience and influence potential avenues for and rates of transformation. For example, the modularity, redundancy, diversity, and safe failure characteristics of a water system, along with key links to, say, energy systems, determine its resilience. In contrast to overall patterns of urban growth, these factors change and can be influenced relatively rapidly as components wear out or are replaced.

Very practical steps to, for example, increase the diversity of sources influence the behavior of water users and suppliers, ensure that reliability of energy supplies will

increase the system's resilience, and also contribute to the resilience of the urban area as a whole. Transforming a water system that has large undesirable features might, in contrast, involve shifting to a different kind of system. Most urban areas depend on large water utilities to supply consumers through piped networks. This functions well in areas where supplies are unlimited and there is little need to closely control consumer behavior. When water supplies run short, however, or there are major dysfunctions in urban utilities, shifts that transform the system away from a centrally supplied utility based model may be essential. That is what has, in effect, occurred in locations such as Kathmandu, many cities across India, and Yemen, where water markets are a major, if not dominant, source of supply for most households. While water markets can have an array of socially undesirable characteristics such as high prices for the poorest and poor water quality, they clearly encourage efficient end-use, maintain essential supplies, and are often highly resilient. Our work across Asia suggests that in many such cases, transformation has involved either slow development of or the incremental collapse of a utility-based system accompanied by the growth of a much more diversified and flexible market based system for water delivery.

Social equity and governance

This section makes the following core arguments:

1. Ultimately, there are direct human losses in dynamic, adaptive, and resilient systems. Resilience, by and large, cannot benefit everyone.

2. Governance systems need to play a central role in balancing the costs and benefits of resilience across society and in the management of efforts to build resilience or support transformation.

Before moving into illustrative cases, the final conceptual question relates to social equity and the governance of decision-making regarding efforts to build the resilience of or support transition in social-ecological systems. For systems to remain dynamic and adaptive, cycles of release and reorganization must occur. In the case of economies and livelihoods, these will involve direct human losses. They will also involve changes in many attributes that different groups value.

The water market case discussed immediately above illustrates this well. Globally, there are now movements to enshrine a human right to water in framework documents of the United Nations. In practice, this right is generally interpreted as implying an obligation *of national governments* to deliver a certain minimum level of water services (*per capita* water supplies) to their entire population. Governments, in turn, generally attempt to achieve this through the establishment of water utilities covering urban and in some cases rural areas.

For systems to remain dynamic and adaptive, cycles of release and reorganization must occur.

In the case of economies and livelihoods, these will involve direct human losses. They will also involve changes in many attributes that different groups may value.

Throughout much of the world, this model is under strain for a host of reasons related to poor operation and maintenance of utilities (a challenge related to the behavioral incentives facing most hierarchically structured agents), growing competition over limited water supplies, and difficulties in encouraging efficient end-use behavior (another agent related issue). Strong arguments could be made that the utility model of water supply has inherent fragilities and tends to be less resilient. Markets, in contrast, involve the effective privatization and sale of water by those with access to source areas to large groups of consumers. This dynamic encourages, as do utility models, better service delivery to wealthy consumers who are able to purchase supplies in bulk or afford higher quality. The poor typically pay more for lower quality supplies. Despite this, the market systems function in ways that generally meet minimum survival needs in one manner or another. From a resilience perspective, the markets are highly flexible and responsive to both demand and supply conditions. They also tend to be structured modularly and may not be as subject to cascading failure as more centralized utilities.

While change processes that contribute to resilience or patterns of transformation may have broad social benefits, there will also always be losers who will typically come from the least wealthy and most marginalized groups.

The growth of water markets is generally not an active decision. Instead, it reflects the inability of the utility-based model to function well and the growth of market actors to meet the resulting demand. The global or national debates that emerge as a result are largely political and ideological: *Should* people have to buy water; *should* the government supply it? The equity implications are, however, clear: in most cases socially marginalized groups and the poor have lower levels of access to water in the quality and quantity they desire, even if basic survival needs are met. Furthermore, neither approach to water supply addresses basic issues related to the management and sustainability of the ecological systems on which water supplies depend. These might be addressed, for example, by specific measures to ensure affordable water supply to marginalized groups or to protect critical ecosystems.

Similar equity issues are present in the case of economic resilience. As noted above, maintaining economic dynamism at an urban or higher level depends on the ongoing rise and fall of businesses as conditions, technologies, and a host of other factors change. While some people do well in the context of such dynamic change processes, job losses and the displacement of livelihoods are an inherent implication. While this may contribute to resilience or patterns of transformation that have broad social benefits, it implies that there will always be losers who will typically come from the least wealthy and most marginalized groups. Similar issues are present with regard to aging and healthcare. Furthermore, as in the case of water supply, there are large political and ideological debates regarding the relative role of government and market actors in the economy. They also involve the relative weight given to the fundamental factors that determine access to work versus the creation of social safety nets for those who lose livelihoods.

All this suggests the central role governance systems have to play in the management of efforts to build resilience or support transformation. Mechanisms are needed to ensure that both the costs and benefits of resilience are distributed in a manner that is socially equitable and corresponds to wider values within society. An economy that is dynamic and resilient in the face of economic turbulence because it has access to a large body of easily dismissed workers places the costs of resilience on

the workers but may not deliver equivalent benefits to them. Similar issues exist with aging populations where support is essential but also withdraws resources from the economy, and with environmental systems where the short-term benefits of extractive use may enhance the resilience of current lifestyles at the expense of future generations. The relative desirability of one or another system state and how such costs and benefits should be distributed depends on social perspectives and values. It is, as a result, a political issue that needs to be mediated by effective governance mechanisms. Overall, the political and other processes through which courses of action are negotiated on an on-going basis are of critical importance.

Governance systems play a central role in the management of efforts to build resilience or support transformation.

Mechanisms are needed to ensure that the costs and benefits of resilience are distributed in a socially equitable way that corresponds to wider values within society.

Illustrative cases

The brief case studies presented below have been selected to illustrate how some of the conceptual elements discussed above play out in practice and appear in the light of complex day-to-day realities. The case studies are all drawn from the array of work ISET-International and our partners has undertaken over the last decade on projects supported by the Rockefeller Foundation, IDRC, DFID, CDKN, USAID and other donors.

Gorakhpur: Mobilizing communities to build climate resilience across a city

In Gorakhpur, India the core strategy to build urban climate resilience focuses on community mobilization.

In 2009, Gorakphur was selected for participation in the Asian Cities Climate Change Resilience Network (ACCRN), which focuses on building resilience to climate change in urban centers. Subject to regular flooding and a rapidly growing population, whether it is transport, power, water supply, drainage or flood protection, the critical systems on which Gorakhpur depends are fragile. Gorakhpur lies in the central portion of the Ganges River Basin in the state of Uttar Pradesh in India. Gorakhpur is a medium size city of approximately 4,000,000 inhabitants[5] and is growing rapidly. It lies at the junction of two major tributaries to the Ganges, the Rohini and Rapti rivers, in one of the poorest sections of India. The location where it lies is subject to regular flooding during the monsoon. This has been exacerbated by rapid unplanned development, the filling of the many lakes that once dotted the urbanizing area, and the construction of roads and other lineaments. Drainage is poor and, in addition to large scale regional flooding, water logging is common in many low-lying portions of the city. This is particularly true in newly settled areas where public drains either have not been constructed or are blocked by solid waste and other debris.

Gorakhpur is also socially fragile. Most areas in the city have been settled by recent immigrants from rural areas across the wider region. Few people living there know each other and there is little sense of a neighborhood community. The municipal government is also weak. It lacks formal control or influence over areas beyond the municipal boundary, including the large area into which the city is expanding. This falls under a completely separate entity, the Gorakhpur Development Authority. It is responsible for development of basic urban infrastructure and is intended to support development and turn over the area, once urbanized, to the Municipal Authority. Furthermore, the municipal authority depends on the state for funding, lacks legal authority in many key areas, and is plagued by the challenges of governance and corruption that affect most cities in the region.

In this context, the core strategy to build urban climate resilience has focused on community mobilization. Led by a local non-government organization, Gorakhpur Environmental Action Group (GEAG), the approach was to identify issues that

were of broad concern to local communities and use those as a point of entry to build capacity and address a much wider array of climate related challenges. GEAG selected a small area in one of the poorest recently settled city wards, Mahewa Ward, to start with and, based on community concerns over waterlogging and sewage clogged streets, started with a small drainage project. This project demonstrated practical benefits, but more importantly, served as a mechanism for creating relationships among community inhabitants and with the municipal government. As those relationships have grown the array of activities has expanded to include urban agriculture, flood early warning, the construction of flood resilient homes and schools, wider community mobilization, and a host of other activities. This array of activities, while important in its own right, has both enabled and pressured the municipal government. It's given the government something it can show to the state, the central government, and international donors that demonstrates effective responses to flood related challenges. At the same time, as other communities see the benefits, they are increasingly forming similar neighborhood based associations and demanding similar activities in their own areas. If continued over time, these changes could incrementally reduce the city's vulnerability to flooding.

Conceptually, what's important to recognize here is how the strategy followed in Gorakhpur reflects a combination of considerations related to agents, urban systems and the institutional context. At its core, the strategy rested on the creation of identity and relationships within Mahewa Ward. That was done by focusing attention on problems related to the highly fragile water/drainage system *at the local level* where action was practical and within the capacity of the community to undertake even without substantial resources or organization. Creation of a community identity along with practical action generated both opportunities for and pressure on the more hierarchical city government. In addition, some activities, urban farming and the development of flood resilient housing designs created opportunities that are of interest to more individualistic private sector actors. Overall, the approach attempted to catalyze "bottom-up" changes in critical systems through an approach based on the driving motivations associated with different forms of organization.

Strategies need to follow a combination of considerations related to agents, urban systems, and the institutional context.

In Gorakhpur, the strategy was to catalyze "bottom-up" changes in critical systems by working with the factors that motivate different forms of organization.

Boulder, Colorado: Urban flooding

Boulder, Colorado, in the USA falls at the opposite end of the wealth and development spectrum from Gorakhpur, Uttar Pradesh. Consistently rated among the top most desirable places to live, Boulder is a center of wealth and innovation with many world-class institutions and a beautiful and well-managed surrounding natural environment. Sitting at the mouth of a canyon along the foot of the Rocky Mountains, it is, however, one of the most flood-vulnerable cities in Colorado, if not the Western U.S. In addition, the mountain areas surrounding the city are subject to high levels of risk from fire and, although the city has better water rights than many neighboring cities, drought is also a recurrent risk. All these hazards are likely to increase as climate changes. As a city, however, Boulder has tended to view itself as well prepared. Starting in the 1950s, a program to protect large areas was initiated and a very large belt of open space now surrounds the city.

In addition, the University of Colorado at Boulder has been host to some of the world's top water management experts, such as Gilbert White. Utilizing examples from a long history of flood events in Colorado, such experts supported the city in developing early warning systems, protecting urban flood corridors, and designing critical infrastructure, particularly roads and bridges, to accommodate flood flows.

In September of 2013, following three years where fires dominated the headlines, Boulder experienced a massive flood event. This event shocked the city out of its complacency: Boulder might be well prepared, but many of the factors that saved the city from wider destruction weren't planned in advance. The flood event wasn't the one that had been expected. Rather than a single extreme storm generating one flood down the main canyon, the storm stretched out regionally over a three-day period resulting in all the minor streams flooding across a very wide stretch of the Front Range. As the flooding increased, road connections into the mountains and across the lower plains area were washed out. Many communities became inaccessible except by helicopter. In addition, key utility systems, particularly water and sewerage, came close to failure. Lyons, a town fifteen miles north of Boulder, lost both systems. Neither of the Boulder systems failed but both required actions outside the "normal playbook" to keep them operational.

During the 2013 Boulder Floods, much of the response was self-organizing.

In the water supply case, power failed and diesel to keep backup generators running for the six days the main plant was cut off needed to be delivered overland by the mountain fire departments. The city was also lucky to have two operators present at the plant who could keep it running for the entire period they were cut off. Since staff are expensive, prior to the flood the city had considered cutting the number of operators and only having one on site at a time. In the sewer system case, while the main treatment plant had been hardened to resist flooding, the single main drainage pipe leading to it nearly failed. Sewer treatment plants are typically located in flood plains where treated water can be returned to rivers. As a result, the main pipes leading to them often cross river channels. In Boulder, during the most intensive phase of the flood, water was rapidly eroding the riverbed in which the main drainage pipe was buried. This necessitated urgent and unplanned action by the Emergency Operations Center to locate equipment, people and material to build a cradle in the midst of the flood that could hold the pipe in place and prevent collapse of the entire system. Similar urgent measures were also needed at various points in the water supply system, which also follows stream channels. If either the water supply or sewage system had failed completely, Boulder probably would need to have been evacuated for an extended period. While the unplanned actions above saved both the systems, major problems remained. In the case of the sewage system, for example, groundwater levels increased dramatically as a result of the flooding, leading to water entering the sewer system and forcing sewage back out through toilets and drains into basements, roads and the river.

During the floods, much of the response was self-organizing. Where the government was concerned, the Emergency Operations Center played a critical role. With key officials located in one place, it was possible to organize responses to events, such as those outlined above, as they unfolded in ways that would have been impossible to plan in advance. Beyond this, however, communities at all

levels organized responses to needs as they emerged. Neighborhoods, particularly outside the city area, organized groups to protect people and assets and the Occupy movement, a loose organization focused on political change, transformed itself into a highly flexible response structure as the Mudslingers. These emergent forms of organization working outside the formal government and non-governmental response structure provided residents with some of the most immediate forms of relief. Formal agencies, FEMA, the National Guard, the Red Cross, faith-based groups, and other humanitarian organizations took slightly longer to mobilize, but then provided more structured forms of rescue, relief, and emergency response.

Following the floods, FEMA and other government agencies have made substantial funding for recovery available. Insurance has also played a role and, in some cases, communities have mobilized resources on their own. The city of Boulder has initiated a longer-term program to build resilience with support from the Rockefeller Foundation's 100 Resilient Cities program to work with the surrounding county to address regional issues (Rockefeller Foundation, 2015). In both strategies, significant emphasis is being given to neighborhood engagement as well as to the repair and redesign of critical infrastructure and environmental features. In many areas, individuals are also taking action, mostly to protect their own property, and community groups continue to be engaged.

Following the floods, emergent organizations working outside the formal government and non-governmental response structure provided residents with some of the most immediate forms of relief.

From a conceptual perspective, several things stand out in the Boulder flood case:

1. **The role of surprise:** Despite extensive planning and efforts to forecast events, the type of flood that occurred and the manner in which it affected systems was fundamentally different from what was expected.

2. **The interconnected nature of systems:** Both the water and sewage systems nearly failed not because of direct impacts on major facilities but because of dynamics in interlinked systems. In the water supply case, the system depended both on the power grid and on the road transport network to access both diesel and human operators. When the roads failed, the water system nearly did too. In the sewerage case, it was interaction between the network of drainage pipes and the wider hydrologic system, both flood flows and groundwater, which nearly caused failure.

3. **The interaction between different forms of agency:** Identity groups (neighborhoods, the mountain communities, the Occupy movement, faith-based groups) all played a central role in the emergency response, and continue to play a significant role in voicing community interests during recovery. These emergent responses would, however, have been inadequate without the far larger resources and organization brought in by more hierarchically organized external actors such as the government. Finally, many responses depended on the initiative of individual actors and businesses to protect or repair their own assets and to provide critical equipment, material and other resources.

4. **The critical importance of relationships and self-organization:** Interviews with individuals and organizations following the floods highlight the importance of relationships in both response and recovery. It was personal relationships between city officials and the totally separate volunteer mountain fire departments that enabled the city to get diesel to the water supply plant. Similar relationships and trust underpinned the ability of the sewer treatment plant operators to mobilize the resources necessary to protect their main pipe. On a more local level, knowing one's neighbor has emerged time and again in discussions of the help people received during and following the flood. The Occupy movement's transformation into the Mudslingers is another example. Overall, relationships and the resulting ability to self-organize appear of fundamental importance to resilience in disaster contexts.

5. **Boulder is highly resilient, but not necessarily equitable:** Boulder has bounced back from the floods. As in most regions, however, the recovery has not necessarily benefited socially marginalized groups and the poor. While at the time of writing most of the population has been able to return home, much of the low-income housing destroyed in the floods, located in the flood plain, has not been replaced. In locations such as Lyons, many families remain displaced. Furthermore, although they account for a significant portion of the population and were heavily affected, very little attention has been given to the impacts that occurred on the Hispanic community. Beyond this, the vibrancy and resilience that make Boulder desirable also contribute to rising housing prices and a cost of living that make it unaffordable for the majority of the working population to reside here; over 50% of Boulder's work force commutes in on a daily basis.

Relationships between individuals, organizations, and government were of fundamental importance during flood response and recovery, and resulted in the ability to self-organize to provide relief and emergency services.

The above patterns are common globally. They reflect the fundamental behavioral dynamics of systems and the incentives facing different sets of agents.

Viral forms of risk: Ebola

The recent Ebola epidemic in Liberia challenges the idea that resilience can be thought of as a general property. Most studies suggest that relationships, particularly at the community and household level, contribute to resilience in the face of both stresses and sudden shocks. Until recently, this certainly seemed to be the case in Liberia, as communities faced the combined impacts of poor governance, a fourteen-year civil war, agricultural failures and economic decline. Throughout this, relationships between extended family members and wider village or neighborhood communities were vital to survival. With complete lack of trust in the government, families and neighborhood relationships became the place to turn to for succor and support (Onishi, 2014). When Ebola hit, however, these trusted relationships ultimately contributed to the spread of the disease. Instead of safe havens, family and community relationships acted as vectors for the virus.

Because of the contagious nature of the disease and the mechanisms through which the virus is spread, via infected bodily fluids, caretakers are the most at risk for contracting the disease (Centers for Disease Control and Prevention, 2015). Moreover, in places where running water and electricity are in short supply and health care and supplies of proper protective equipment are limited, family members become the default caretakers. This places them at risk of contracting the virus and infecting not only themselves but also other family members. In this case, relationships that helped families to weather both political strife and war are the same that facilitated the spread of Ebola.

In the face of the combined challenges of poor governance and Ebola, individuals were left with nowhere to turn. The government was neither trusted nor capable of providing needed support in the form of vaccines or healthcare, and families themselves were no longer the safe haven they were during the civil war. When thinking of resilience in these contexts, we can see how resilience in one situation may not actually translate to resilience in another situation. Personal relationships are often a core source of resilience in the context of disaster or political turmoil, but can communicate disruption when exposed to a disruptive viral element that follows networks. In the case of viral risks, resilience is dependent on the ability to isolate infected elements from the rest of the network. The question of resilience "for what" is thus particularly relevant here, especially when approaching resilience through an applied lens.

The factors that contribute to resilience in relation to many types of disruptions can also undermine resilience to other forms of disruption.

The core lesson here is that the factors that contribute to resilience to a broad array of disruptions can also undermine resilience to other sources of disruption. What may provide a benefit when facing one challenge may actually undercut resilience when faced with a different class of threat. The basic principles underlying viral contagion in the Ebola case would, for example, apply to a broad class of viral disruptors in other areas such as information, market, or social networks. The disruptive effects of computer viruses on information networks are well known. Similar impacts can, however, occur in market and social networks when panic or other behaviors spread in a viral manner.

Kathmandu: Water systems

The water supply system in Kathmandu raises interesting questions regarding the nature of resilience. The municipal water supply system in the Kathmandu Metropolitan area, which includes multiple individual municipalities, has been stressed for decades. Piped water supplies were initially developed to serve the heart of Kathmandu itself, primarily the royal palace and immediately surrounding areas. The remainder of the valley depended for water supply on local sources including private wells, small ponds, irrigation channels, and the traditional *dhungi dhara* (public stone water spout systems). As the municipal area has grown, piped water has been extended to many areas, mostly in an incremental manner. Traditional sources such as ponds and irrigation channels have declined. Wells remain widespread and some of the traditional *dhunghi dhara* remain functional.

Currently, the formal water supply system draws supplies from the seven small rivers that flow into the valley along with a range of groundwater sources. For a variety of reasons including leakage, active diversion, limited supplies and exploding demand, the actual provision of water is highly variable. Houses typically receive water for a few hours a week at most and, due to low pressure in some locations, water rarely flows to many household connections. In addition, many local sources of water supply are now heavily polluted. The Melamchi project to import water to the valley has been underway for more than a decade, yet as of April 2015 the main water supply tunnel remains less than half way to completion[6]. While the Melamchi project would increase supplies substantially, it would not address the multitude of management issues within the delivery system. Furthermore, sanitation systems throughout the Kathmandu Valley are limited and, in the case of at least one major waste treatment plant, have never been completed or connected. As a result, raw sewage flows into the main Bhagmati River at numerous points once it enters the valley. Under current conditions, introducing additional water to the system could exacerbate existing pollution problems.

Despite the high levels of pollution and inequality in access to clean water, elements of the Kathmandu water supply system can be seen as resilient.

In this context, tanker markets emerged as a primary source of water supply for many households and businesses. In the late 1990s, approximately eighty small tanker companies operated in the Kathmandu valley (Moench, Caspari, & Dixit, 1999). A decade and a half later, the number is now reported at over 800. The market for purified and bottled water has also exploded and this is now the primary source of water for drinking and cooking for many wealthy families. At the household level, rooftop water storage tanks and underground cisterns are essential. They serve to store whatever comes through the municipal system along with any purchased water. Storage is a critical factor in the price of water. Those able to afford to pay for deliveries from a large 12 cubic meter tanker pay far less per unit volume than those who are only able to store smaller amounts. Those without land or a well-constructed house typically must store small volumes of water in pots and either depend on local, often polluted, sources, such as the *dhungi dhara* and wells, or pay far more from water markets.

In addition to water markets, many individuals and businesses such as hotels and schools are now installing rooftop water harvesting systems. Businesses, such as SmartPaani (Paani meaning water), have now emerged and are growing significantly to meet the demand (SmartPaani.com). Rainfall in the Kathmandu Valley is highly variable, making the ability to collect and store large amounts of water central to the effectiveness of rooftop rainwater harvesting as a source of supply. As a result, rooftop rainwater harvesting is primarily effective for and wealthy individuals and institutions.

Despite the high levels of pollution and inequality in access to clean water, elements of the Kathmandu water supply system can be seen as resilient. Despite major issues with water quality, following the earthquake a wide range of our personal contacts in the Kathmandu Valley report the critical importance of cisterns, wells and private water tankers as immediate sources of supply. With the caveat that, at present, all water comes from within the valley, sources of supply are highly diversified, modular and distributed. Wells, an array of different streams, traditional *dungi dhara*, some

ponds, and rainwater all serve as sources. The tanker market system also has a high degree of flexibility and responsiveness, attributes that many of our contacts mention as critical following the earthquake. This is further enhanced by the presence of traditional sources and new approaches such as rainwater harvesting. Storage is also highly distributed, with significant amounts held in cisterns, rooftop tanks, and household vessels. Furthermore, in contrast to a utility-dominated system, a very diverse array of actors is involved in water supply. These range from the government utility to businesses and, in the case of traditional source management, community groups. As a result, despite the widespread disruption in the recent earthquake, early reports from personal contacts suggest that access to water has not been as much of an issue as in similar events elsewhere.

Despite these indicators of resilience, many of these features are a direct response to the wider environmental and management stresses on the piped drinking water and sanitation system. If the municipal supply and sanitation system were functioning well, then the incentives driving water markets, the growth of rainwater harvesting, and the maintenance of traditional sources would decline. Furthermore, while the combination of wells, water harvesting, tankers and storage increases the reliability and flexibility of water supplies, it does little to protect quality. Overall, the resilience of the system keeps it "alive" and ensures continuity of water services, but the current situation is, on many levels, far from desirable. This is particularly true with respect to degradation of the valley ecosystem, health, and social equity.

Resilience is often generated as a response to stress or disruption.

Beyond water services, it is also important to recognize that the factors contributing to the current status of water systems in the Kathmandu valley are deeply embedded in Nepal's social and institutional culture, supported by numerous feedback loops, and difficult to change. Despite numerous initiatives and large investments by international donors over decades, the structure and function of many water system elements have remained the same. This is particularly true in terms of the public sector organizations charged with managing the water system and behaviors at the individual and household level. The incentives facing different agents and the institutional structures within which they operate have, despite substantial efforts to drive improvements, generated an on-going decline in environmental conditions. This embedded process demonstrates what might be called negative resilience.

Conceptually, this case clearly illustrates how systems can have many resilient and desirable aspects but also generate highly undesirable effects. It also illustrates a key basic principle found in many systems: resilience is often generated as a response to stress or disruption. If the municipal water system provided a high level of service, many of the other highly diversified avenues through which households meet their needs would no longer be in demand and would fall out of use. While early reports suggest the presence of these avenues may be playing an important role in ensuring water access following the earthquake, they also reflect the stress and ineffective management that preceded it. This is parallel to the effects of embankments for flood protection. Once constructed, there is little incentive for homeowners building behind them to raise houses or invest in flood mitigation measures at their own level. In such cases, if the embankment or water system fails, the disaster can be much larger because backup and mitigating systems are no longer in place.

Nepal: Earthquake

On April 25, 2015, a 7.8 magnitude earthquake hit Nepal, causing widespread damage and fatalities across 39 districts in north central Nepal, including the country's capital, Kathmandu. While the numbers are likely to have increased since the writing of this paper, as of May 1st, the death toll from the earthquake had reached over 6,000 with 14,000 reported injuries and close to 160, 000 homes destroyed (Office of the Resident Coordinator, 2015b). In May 2015, the UN reported that rural mountain villages remain largely inaccessible due to the blocked roads by landslides and avalanches; over 2.8 million Nepalese impacted by the earthquake will require food, water, shelter and sanitation services in addition to health care in coming days and months (Office of the Resident Coordinator, 2015a).

The April earthquake follows a historical pattern of similar seismic events along the fault line that lies underneath the Kathmandu Valley, with the last earthquake of a similar magnitude occurring over 75 years ago, in 1934 (OCHA, 2013). While scientists have long anticipated that an earthquake would occur along this fault, with the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) even outlining strategies for providing shelter, food, and water to displaced and impacted populations in May of 2013 in preparation for such an event (2013), the earthquake exposed the fragility of many key systems in the capital and the wider Kathmandu Valley and further exacerbated underlying vulnerabilities.

The earthquake exposed the fragility of many key systems in Nepal and further exacerbated underlying vulnerabilities.

OCHA noted in a prescient news release in 2013 the vital role that transportation networks would play in delivering resources to isolated villages (2013). In their article, OCHA highlighted the need to plan for hampered efforts to reach isolated villages by road in the case of an earthquake (2013), a prediction which, unfortunately, has come to pass with access to many rural villages hindered by both landslides and avalanches (Matthew, 2015). As a result, people are evacuating impacted areas largely via both private and army helicopters (Lord, 2015; personal communication, April 28, 2015) Helicopters are acting as the only, yet limited means, of delivering much needed supplies to the 2.8 million people displaced by the earthquake (Office of the Resident Coordinator, 2015a). Efforts to distribute aid are further constrained by congestion at the Tribhuvan International Airport in Kathmandu with tourists gathering to catch outgoing flights and with limited slots available for inbound flights (Office of the Resident Coordinator, 2015a).

In addition to food, water distribution and supply are becoming the focal points of many disaster relief organizations and efforts (Office of the Resident Coordinator, 2015a). In our analysis of Kathmandu's water system above, we emphasized both the resilient and undesirable aspects of water markets and rooftop water harvesting emerging in response to the formal water supply's unreliability and high costs. As a consequence of this emergent response to the limitations of a utility-based system, a variety of agents became involved in water supply including government utilities, business and community groups, amongst others. This emergent diversity contributed to resilience prior to the earthquake and may have helped maintain services following it.

At the same time, however, the earthquake highlighted the fragilities of the water system in Kathmandu and throughout the impacted areas with regard to quality. Lack of safe water and sanitation systems increases the risk for the spread of waterborne diseases, as we saw with the cholera epidemic following the 2010 earthquake in Haiti. Admittedly, cholera was introduced into Haiti via an external aid group, but the underlying conditions of Haiti's water and sanitation systems ultimately contributed to the spread of the disease (Enserink, 2011; Friedrich, 2011). In the face of limited water supply and sanitation services, impacted areas in Nepal face a similar threat to Cholera as that experienced in Haiti, especially as the disease is endemic to the country (BBC News, 2015).

Oliver-Smith and Hoffman note the "processual" character of disasters (2002, p.3), with the impacts of an event such as an earthquake cascading across both time and space. This suggests that while the earthquake in Nepal, as the triggering event, occurred within a specific time frame and impacted a specific geographic area, the disaster unfolding in Nepal will not be limited to just the immediate shock of the earthquake. Rather as time progresses we may very well see cascading impacts from this event across the impacted areas with continued landslides, floods, and disease outbreaks as the result of environmental and structural fragilities in the country.

The disaster in Nepal is not limited t the immediate shock of the earthquake. Rather, as time progresses, there are cascading impacts from the event across the affected areas as a result of environmental and structural fragilities in the country.

While the vulnerability of the water and transportation systems were exposed during the earthquake, there were many emergent and strong characteristics of agents and systems that also arose in response to the disaster. Remarkably, even with downed power lines and disrupted services, technology and social media have played an integral part in rallying volunteers and in providing key information to the outside world (Lagesse, 2015; Sinha, 2015). *OpenStreetMap*, for example, is a web-based program allowing anyone to upload additional information to maps[7]. In the case of the earthquake, this type of geographical information, particularly where shelters are springing up, where roads may be impassable, or which hospitals are up and running, is particularly important in coordinating humanitarian efforts. Kathmandu Living Labs, a local organization in Nepal, has used this and other media to create maps of many critical features following the earthquake[8]. At a more individual level, immediately following the earthquake and in subsequent days, Nepalese are able to communicate with family members via SMS and provide information over Facebook and other social media platforms. In addition to the powerful role that technology and social media are playing in relaying information, individual Nepalese and groups of Nepalese are sending aid to rural villages in response to government delays in a type of emergent behavior that we also saw during the 2013 floods in Boulder, Colorado. A restaurant in Nepal, for example, managed to get trucks carrying needed aid and materials to Bunkot before the road was blocked by heavy rain yet before more established groups managed to arrive (Burke, 2015).

While these emergent behaviors are important for short-term recovery, how institutions and agents approach longer-term recovery and planning remains to be seen. The fragilities noted in the water and transportation systems will further exacerbate the social and economic vulnerabilities of the Nepalese living in isolated villages in Nepal. While the city of Kathmandu experienced the collapse of older buildings and the disruption of water and sanitation systems, the hardest hit areas

are those outside of Kathmandu that were difficult to reach before the earthquake and are now nearly impossible to access (Matthew, 2015). Focusing recovery efforts on the city of Kathmandu is important, but recognizing and addressing the need of those living in villages between Pokhara and Kathmandu will be vital for ensuring a more equitable, longer-term recovery. This highlights our point from earlier in this paper regarding the question of resilience for and by whom—building future resilience to disasters in Nepal and aiding short-term recovery efforts will require global efforts, careful thought, and local input into the process.

Karnali River Basin: Flooding

In August 2014, intense cloudbursts over the lower Karnali Basin in mid-western Nepal caused major flooding, affecting 149,567 people and 15,000 households, killing 99 people between the districts of Dang, Surkhet, Banke, Bardiya, and Kailali. The Karnali River Basin is enormous, draining almost a third of Nepal. It begins in the high Himalayas and drains into the Nepali and Indian *Tarais* (or plains). The rivers in this basin, especially the Karnali River, carry a lot of sediment that serves to exacerbate the flood risk experienced by communities along the river.

Recovery efforts in Kathmandu are important, but recognizing and addressing the need of those living in villages between Pokhara and Kathmandu is vital for ensuring a more equitable, longer-term recovery.

The Nepal government's response to flooding across Nepal has largely been to introduce major flood control structures such as embankments and spurs along rivers. One of the major flood control projects in the Karnali involves building 43 km of embankments along the east side of the Karnali River with a road on top; this project will cost 11 billion Nepali Rupees. The west side of the Karnali is already heavily embanked. While the government is seeking to protect communities from floods by introducing such structures, these structures are not helping make communities, especially marginalized communities, more flood resilient. Moench (2010, p.977) states, "because interventions at a system level can catalyze patterns of change that are difficult if not impossible to reverse, they can create path dependencies that are ultimately maladaptive." In the Karnali Basin, this statement resonates.

Several communities faced unexpected flooding as a result of embankment breaches and breakages. Embankments, in effect, allow communities, particularly those that are marginalized, to remain and even form in flood-prone areas. While communities that have lived along the Karnali for several decades are aware of the flood risk posed by the river and its propensity to migrate, migrant communities by and large are not. The Nepali *Tarai* has seen an influx of people from the foothills seeking fertile lands and greater economic opportunity. A significant number of these migrants are landless due to "the combination of corruptive land distribution to settlers, diminishing land availability, increasing immigration, and high natural population growth" (Shrestha, 1989, p.370). Their landlessness means that they cannot live on government lands or on public lands, and are pushed to areas that are risk-prone and largely unregulated, i.e. floodplains. The ability of these communities to adapt to floods is greatly hindered by their lack of experience with floods and knowledge of the river and its behavior during floods. The embankments only serve to add a false sense of security that further hinders adaptation.

The 43 km of embankments currently being built will greatly exacerbate this problem because of the road that is being built on top. Research has shown that development thrives along roads due to greater access to markets and income-generating activities (Barwell, 1996; Eberts, 1991). Multi-use protection structures, in many situations, have been successful and have the tendency to garner community buy-in. Boulder, Colorado's flood protection system, for example, consists of a series of paths that function as floodways and bike paths. During the 2013 floods in Boulder, these paths safely failed in their function as bike paths and were able to drain water back into the creeks (MacClune, Allan, Venkateswaran, & Sabbag, 2014). The Karnali embankments, however, are poorly conceived. First, these embankments are, in effect, being designed for much smaller flows than seen during the 2014 floods. Although they are being built to the water levels seen during the 2014 floods, the design does not take sedimentation rates into account. Second, the road will bring people and development into an extremely flood-prone area. Third, the embankments are only being built for a lifespan of 20-25 years. This is extremely problematic because the road cannot also be a short-term investment. Roads lead to longer-term development that depends heavily on their presence to survive. In this sense, these embankments will not fail safely. As a result, when the embankments do fail, it will be catastrophic. People will be deeply impacted by the resulting deaths, injuries, property losses, infrastructural losses, loss of market access, livelihood losses, and so on. Recovery will be difficult because the Nepal disaster management focuses primarily on immediate response to and recovery of infrastructure, and not on the short to long-term recovery of impacted people.

Construction of embankments by the Nepal government follows the age-old paradigm of engineering nature to control it without considering how people will interact with the built systems.

What is evident so far is that the Nepal government's embankment construction follows the age-old paradigm of engineering nature to control it, and then not giving due consideration to how people interact with built systems. The Climate Resilience Framework (CRF) shows that a resilient system comprises of interacting agents, institutions, and systems (Tyler & Moench, 2012). In this case, how do people perceive embankments? How do embankments impact people's perceptions of flood risk? How will the roads impact people? Based on past experiences with floods, where should embankments be built? Should a road be built on top? What kinds of changes and needs will the embankments and roads bring? Such questions relate to fundamental drivers of agent behavior and the ability to learn. The only way that the interactions and linkages can be parsed out is through an iterative learning process (Tyler and Moench, 2012). These embankments are not being designed through such a process, involving government, engineers, and communities. Rather, embankments are being planned, communities informed—and displaced or stripped of productive lands, and then built. Much of the problem is that communities, especially poor, low-caste communities[9] are typically excluded from decision-making processes (Gurung, 2006; Pradhan, 2006). Instead, hierarchical structures are enforced and systems are designed in Kathmandu with little knowledge about local realities.

So what needs to happen? If embankments are to be built, they need to be built alongside a multitude of smaller solutions that account for the social, political, and environmental complexities that embankments generate and/or exacerbate. This

would reflect broad lessons on diversification and exposure to risk that contribute to system resilience. Another option is to shift the paradigm from engineering and controlling to nature to one that recognizes alternative development pathways that are co-produced and reduce flood risk while increasing the ability of communities to live with a dynamic river.

Pakistan: Systems and flood recovery

The 2010 flooding event in Pakistan was the largest in recorded history along the Indus. According to the United Nations Secretary General, almost 20 million people required shelter, food, and emergency care (Khan, 2013). Across the country major transport, energy, shelter, sanitation, food supply, and other basic systems failed. In many areas embankments failed or, in some cases, were intentionally breached in order to protect other areas including major urban centers.

From a complex systems perspective, the Pakistan flood case clearly indicates the difficulty of using simple development measures to evaluate resilience.

Following the floods, rates of recovery varied greatly between areas. Research on recovery in a series of sample regions conducted by ISET-International in 2012 clearly documents the role access to critical systems and services played in flood recovery, as measured by the rebuilding of housing assets (Khan, 2013). The importance of specific services and systems, however, varied greatly between regions. Access to electricity, a major factor determining access to communications, finance and other related services, was a major factor in the rate of recovery in all areas[10]. Improvements in sanitation and health services were also a statistically significant factor influencing recovery rates across regions. The role sanitation played, however, appeared particularly important in areas where inundation flooding could result in long-term contamination of surface and groundwater supplies, but somewhat less important in desert and high mountain areas. The importance of access to an improved, piped water supply, however, varied more between regions. This appeared to be due to differences in the nature of primary water sources. In those regions that depend on easily polluted surface water supplies, access to improved sources was a statistically significant factor in recovery rates. In areas, however, where most of the population depended on private tube wells and other sources that are less easily subject to contamination by flood waters, access to modernized water systems did not contribute to recovery rates. Similar differences with respect to access to credit, mobility, and transport were also present between regions. In the case of credit, speed of access appeared to be important. Those farmers who could access the credit required to purchase scarce and expensive seed prior to the 2011 cropping season recovered faster. Similarly, where transport and roads were concerned, affordability, social norms (female children not being allowed to travel outside the village for schooling in some regions), and reliability were important considerations.

From a complex systems perspective, the Pakistan flood case clearly indicates the difficulty in using simple measures of development to evaluate contributions to resilience. While the ability of different groups of agents to recover from the flood was clearly influenced by the continuity of critical services, standard measures of development, such as the presence of modernized water supply systems, were not necessarily good indicators of that. In addition, the importance of specific services

varied between contexts. This is similar to the finding noted above in the viral risk case where the factors that contribute to resilience are, in some cases, context specific.

Development pathways: Da Nang flood example

In many areas around the world, decisions on approaches to flood management and a range of core infrastructure made as part of an overall approach to development create both physical systems and associated institutional relationships that are highly resistant to change and can have major environmental or social consequences. Such decisions, in effect, determine major elements of the pathway future development will take and determine a range of likely future social and environmental consequences. This is illustrated well in ISET-International's recent work undertaken in Da Nang, Vietnam.

Da Nang is a rapidly growing port city on the coast of Vietnam. It serves as a major business and transport hub and, as part of a major program to improve regional transport systems supported by the Asian Development Bank and other organizations, is increasingly linked to other areas throughout the Greater Mekong Sub-Region. As Da Nang develops, land close to the city center and adjacent to the port and major river areas is in high demand (Tran & Tran, 2013). Most of the available land is in the flood plain and, from the perspective of flood management and the likely impacts of climate change, such land would ideally be left undeveloped or for agricultural uses.

In Da Nang, the risk of catastrophic failure during large-scale flood or storm events may increase due both to the inherent thresholds associated with levies and changing deltaic dynamics.

The city administration, however, earns most of its revenue through conversion of agricultural lands and the sale of such lands to developers. As a result, in large areas along the major rivers, the city administration brought in soil and raised large sections of the flood plain by as much as four meters. This reduces the frequency and depth of flooding in those specific areas and makes them attractive for private developers. The result, however, will be to displace floodwaters to other low-lying areas, many beyond the administrative boundaries of province and city administration.

As sea levels rise and the likelihood of extreme events increase with climate change, flood impacts on such low-lying areas, and the lower-income agricultural and fishing communities that inhabit them, are likely to increase dramatically. In addition, new high-value developments within the urban area are likely to demand further increases in flood protection. While the level of the land where construction is occurring has been raised significantly, it will be insufficient to limit flooding in major events. Once buildings are constructed, raising land levels will be impractical and additional protective levies are likely to be constructed. Risks of liquefaction in flooded and poorly compacted deltaic soils may also grow. As a result, the risk of catastrophic failure during large-scale flood or storm events may increase due both to the inherent thresholds associated with levies and changing deltaic dynamics[11]. Consequently, as investments are made and the value of the land grows due to its

proximity to the port and city center, the economic and political pressure for flood protection is likely to increase.

In other areas this has already resulted in the construction of embankments and other protective infrastructure in conjunction with softer measures such as early warning systems. Overall, a dynamic is developing that is likely to result in a spiraling attempt to protect economically valuable and politically powerful areas while displacing flood waters to lower income and less powerful areas, particularly those outside the administrative boundaries of the urbanizing area (Tran & Tran, 2013).

The above dynamic is driven by multiple reinforcing factors. Institutionally, unless basic changes are made in how the municipal government is financed, incentives for those in government align strongly with land sales and the development of protective infrastructure. Equally importantly, as Bettencourt and his partners' work suggests would be the case, private sector companies and most individual households value proximity to the city center and port (Bettencourt, 2013c; Bettencourt, Lobo, Helbing, Kuhnert, & West, 2007; Bettencourt, Lobo, Strumsky, & West, 2010). Culturally, Vietnamese also value residences near water sources. These factors combine to drive further development and efforts to protect central areas despite the regular disruptions caused by flooding. To put it another way, the basic system structure underlying the development pathway is likely to retain core elements of structure and function in ways that display resilient dynamics despite the impacts and inequity it generates. This pattern is common globally. It is, for example, a fairly standard practice to protect high-value locations and assets, such as urban areas, from flooding. This creates a self-reinforcing dynamic that tends to concentrate investment and new asset creation in protected areas while distributing flood risks primarily into areas where lower value assets and less politically powerful populations are located. This behavioral cycle is, if one uses the Resilience Alliance definition (2015c), very resilient even though it tends to generate differential impacts on vulnerable populations and result in the creation of fairly rigid protective infrastructure.

The basic structure of the system that underpins Da Nang's current development pathway is likely to retain core elements of structure and function (i.e., display resilient dynamics) despite the impacts and inequity it generates.

Urban heat: Is resilience the answer?

Over coming decades, increases in heat across northern India and much of Pakistan are projected to have major impacts on the productivity, health, and potentially even survival of large populations (Dash & Kjellstrom, 2011; Khan, Malik, & Rehman, 2014; Moench, Khan, *et al* 2015; Mueller, Gray, & Kosec, 2014; Oliver-Smith, Ghosh, Patwardhan, Daly, & Salvi 2015; Zahid & Rasul, 2012). The central challenge is not related to peak temperatures but to increases in sensible heat, the combination of humidity and temperature. Sensible heat measures the manner in which the human body feels temperature (Schneider, Root, & Mastrandrea, 2011). It reflects the fact that the ability of humans and other mammals to shed waste heat depends on evaporative cooling and thus on the surrounding humidity as well as temperature. Human body temperature is 37 °C and heat index temperatures at

that level are a cause for caution with increasingly high levels of direct danger from heat stroke as they pass 40 °C (National Weather Service, 2014).

Heat Index climatologies drawn from bias corrected CMIP5 multimodel ensemble for present day and future conditions for Gorakhpur in India; and Islamabad, Rawalpindi, and Multan in Pakistan indicate that the mean daily heat index is expected to surpass 37 °C for weeks at a time and, in some locations, for over three months continuously each year by 2050 (Ammann, Ikeda, & MacClune, 2014). Increases in the night minima heat index are projected to be particularly severe. While the peak daily temperature is only projected to increase by approximately 2 °C over this period, the minimum night heat index will increase by 5-7 °C (Ammann et al., 2014). The largest increases will be during the monsoon season when night time temperatures don't decrease and humidity increases (Ammann et al., 2014) .

If these projections are accurate, the human impacts will be huge. Cooler temperatures at night are a major factor in the ability of the human body to recover from higher temperatures during the day. Passive cooling techniques are likely to be ineffective because the increase relates to minimum or average ambient heat, not protection from daily peaks. Increases in urban areas are likely to be particularly rapid and higher than the projected regional increases due to the urban heat island effect. As a result, human productivity, health, and potentially survival are likely to require active cooling. At present, much of the population throughout northern India and Pakistan lacks access to reliable sources of electricity, particularly in the amounts that would be required for air-conditioning. Meeting that level of demand at a price that would be affordable for the vast poor population in the region appears highly unrealistic in the near future.

Strategies that focus on building resilience are unlikely to serve as sufficient responses to projected urban heat levels.

More transformative strategies are likely to be required.

From a complex systems perspective, it is unclear whether increases in resilience could contribute to addressing the disruptive effects increasing heat appear likely to have on society. It is difficult to envision how approaches that seek to preserve the basic structure and function of energy systems, approaches to cooling and shelter, or urban areas as currently designed could address heat impacts, particularly on the poor and other vulnerable populations. Instead, the situation seems to call for much more rapid and transformative approaches. Proactive approaches might involve, for example, fundamentally rethinking housing, the private nature of shelter, and the provision of access to cooling. They might also require fundamental changes in energy and cooling technologies. More reactive approaches are also likely to be transformative. Migration and the decline of agricultural and other heat sensitive livelihood activities would, for example, be a logical consequence in the absence of more proactive approaches to transforming the systems people now depend on. Overall, there appears to be a need to shift out of the current basin of attraction and into something quite different. Transformation rather than resilience appears to be the more appropriate conceptual direction to take.

Discussion and conclusions: Key tensions & key points of value

As a term, resilience has a positive, optimistic connotation implying the ability to bounce back from disruption into a healthy state. The analysis and cases above document, however, that as an emergent property of complex systems, the meaning of resilience is much more neutral. The ability of a system to "absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (Resilience Alliance, 2015c) indicates little about the relative desirability of the system. While the ability of an economy or a city to respond and recover from both anticipated and unanticipated events, such as disasters or economic crises, has, as Judith Rodin argues in "The Resilience Dividend," real benefits. Similar factors within complex adaptive systems such as urban areas or economies can perpetuate inequity or environmentally destructive relationships. *Rather than promoting resilience as a panacea or central policy objective, the key question should be whether resilience, or more accurately, systems concepts, could be used to strengthen states where a broad-based social consensus exists regarding their desirability while also providing insights that can be used to destabilize and transform states of low desirability. Implicit in this is the need for effective governance processes to ensure questions of resilience for what purpose, through what mechanism, and for whose benefits are adequately addressed.*

Rather than promoting resilience as a panacea or central policy objective, the key question should be whether resilience, or more accurately, systems concepts, could be used to strengthen states where a broad-based social consensus exists regarding their desirability while also providing insights that can be used to destabilize and transform states of low desirability.

Desirability implies, of course, questions of human values and the political governance processes through which such values are expressed. Values such as equity or environmental sustainability are not, as demonstrated in the sections above, central to resilience concepts and need to be articulated separately.

The fossil fuel based energy system on which most of the world now depends is, despite its ultimate unsustainability, highly resilient. Changing it requires approaches that undermine the resilience of that system and catalyze transformation into a system with a fundamentally different set of structures and functional relationships.

Similarly, highly inequitable forms of social organization can also be highly resilient. In fact, the very factors that contribute to resilience at the level of an economy or urban system imply uncertainty and a degree of inequity at the level of individual businesses or communities. Urban areas and economies are systems-of-systems. Keeping them flexible and adaptive requires churn (the dynamic rise and fall of businesses, exposure to disaster and risk) in the businesses and communities of which they are composed. This essential dynamism, in turn, creates and recreates patterns of vulnerability for those who lose jobs and are too old, infirm or lack the education to compete. It implies maintaining a degree of exposure to risk from floods, droughts or extreme storms along with the potential for very real losses when a theoretical risk becomes a reality.

Resilience depends on the above dynamics. As a result, while it has real value as part of a framework to guide policy and practice, questions of resilience of what, for what purpose, and for whose benefit are of fundamental importance. The very factors that create resilience at an urban scale may also, as a result, generate poverty and vulnerability traps. As an attribute of complex systems, resilience concepts neither capture nor tell us much about these questions.

In addition to values, the analysis above clearly documents the context dependence of resilience. To put it another way, factors that are often described as contributing to the general resilience of an urban area in relation to all sources of disruption, may in actuality only contribute to resilience relative to specific classes of disruption. Community relationships are widely recognized as central to recovery from disasters, war and economic upheaval. These very relationships can, however, serve as the primary vector through which diseases and other viral forms of disruption are spread.

Nuances and awareness of context are, as a result, of fundamental importance for the effective use of resilience concepts to address policy issues or applied activities to address the real problems society faces. Resilience is not a standalone concept, nor should it be a primary objective for policy and practice. As argued above, values are of central importance. Equally importantly, resilience needs to be recognized as part of a family of concepts regarding the properties of complex systems rather than as an umbrella that captures all aspects. Adaptation and transformation are probably best recognized as associated concepts that, while reflecting similar basic processes within systems as those contributing to resilience, speak to somewhat different aspects. Adaptation describes the manner in which systems incrementally evolve in response to stress, opportunity and selective pressures. While that can contribute to resilience, it can also cause systems to "flip" or transform into states with fundamentally different structural and functional characteristics. Transformation is much more relevant than resilience as a concept in addressing the need for large scale change in systems, such as the fossil fuel energy system or poverty traps, that are deeply embedded and self replicating but have highly undesirable attributes. Overall, we argue here that while resilience is important for some broad classes of policy challenges, adaptation and transformation are more appropriate for others. No one term can serve as a catchall.

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Finally, it is important to recognize the practical limitations of resilience concepts in applied contexts, such as those related to urbanization. Urban areas are largely emergent rather than clearly planned or governed features. The physical and other infrastructure systems on which they depend grow incrementally in a manner that is, at most, partially influenced by planning efforts. As socio-ecological entities, they are also shaped by the behavior of different groups of actors, each responding to the structural incentives inherently associated with different forms of organization. These drivers create the professional and operational silos we observe within governments and the private sector. They also create and reinforce the distinctions that underpin the growth of political divisions and professional, social or geographical identity.

Urban systems and their relative level of resilience are emergent features that combine often contradictory elements. Many of the points where such systems can be influenced lie at the bottom—in strategies that provide agents with new technologies (system components) or shape the incentives to which they are responding. Interventions at this elemental level have a chance to replicate upwards in ways that ultimately reconfigure the nature of the mega-systems we call urban areas. At the same time, the development of new technologies and the creation of incentive structures often depend on high-level interventions in institutions or the development of new technologies. Tipping the energy system, for example, requires both improvements in solar and other technologies and the creation of institutional frameworks that support distributed rather than centralized power generation. In practice, this suggests that some of the most important avenues for building resilience or catalyzing transformation will involve a combination of very diverse bottom-up and more structural high-level interventions. Thousands of small changes in businesses and the physical systems on which we depend are enabled and directed by higher-level changes in institutions and the incentives they create.

Some of the most important avenues for building resilience or catalyzing transformation will involve a combination of very diverse bottom-up and more structural high-level interventions.

Overall, the growing global policy narrative around resilience needs to shift and become much more nuanced if, in contrast to the history of many other policy buzzwords, it is to have a sustained and positive effect. Rather than having resilience as a primary policy objective in its own right, far greater emphasis needs to be placed on questions of values and the governance processes through which they can be negotiated. In addition, rather than attempting to serve as an umbrella for other concepts such as adaptation, sustainability, and transformation, resilience needs to be recognized as part of a family of concepts each with equal relevance to the challenges society faces in the context of urbanization, climate change, globalization and other major change processes.

Endnotes

1 See www.resalliance.org.

2 पलटाव, लचीलापन, लोच, लौटाव (translation: "resilience")
See www.shabdkosh.com

3 "Emergence is the idea that simple elements that are governed by a few simple rules and operate through trial and error with interaction and feedback can produce systematic patterns that are quite unlike the original elements. The elements or agents that work best are those capable of collecting resources and generating new variants. Those that cannot do this die out. The interactions among the simpler elements of the system produce higher or more complex levels of component organization, similar to the way atoms interact to form cells, and cells to form organs. The result is increasing competence of the system as a whole in the form of greater productivity, stability, or adaptiveness" (Innes & Booher, 1999, p.417).

4 See: http://www.100resilientcities.org/blog/entry/what-is-a-chief-resilience-officer1#/-_/

5 http://www.census2011.co.in/census/district/559-gorakhpur.html

6 As of April 17th, 2015, the length of tunnel completed stood at 12,702 meters out of a total projected length of 27,582 meters. http://www.melamchiwater.org. Any effects of the subsequent earthquake are unknown at the time of writing.

7 See: http://www.openstreetmap.org

8 See: http://kathmandulivinglabs.org

9 Many of the communities in the Nepali Tarai have faced increasing outmigration of males to India, looking for work. It is common to see communities, especially in rural areas, that are almost entirely made up of women. Women are among the most marginalized groups in Nepal and have very little political power (Gurung, 2006).

10 As measured in areas lacking universal coverage where differences in recovery and access to electricity could be measured.

11 Delta areas tend to subside when sediment deposition patterns are altered, organic rich soils are oxidized, and groundwater is extracted. Attempts to raise land are often ineffective over time due to these factors and also to the instabilities created when unconsolidated fill and buildings are placed on top of soft saturated deltaic deposits.

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We live in a world shaped by complex webs of socio-ecological systems. Although our survival depends on them, these webs are poorly understood and often beyond our ability to control as individuals, communities and even nations.

The foundational analogy increasingly used to describe complex socio-ecological systems follows the dynamics of natural ecosystems. A resilient ecosystem cycles through phases of growth, conservation, release, and reorganization. As these cycles proceed, individual species within the larger ecosystem grow, decline, evolve and in some cases disappear. Resilience is lost when the cycles are blocked and the ecosystem becomes increasingly structured and rigid. Diversity and flexibility decline and ecosystems can become trapped in states that are highly resilient to change. Tipping points are, however, almost always reached sooner or later that disrupt established patterns. Once a tipping point is reached in such cases, ecosystem change tends to be dramatic, fundamentally altering the structure and function of the system and creating new patterns of productivity, resilience, and vulnerability.

While the above principles can be applied to socio-ecological systems, they do not account for the full range of drivers that create social outcomes. Humans have the ability to act and shape their environment. Complex political dynamics shape relationships and together with institutional rules govern the approaches we develop to manage and shape the world we live in. It is unclear, however, whether the consequences of agency and institutions override the underlying drivers of ecosystem dynamics in determining social outcomes. The purpose of this paper is to explore this question and the implications our understanding of complex systems dynamics have for efforts to address some of the real challenges global society now faces in the context of globalization, rapid urbanization, and climate change. We follow the analogy, explore the questions it poses and, along with the role of agency, ask: What is the meaning of resilience? What is the purpose of resilience and who does it benefit; on what time, institutional, or geographic scale; toward what ultimate objective? What are the tradeoffs, who chooses, who loses, and who gains? Can resilience be for everyone?

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