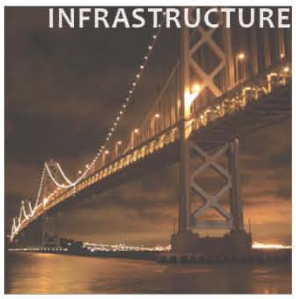

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Community Resilience:

A function of resources and adaptability

WHITE PAPER

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Executive Summary

This white paper is intended for people who must help communities prepare for surprises. It assumes that no community can protect itself from every conceivable threat, but can increase its ability to be resilient or 'bounce back.' The resilience approach described below is written in plain language and as culturally-neutral as possible in order to make it globally applicable across a broad range of communities. We recommend that communities assess their resources and adaptive capacity for a variety of community systems: ecological, economic, civil society, government, and infrastructure in order to find the balance that achieves the degree of resilience most appropriate for them. This approach also requires attention to the intersections and overlaps of these systems. The ideas presented here are consistent with the most current efforts at defining and assessing resilience, even if the terminology varies. The paper concludes by outlining the next steps for concept refinement and validation through case-based research and development of assessment tools for practitioners.

The Problem

Governments and non-governmental organizations in many countries face a daunting task: the design and implementation of policies, programs and systems that help local communities cope with a wide range of threats – from terrorist attacks to natural disasters. In highly developed societies, this task is often compounded by associated problems such as aged, overburdened, and complex critical infrastructure systems; the catastrophic nature of chemical, biological, radiological, nuclear and explosive (CBRNE) threats; and the increasing interconnectivity of many global systems for transportation and communications.

Can any community prevent or protect itself from all the possible dangers it may face? Even with unlimited resources, it is highly unlikely. In the United States for example, complex distribution systems are now the primary mechanism for supplying populations with food and water. Gasoline-powered vehicles remain the dominant mode of transportation. Individuals and organizations are more reliant than ever on electricity, computerized systems and communication networks supported by distant satellites for everyday activities. Each of these modern conveniences allows communities to function more efficiently. Yet, few people maintain a stockpile of food and water for emergencies or possess alternative modes of transportation, power generation, or communication. Never before have governments, communities, and individuals been so devastatingly unprepared to cope with disturbances to infrastructure, vital resources or public goods and services.

In current policy debates, the meaning of resilience varies by disciplinary perspective. For most, resilience, with its roots in the Latin word *resilio*, means to adapt and 'bounce back' from a disruptive event.[1] Similarly, resilience also refers to the ability of a system to absorb, change, and still carry on.[2] As applied to social systems, resiliency also refers to the capacity of a community network, or part of that network, to absorb and recover from hazardous events.[3] As such, we define resilience as *the capacity of a system to absorb disturbance, undergo change, and retain essentially the same function, structure, identity, and feedbacks.*[4] It can be a characteristic of individuals, small groups, networks, organizations, regions, nations, ecosystems, or a whole host of systems and subsystems within our planet.

Too often, resilience is confused with 'mitigation' – measures put in place before an incident to reduce damage – is a crucial part of the planning process. It also helps to save lives and minimize short and long-term recovery expenses.[5] As such, hazard mitigation planning refers to a coordinated series of structural and non-structural measures and processes intended to lessen the probability of future damages to property, while also reducing the impacts stemming from natural and technological (or "man-made") hazards and disasters.[6] Closely related to mitigation, resilience is also confused with the term 'resistance' – an attempt to prevent or stop disruptive events from happening. Resistance strategies include physical countermeasures such as trying to stop terrorists from boarding aircraft and building firewalls to protect computer systems from intruders. Whereas, resilience strategies assume that resistance may not always be possible and thus include the provision of and access to alternative resources and services.

Resistance and mitigation we believe are not antithetical to resilience. Rather, resilience subsumes both.[7] If a community can resist a disturbance, its qualities and resources are robust enough to prevent the disturbance from reducing community functioning without any need for adaptation. Even if a community attempted to resist all danger to its vital systems, a strategy that only directs resources toward resisting threats would almost certainly be costly, and possibly conflict with societal norms and individual liberties. Moreover, when resistance strategies fail they have a tendency to fail catastrophically. In recognition of this, policymakers have recently returned to an earlier emphasis on building resilience to disruptive events.

This new focus on resilience to disasters as a strategic goal is both profound and profoundly challenging. It is recognition that governments have limitations on the extent to which they can prevent danger and protect their citizens. There is an increasing acceptance of the idea that individuals and local communities must play a key role their own resilience. This is both empowering and difficult to implement. How do communities build resilience? How do governments allocate resources between programs designed to protect people and infrastructure from disasters? This policy brief summarizes our efforts to expand resilience beyond a theoretical concept, into a practical approach that communities can use for thinking about how to build their own resilience.

The Starting Point: A Theory of Community Resilience

This section provides a primer on resilience theory as applied to communities. It draws heavily upon the work of several distinguished interdisciplinary scholars at the Resilience Alliance[8] as well as additional contributions in describing the dynamic attributes of resilience for use in disaster preparedness.[9] We begin with an introductory discussion on the community as the object of resilience. From there, we introduce the core concepts and variables that underpin resilience, placing them in the context of a community.

A community is a group of people that shares a common physical environment, resources, and services, as well as risks and threats. It is also a collective body that has boundaries (often geographic), internal and external feedbacks, and "a shared fate."[10] Because of this, a community is a complex physical and social system comprised of many sub-systems.[11] For example, a typical metropolitan area encompasses a diverse collection of districts and neighborhoods with the central city and its suburbs with differing land use, function, and income levels. Some experts refer to the 'footprint' of a community as the region from which a city pulls its resources, that receives the city's waste, or that depends on the city's economy. They usually reach far past the city limits.[12] Disruption of community systems can both come from external points and have broad effects within and without. For example, the source that generates and provides power to an urban energy system is part of that system but may be located well outside of the given urban area. Many other subsystems contribute to its functioning (i.e., governance, economy, public services).

In contrast, a rural community might be limited to a smaller collective of residents inhabiting a valley or mountainous region. Likewise, rural subsystems will vary in form and significance to overall community functioning. For instance, the family (as an institution) and religious organizations may play a more dominant role in rural settings that they do in urban settings.

We focus on resilience at the community level because most disasters are local and affect communities differently – a flood or earthquake would not affect residents of Singapore the same way that it would affect residents of San Francisco, California. Communities are unique and have their own local needs, experiences, resources, and ideas about prevention, protection, response, and recovery from different types of disasters. Each community has access to resources and the ability to manipulate and make decisions that single individuals do not. Since all planning, and actual disasters require the immediate involvement of a wide range of local institutions (as opposed to state and national organizations), they are typically the appropriate level of focus for emergency planning and response activities. A community level focus on resilience results in local participation, ownership, and flexibility in building resilience, as opposed to a 'one-size-fits-all' or 'top-down' approach.[13] Moreover, because communities are parts of greater wholes (states, regions, nations), a bottom-up, community resilience approach, concomitantly builds state, regional, and national resilience.

Within both communities and regions, there is usually a high level of interaction among government, corporate, nonprofit, and individual participants when addressing common needs.[14] Vulnerability to disasters is a matter of perception, and in the perception of most governing agencies, very little

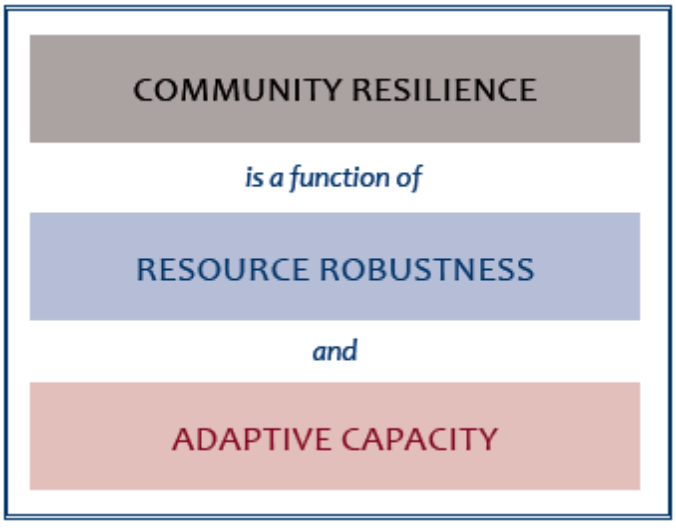
consideration is given to the view of local people. Agencies tend to think on behalf of the victims, but do not account for the reality that disaster-prone communities might have different interpretations of their own circumstances. Thus, if planners and managers are seeking to improve community resilience, communities themselves must have their perception of risk included within the planning process.[15] Herein lies the crux of the problem, as today's top-down approach appears to be an operational example of the gap that Wisner[16] identified between municipalities and civil society regarding their own vulnerability.

We are in the process of developing a bottom-up approach that ensures cross-cultural application, making it useful in multicultural communities and across national boundaries. By accounting for the intermestic domain (the merging of international and domestic concerns), our analytical model seeks to close the practical gap between state-provided security, human safety challenges such as disasters and terrorism, and trans-boundary connections across cross-sectoral planning and response levels.[17]

So what, then, is resilience in a community setting? Simply put, it is the ability of a community to absorb a disturbance while retaining its essential functions. This does not mean that its degree of functionality remains in a constant state – that, rather, is resistance to disturbance. To be resilient, the community must have both the resources available and the ability to apply or reorganize them in such a way to ensure essential functionality during and after the disturbance. Furthermore, since the disaster governance process will differ based on each geographical setting, measures taken with the aim of improving a community's assessment of its own resilience must be highly context-specific. Using the concepts developed by the Resilience Alliance, we propose a simple model of community resilience as a function of the robustness of a community's available resources, and the community's adaptive capacity to utilize its resources toward the goals of prevention, protection, response and recovery in the face of a disaster.[18]

Community Resilience = *f* (Resource Robustness, Adaptive Capacity)

Before elaborating further on what resource robustness and adaptive capacity entail, we note the broader implications for communities. Communities with a highly robust pool of resources and a high degree of adaptive capacity will be the most resilient. If a community is either high in resources or high in adaptive capacity, they can afford to have somewhat less of the other and still remain relatively resilient. However, when communities possess low levels of resources and low levels of adaptive capacity, they will be less resilient. If a community is lacking in resources, it can concentrate on building its adaptive



capacity. Strengthening local coping capacity can help empower local communities rather than furthering institutional dependency.[19] Hypothetically, two communities could have an equal amount of resilience, but a different mix of resources and adaptive capacity.

Resource Robustness = *f*(Performance, Redundancy, Diversity)

A community's *resource robustness* is based upon the performance, diversity and redundancy of its available resources. Resources are defined as "objects, conditions, characteristics, and energies that people value."[20] A community resource could range anywhere from snowplows to schools, from hospitals to lakes, or from social cohesion to economic wealth.

Performance "describes the general level of capacity and quality at which an element or elements of a system performs an essential role."[21] For example, a hammer performs better than a wrench for sinking a nail. Performance also includes relative quality (a higher quality hammer performs better than one of lesser quality).

Diversity is a measure of different types of available resources that perform a particular function.[22] Hammers, nail guns, and other hard objects all provide a diversity of options to sink nails, albeit at different levels of performance.

Redundancy is a quantifiable measure of a single resource type that performs a specific function.[23] Redundant resources provide a failsafe, or back up, when any individual unit fails. As such, having many hammers provides a high degree of redundancy for sinking nails.

When combined, performance, diversity and redundancy of available resources determine their overall robustness.[24] For example, the robustness of a water system would be greatest when the system has high performance (i.e., sound delivery mechanisms, pipes, pumps, etc.), redundancy (i.e., multiple water lines), and diversity (i.e., multiple sources such as rivers, lakes, aquifers, and runoff). Every community, and subsystem within a community, has to decide how to allocate time and money between performance, redundancy and diversity, keeping in mind that it is best to have a balance of the three attributes – not to maximize one to the detriment of the others.[25]

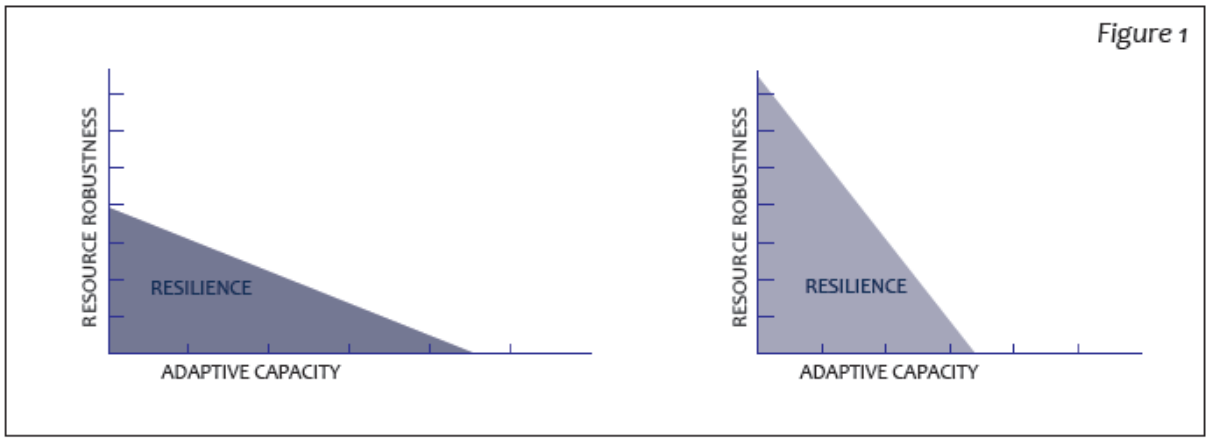


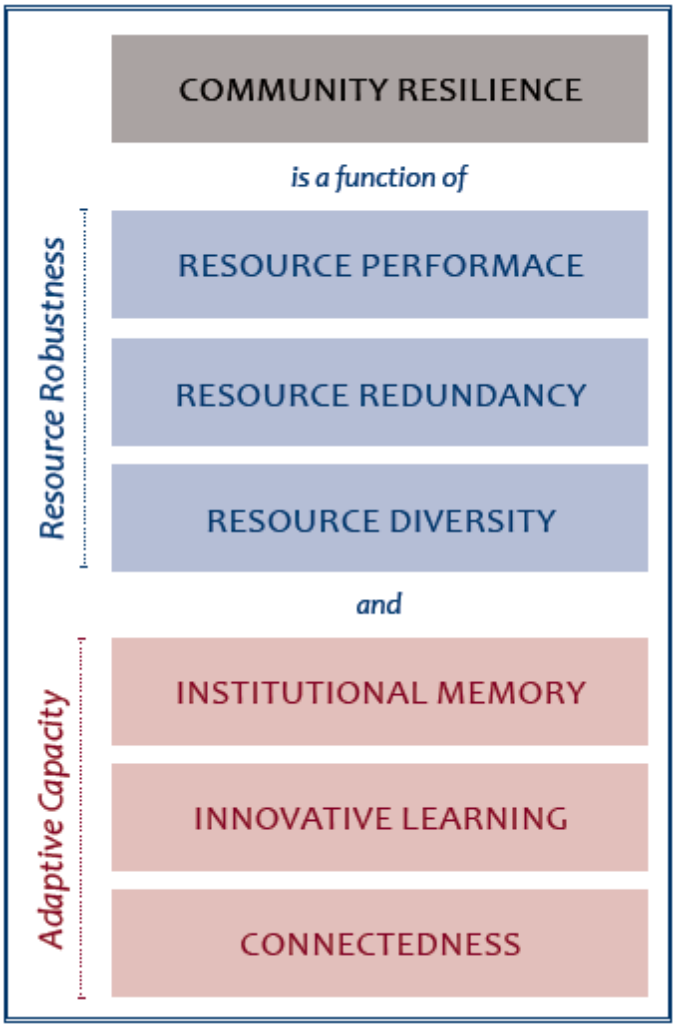
Figure 1

Adaptive Capacity = *f* (Institutional Memory, Innovative Learning, Connectedness)

A community's *adaptive capacity*[26] is a function of its collective ability to: 1) store and *remember* its experiences; 2) use that memory and experience to learn, *innovate*, and reorganize resources in order to adapt to changing environmental demands; and 3) *connect* with others in the community to communicate experiences, lessons learned, and self-organize in the absence of direction.

Institutional memory is the accumulated shared experience and local knowledge of a group of people. Over time, institutional memory is amassed through group-level observation and stored in a variety of ways such as documented records and repetitive rituals and ceremonies that are carried on as group membership evolves over time.[27] Rituals reinforce institutional memory by facilitating and reinforcing the recollection of rules and policies as well as the interpretation of changes or disturbances in the environment. Information and knowledge management systems that store, distribute, and aid in interpretation of large quantities of data are helpful in retaining institutional memory but only if they are accessible by people who need them, when they need them.

Innovative Learning is the ability of the group to use its information and experience to create novel adaptations to environmental changes, vice failing to change or repeating old mistakes. Innovation is a form of dynamic learning as it places emphasis on the capacity to identify and "create new responses or arrangements."[28] Innovative institutions typically encourage trial-and error type learning by allowing "errors and risk-taking behavior."[29] Innovation and learning are mutually increased through the practice of "adaptive co-management" which combines a management culture that places a premium on risk taking and experiential learning with the linkages and partnerships associated with cooperative management.[30] Generally, the creation of new ideas, resources, processes, and forms of organization are all results of innovative learning. A community is in a position to learn and innovate when individuals and groups are able to experiment through trial and



error. Repeated variations on experiments create knowledge – and hopefully institutional memory – of what new ideas, processes, and organizational designs work and those that do not.

Finally, interpersonal and group *connectedness* is critical to the diffusion information and knowledge throughout the community. A high degree of interconnectivity within society facilitates the diffusion of information, lessons learned and the accumulation and recall of institutional memory. Community systems and subsystems typically will have a variety of internal and external (cross system and cross-scale) links between their various component parts – more commonly known as social and organizational networks.[31] In the absence of formal direction, these connections – which often vary in strength[32] – allow systems to self-organize.

When a community possesses a high level of all three traits – institutional memory, innovative learning, and connectedness – it in turn, possesses a high capacity to adapt to changes in the environment. If it has a relatively low level of one trait, it can often make up for this deficiency with a higher level of another. For example, a large city with low levels of connectedness between ethnic groups could address this problem directly by creating bridges through structured dialogue. However, if such a strategy proves unfruitful, it may still be able to improve adaptability by increasing the access of these groups to a shared knowledge center, or by encouraging innovation and learning across all groups.

Applying Resilience Theory in Community Systems

With the ability to make sound self-assessments of their resilience to disasters, communities can more appropriately prioritize preparedness efforts, allocate funding, and develop more innovative ways to organize their material and human resources. In order to help communities think about their resilience, our model applies the concepts above to the separate assessments of five key community subsystems: ecological, economic, civil society, governance, and physical infrastructure.[33] We recognize that these subsystems are inherently interdependent, overlapping, and complex, even in small communities.

Within each subsystem described below, we describe the attributes and characteristics of what we believe indicate resilience in each subsystem, that is, the robustness of the resources that make up the subsystem and its adaptive capacity. Attributes of resilience will vary depending on the type of sub-system in question. For example, "diversity" in an ecosystem may be the number of different types of species, while diversity in an economic system may include the range of skill sets within a labor force.

Ecological System

Ecological systems are the combined biological and physical elements of the environment in which a community is located. An "[e]cosystem is the complex of interconnected living organisms inhabiting particular area or unit of space, together with their environment and all their interrelationships and relationships with the environment. An [e]cosystem is characterized by the description of populations; [the abundance] of individual species; interspecies relationships; activity of organisms;

physical and chemical characteristics of environment; flows of matter, energy, and information; and description of changes of these parameters with time."[34] Humans are an important part of a community's ecosystem but they are not the only important part. Without outside resources, they cannot survive if the local environment does not support agriculture or provide enough clean water.

Some parts of an ecological subsystem will be beyond the control of a community, but are nonetheless helpful in describing a community's setting and natural resources. These parts might include resources such as climate, soil quality, and topography. The important task for each community is to look at the aspects of their ecological systems that they value most in order to consider them when they are forced to bounce back from a surprise. For example, it would be important to know wind patterns if you must respond to a cloud of volcanic ash or a biological attack.

In order to assess the resource robustness of the local ecological subsystems the community would look at things like the amount of available land for new uses such as food production or temporary shelter construction. In addition, a diversity of habitats would allow some flora and fauna to survive if one habitat is rendered uninhabitable. Will these habitats support local food production? Does the environment support growing other crops if the current ones become economically unsustainable?

The adaptive capacity of ecological subsystems might be measured by how quickly key elements of the local environment can regenerate in the event of a disaster such as flooding or fire. Grasses and insects will regenerate much faster than trees and mammals, respectively, due to the length of their life cycles. Through evolutionary adaptation, many plants 'remember' how to bounce back from dangers such as fire by developing protective surfaces on their seeds. For agriculture, this adaptation period will be the time it takes to prepare the land and then plant either the existing crop or a new one that is more appropriate to new ecological (or economic) conditions. New crops may need new machinery and specialized knowledge to accomplish successful adaptation. Indicators of adaptive capacity include the ability of the environment to support a diversity of crops and wildlife.

Economic System

Economic systems are comprised of people, firms and institutions that interact to accomplish the production, distribution and consumption of goods and services. Having a resilient economy can be essential for recovery efforts in a post-disaster setting.[35] Ensuring that small businesses can get up and running; ensuring that people feel safe going to markets; ensuring that the flow of currency is secure and individual savings accounts are protected – these are all activities that can be put at risk as the result of a major disaster or catastrophic event.

Resource robustness in an economic subsystem would generally include the performance, diversity and redundancy within the labor markets, the capital markets and "land" or natural resources within a given community. According to some economists, the measure of these resources denotes the potential for "shock-absorption."[36] To assess the resources within an economic subsystem, economists might look at the conditions of the labor market, the make-up of the community's

businesses, the preferences of consumers, measures of unemployment, and growth and/or inflation, among other signals.

Adaptive capacity in an economic subsystem might come in the form of policy options available to community leaders, such as making adjustments in monetary or fiscal policy, or to borrow, trade, finance, or substitute goods. Such tools increase the potential for "shock-counteraction"[37] and amount to the ability of the subsystem to innovate and learn. To assess the adaptive capacity in an economic subsystem, experts could consider the fiscal position of the community – a healthy position would allow leaders to cut taxes or raise expenses to counteract the harmful shock; economists might also look at the community's freedom to trade or make adjustments to trading relationships. In the labor market, economists might look at the ability of workers to change jobs or get new training in various industries.

Physical Infrastructure System

Physical infrastructure "refers to the substructure or underlying foundation or network used for providing goods and services; especially the basic installations and facilities on which the continuance and growth of a community, state, etc., depend...[and] include roads, water systems, communications facilities, sewers, sidewalks, cable, wiring, schools, power plants, and transportation and communication systems."[38] The practitioners, engineers and policy makers that use, design and manage these assets are included within the subsystem as well.

Assessing the resource robustness within a community's physical infrastructure subsystem would require an accounting for each of the infrastructure sectors listed above, especially considering that the robustness of each sector could vary dramatically within the same community. A community in the Midwestern United States could have a superior transportation system, but a woefully inadequate water system. In addition, communities have varying control over the complex, networked infrastructure systems on which they rely. For example, in the United States many communities rely on power from the electric grid. As such, they are unable to affect the performance or redundancy of their own energy infrastructure because it is managed on a higher scale. Realizing this, communities might work to develop a diversity of local energy options for themselves.

An adaptive capacity assessment in a given infrastructure sector depends, in part, on the nature of the component under consideration. Some components are structured or designed to adapt. The internet, for example, automatically reroutes information around damaged networks. Other components that consist of fixed resources, like a transportation system that consists of bridges and roads, can only adapt through the innovation of the system's users and managers that reroute traffic around damaged areas.

Civil Society System

For this approach, civil society refers to the formal and informal modes of social organization and collective action outside of governmental authority (i.e., non-governmental and philanthropic organizations, health and human service organizations, faith-based organizations, unions, associa-

tions, etc.). These institutions contribute to community values, provide a forum for civic action and dialogue, and enhance quality of life and social welfare.

Assessing the resource robustness within a community civil society subsystem would entail accounting for the number of different types (diversity) of civil society organizations, their total number (redundancy) by category, and the performance of these diverse organizations in accomplishing their missions. A large number of volunteer organizations in a community may appear to offer high redundancy, but if these organizations experience difficulties maintaining membership, mobilizing support, or accomplishing meaningful projects for the community, they may not necessarily be considered robust resources.

An adaptive capacity assessment in a given community would require a careful examination of the mechanisms and procedures of how civil society retains and recalls its collective experiences, the production of new and innovative techniques for achieving community goals, and the strength of ties between civil society organizations. Using the volunteer sector again as an example, indicators such as organizational longevity and growth of new organizations would provide a general sense of institutional memory. However, this should also take into account how organizations retain and embed their experiences in processes and individuals.

Government System

Systems of governance include the public organizations (political, legislative, judicial institutions) that contribute to the administration of the state, though there may be overlap into the social and private spheres through public-private partnerships. Governance also includes the processes through which government institutions, or any group of people with a mandate or with a common purpose, make decisions.[39] The governance process is a hodgepodge of strategic projects in which planning aims are created and administered, and power games are played out through coalition building and manipulation through politics.[40] Governance also sets the parameters for ordered rule, cooperative action[41], decision making, and power sharing through institutions.[42]

Assessing the resource robustness of a community's governance subsystem is often limited to a performance assessment in terms of the governing entity itself because competing governing entities undermine the system. This is apparent in post-conflict communities that suffer from diverse governing structures (tribal, national and intervening structures) all operating at once. (The value of alternative, authoritative and organizing structures is better reflected in the civil society subsystem.) Performance may be measured in multiple ways – from the cost and quality of services delivered in relation to the resources collected from the citizens, to the strength of the government's mandate to act on the citizen's behalf.[43] There is great value, however, in having redundancy and diversity in staffing, especially for critical positions, and in the resources required for providing government services.

An adaptive capacity assessment in a given community would entail a range of inquiries. Does the government have the capacity to institutionalize and adapt lessons-learned, such as modifying emergency response plans following an event? How extensive is the discretionary authority granted

to government officials during a crisis, for example, the authority to commandeer resources or waive regulatory restrictions as needed?

Looking Ahead

In order to move resilience research forward, our first priority is to seek feedback on our ideas and theory represented in this brief discussion. It is through critical dialogue and debate that we hope to further refine a testable set of ideas regarding communities that can be translated into practicable recommendations for communities around the globe. Our second priority is to generate an inventory of community systems and the relevant attributes of each system's resources and adaptive capacity. Next, to synthesize our inventory of community systems around an analytical framework that accounts for both general and specific resilience, we are currently identifying the most optimal qualitative and quantitative methodologies that focus on the myriad determinants of vulnerability and adaptive capacity for each grouping of community-level systems (Physical, Ecological, Civil, Economic, Government). Taken as a whole, this set of methodologies will link cutting-edge community hazards analysis and vulnerability reduction frameworks with emerging research agendas centered on the comprehensive analysis of community resilience.

Once completed, this phase of the research project will drive the development of a thorough indicator set which draws upon subject-matter experts. We believe this research area lends itself to a case-study approach that will be best executed when it is based on a comprehensive theory about resilience. Through a testable set of indicators, along with an improved set of methodologies driving the assessment of community resilience, our research team will design and execute a series of case studies in order to elaborate and refine the theories laid out above. Finally, in a critical evaluation period, we will refine and publish the results of our case study analyses and revised indicator set in order to provide additional resources to the resilience practitioner and research community.

Clearly, these systems cannot be described or evaluated without reference to all. Their connections to each other imply that what negatively impacts one could damage others. They should be evaluated *not only* by people who are experts in one system, but holistically by a group of people who can think about the individual systems and also the larger community of which they are a part. This inter-system cooperation among system experts will not be easy but it is critical to the success of community resilience planning. An important function of academia and government will be to study how this is being accomplished in communities around the world.

Endnotes

[1] Klein, R. J. T., Nicholls, R. J., & Thomalla, F. (2003). Resilience to natural hazards: How useful is this concept? *Global Environmental Change Part B: Environmental Hazards,* 5(1-2), 35-45; S. Manyena, "The Concept of Resilience Revisited," *Disasters*, 30, No. 4 (2006): 434-450.

[2] C. S. Holling, "Resilience and Stability of Ecological Systems," Annual Review of Ecological Systems, 4 (1973): 1-23.

[3] Timmerman, P., 1981. *Vulnerability, Resilience and the Collapse of Society: A Review of Models and Possible Climatic Applications.* Institute for Environmental Studies, University of Toronto, Canada.

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[5] C. Perrow, "Using Organizations: The Case of FEMA," *Homeland Security Affairs*, I, no.2 (2005) http://www.hsaj.org/?article=1.2.4

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[7] Some scholarship categorizes resilience strategies into two types: engineering resilience and ecological resilience. Resistance can be viewed as a form of engineering resilience. See e.g., C.S. Holling, "Engineering Resilience Versus Ecological Resilience," in P. C. Schultz (ed.) *Engineering Within Ecological Constraints*, (Washington D. C.: National Academy Press, 1996); G. Taguchi, *Introduction to Quality Engineering*, (Tokyo: Asian Productivity Organization 1986); and T. Foster, *Managing Quality: An Integrative Approach,* 2nd Ed. (New Jersey: Pearson Prentice Hall, 2004). *Engineering-type resilience* is the ability of systems to maintain, or return to a pre-designed state or function after a disturbance. For instance, a computer's resilience is measured in the time it takes for it to come back to system specifications or the number of different conditions under which it will continue to operate. The engineering design attempts to limit variables that will have an adverse impact or the system. This strategy is often appropriate where we know *how* a system will be surprised but not *when*. This type of resilience is often very efficient in its use of resources, but it would not be an appropriate goal for a community that must adapt to changes in the environment or generate innovations to help it cope with changes. *Ecological or adaptive resilience* is a property of systems that have frequent surprises and must focus on persistence and adaptation. Sometimes a surprise will bring such fundamental changes in local resources that it becomes impossible or even dangerous to return to previous patterns of operation. The strategies for this type of adaptive resilience capacity will depend on whether the "surprise" faced by the community is long-term (developing over time, such as climate change) or short-term (developing very quickly, such as hurricanes).

[8] More information about the Resilience Alliance is available at http://www.resalliance.org/1.php.

[9] For example see M. Bruneau, S. Chang, R. Eguchi, G. Lee, T. O'Rourke, A. Reinhorn, "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities" *Earthquake Spectra*, 19 (2003): 733-752.; D. Godschalk, "Urban Hazard Mitigation: Creating Resilient Cities" *Natural Hazards Review* 4, no. 3 (2003): 136-143; and F. Norris, et al., (2008).

[10] F. Norris, et al, "Community Resilience as Metaphor," 128.

[11] Communities must be thought of as *complex systems* as opposed to simple, linear systems (where 2+2 always equals 4). Researchers from many fields, including public administration, have discovered that complex systems often behave in similar ways; see, e.g., L. Dennard, K. Richardson, and G. Morcol, (Eds), *Complexity and Policy Analysis: Tools and Methods for Designing Robust Policies in a Complex World* (Goodyear, AZ: ISCE Publishing, 2008). Also, while there is no universally accepted and comprehensive definition of complex systems, there are some things that they seem to have in common: they are made up of many components; contain intricate webs of causal links and feedbacks that are tightly or loosely coupled; have interdependencies among components (or modules); are open to influences from the outside environment; are as a whole, are more than a sum of their parts; exhibit nonlinear, dynamic behavior; have so many dimensions or variables that they are mathematically intractable. For an explanation of this list that is readable by a non-specialist, see, Melanie Mitchell, *Complexity: A Guided Tour* (Oxford and New York: Oxford University Press, 2009); and Thomas Homer-

Dixon, *The Ingenuity Gap: Facing the Economic, Environmental, and Other Challenges of an Increasingly Complex and Unpredictable World* (New York: First Vintage Books, 2002), pp. 110-115.

[12] V. Heiken, R. Brown, G. George, O. Jones, and C. Andersson, C, "Modeling Cities: The Los Alamos Urban Security Initiative," *Public Works Management and Policy, 4* (2000): 198-212.

[13] There is growing agreement among many organizational theorists that the best responses to challenges often come from the bottom up and not from the top down, or a combination thereof. See, e.g., John Seely Brown and Paul Duguid, *The Social Life of Information* (Cambridge, Mass.: Harvard University Press, 2000).

[14] R. Platt, *Disasters and Democracy. (*Washington, D.C.: Island Press, 1999).

[15] A. Heijmans, A, "From Vulnerability to Empowerment, " in G. Bankoff, G. Frerks, and D. Hilhorst, D. (eds.) *Mapping Vulnerability: Disasters, Development, and People (London: Earthscan, 2004).*

[16] B. Wisner, B, "Disaster Risk Reduction in Megacities: Making the Most of Human and Social Capital," *Proceedings of The Future of Disaster Risk: Building Safer Cities. (*Washington, DC: World Bank and the ProVention Consortium, 2002).

[17] Sundelius, B. (2005). A Brief on Embedded Societal Security. *Information & Security, 17, 23-37.*

[18] See FEMA/DHS definition of integrated preparedness, as established in Post Katrina Emergency Management Response Act, 2006.

[19] B. Wisner, P. Blaikie, T. Cannon, and I. Davis, I, *At risk: natural hazards, people's vulnerability and disasters. (*London: Routledge, 2004).

[20] F. Norris, et al, "Community Resilience as Metaphor," 131.

[21] Homeland Security Studies and Analysis Institute. "Resilience Conceptual Development: An Operational Framework for Resilience," August 27, 2009, pp 22. Found at http://www.homelandsecurity.org/hsireports/Resilience_Task_09-01.pdf

[22] Researchers in many disciplines have observed that having multiple different options, or diversification of resources, is an asset when developing resilience, see e.g., W. Brian Arthur, "On the Evolution of Complexity," In G. Cowan, D. Pines, D. Meltzer (Eds), *Complexity: Metaphors, Models and Reality (*Santa Fe Institute Studies in the Sciences of Complexity Proceedings, vol. 19, 1995), 65-78, 67. However, when a system gets more diverse, its complex interaction networks spread unevenly and the forces working on the system do not have the same effect on the diverse components. Thus, a successful strategy to increase the survivability of individuals or groups in such a system will almost never be "one size fits all" and will be most effective if choices and allocations are made at the lowest possible level.

[23] Redundancy is usually a resistance strategy and is employed where the danger to be avoided is relatively predictable or potentially catastrophic. Aircraft, for example, have multiple engines so that if one fails the redundant system will pick up that function. In human engineered systems, sometimes-identical systems are added to back up critical systems that might fail. This type of redundancy is frequently designed into the system and generally makes it more costly. See e.g., S.D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons.* (Princeton, NJ: Princeton University Press, 1993).

[24] Fundamentally, robustness depends on the ability of individuals, groups, or technologies to tolerate a broad range of conditions. Robust systems have *broad tolerance* for changes in their environment. For example, a machine that can work under a wide variety of external conditions is said to be very robust. In other situations, broad tolerance depends on the ability to adapt to *changing* conditions. For example, some species are said to be robust because they can go into hibernation when water supplies are low. The ability of humans to find new ways to meet their needs in the face of surprise greatly increases their robustness or broad-tolerance resilience. We can often figure out alternative ways to procure water, food, and shelter. Sometimes robustness is accomplished with systems that are capable of performing multiple functions and can act as backup for another system. This is called *distributed robustness* in some systems and redundancy in others, see, e.g., A. Wagner, *Robustness and Evolvability in Living Systems* (Princeton NJ: Princeton University Press, 2005): 239-246.

Buffering is also a resilience strategy that results from building in diversity and redundancy into a complex system. A buffering strategy may attempt to stop bad things from spreading to critical components of a system, or, it might be a conscious allocation of resources that will be kept in reserve to use to shield the systems from the effects of a surprise. Levies are a buffer against rising water in a river. Computer systems often have buffers that will stop a virus from invading critical part of the system. Emergency savings accounts, surplus inventories, and slack time in manufacturing operations are also buffering strategies. All come with significant financial or opportunity cost, but they are good for dealing with frequently occurring or potentially catastrophic risks.

[25] There are tradeoffs between these three attributes. For technology with high customer expectations of reliability, betting the farm on redundancy can lead to disaster when the system is faced with a surprise that was not anticipated by the designers, and one that cannot be handled with redundant capabilities. In addition, redundancy and/or diversity could be counterproductive if the complexity of the system makes it more opaque and difficult to understand for the people who must operate it. Redundancy can also lead people to have too much confidence in the system and forget to watch for surprises. Heavy layers of redundancy or lots of diversity can furthermore make it possible to conceal errors and surprises (fearing the 'blame game'), with the result that there is less accurate information about how the system is operating.

[26] Complex systems are *adaptive* when individual agents operate independently and change their behavior in response to forces in their environments via feedback. Other agents will copy changes that result in the agents' obtaining more resources. These systems evolve over time and are called *complex adaptive systems*. Animal species, including human beings, are made up of individual agents, and the species will evolve in order to adapt to changes in their environment. Sometimes the changes in the environment will be only temporary (such as a tornado or a cyclical economic decline) so survival will require adaptations that allow people and technical systems to bounce back to previous conditions. Nevertheless, sometimes the changes in the environment will be for a much longer term (global warming, loss of access to a key natural resource such as water) and the survival of individuals and groups will require them to adapt to the new realities.
There is some evidence that the most resilient organizations are those that have some experience with surprise and have adapted in order to survive, see Dennis S. Mileti and John H. Sorenson, "Determinants of Organizational Effectiveness in Responding to Low Probability Catastrophic Events," *Columbia Journal of World Business*, (Spring 1987), 14. We would thus expect a culture that has not changed or adapted to be less resilient. In addition, the ability of an individual or group to adapt may be tied to the state of their development. Humans, organizations, social systems, and ecosystems all *develop*; that is, they change over time in form and function such that they grow, mature, die, and change in interesting ways characteristic of the species or type of organization or ecosystem, as shaped by cultural and biological evolution; see Gunderson and Holling, *Panarchy: Understanding Transformations in Human and Natural Systems.* (Washington, D.C.: Island Press, 2002).

[27] F. Berkes and C. Folke, "Back to the Future: Ecosystem Dynamics and Local Knowledge." In Gunderson L. and C.S. Holling, *Panarchy: Understanding Transformations in Human and Natural Systems.* (Washington, D.C.: Island Press, 2002), 141.

[28] F. Berkes, "Understanding Uncertainty and Reducing Vulnerability: Lessons from Resilience Thinking" *Natural Hazards* 41 (2007): 291.

[29] Ibid.

[30] Ibid, citing C. Folke, S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling and B. Walker, "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations" International Council for Science, ISCU Series on Science for Sustainable Development, No. 3 (April 2002) Available at: http://www.sou.gov.se/mvb/pdf/resiliens.pdf.

[31] There is almost universal agreement that the best starting point for trying to manage an unpredictable system is to identify the various temporal and organizational scales involved, see P. H. Longstaff in *Security, Resilience, and Communication in Unpredictable Environments Such As Terrorism, Natural Disasters, and Complex Technology,* Program for Information Resources Policy, Harvard University, (November 2005). Available at http://pirp.harvard.edu/pubs_pdf/longsta/longsta-p05-3.pdf. In systems that operate on more than one scale, resilience strategies can operate within each scale but also across scales. For example, in the human body, the immune system acts first on a local scale to confront an infection by sending a variety of forms of immune cells (within-scale resilience through diversity). If this strategy fails, the system responds by "scaling up" its response and inducing fever. When similar functions (not necessarily similar mechanisms) operate across scales, they make the system more resilient because they are redundant: if one function fails, the other goes into action. Each level of the system operates separately, and often each level has its own emergent properties and/or operates over different time scales and responds to different cycles. Surprises or risks that manifest themselves over a long period require different strategies than dangers that can pop up at any time. Risks to one part of the system are treated differently from those that might affect the entire system. The boundaries between scales should receive careful attention because that is where surprises are likely to occur.

[32] Network theory and science provide a substantial knowledge base on the significance of social and organizational links. See e.g., Albert-Laszlo Barabasi, *Linked: The New Science of Networks* (Cambridge, Mass.: Perseus Press, 2002), Chapter Six; Duncan J. Watts, *Small Worlds: The Dynamics of Networks Between Order and Randomness* (Princeton, NJ: Princeton University Press, 1999), 285.; John W. Meyer and W. Richard Scott, *Organizational Environments: Ritual and Rationality* (Beverly Hills, Calif.: Sage, 1983). Brian Uzzi, "Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness," *Administrative Science Quarterly* 42, no. 1 (1997): 35-67 and Marc J. Dollinger, "The Evolution of Collective

Strategies in Fragmented Industries," *Academy of Management Review* 15, no. 2 (1990): 266–285. E. Patterson, D. Woods, R. Cook and M. Render, "Collaborative Cross-Checking to Enhance Resilience," *Cognition, Technology and Work* 9, no. 3 (2007): 155-162. J. Douglas Orton and Karl E. Weick, "Loosely Coupled Systems: A Reconceptualization," *Academy of Management Review* 15, 2 (1990): 203–223.

[33] K. Perrin. "Operationalizing Resilience: Assessment Models for Community Resilience" Resilience and Security Working Paper, Institute for National Security and Counterterrorism, Syracuse University, August 2009. Available at http://www.insct.syr.edu/Projects/Resilience/Home.htm.

[34] S. A. Ostroumov, "New Definitions of the Concepts and Terms Ecosystem and Biogeocenosis" Doklady Biological Sciences 383 (2002): 141–143. Translated from Doklady Akademii Nauk, 383, no. 4 (2002): 571–573.

[35] See Adam Rose, "Economic Resilience to Natural and Man-made Disasters: Multidisciplinary Origins and Contextual Dimensions" *Environmental Hazards* 7 (2007): 383–398.

[36] Lino Brigulio, Gordon Cordina, Stephanie Bugeja, Nadia Farrugia, "Conceptualizing and Measuring Economic Resilience," Working Paper. Economics Department, University of Malta, 2006. Available at https://secure.um.edu.mt/__data/assets/pdf_file/0013/44122/resilience_index.pdf

[37] Ibid.

[38] See U.S. EPA, Office of Grants and Debarment, Definition of "Infrastructure" for purposes of the American Recovery and Reinvestment Act of 2009, May 8, 2009, http://www.epa.gov/ogd/forms/Definition_of_Infrastructure_for_ARRA.pdf. Because of the critical nature of information sharing to community resilience we exclude communication infrastructure from this section of our analysis and explore it as a standalone category.

[39] U.S. Agency for International Development (USAID), "How Resilient is Your Coastal Community? A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Coastal Hazards." U.S. Indian Ocean Tsunami Warning System Program, (2007). [Online.] URL: http://apps.develebridge.net/usiotws/13/CoastalCommunityResilience%20Guide.pdf.

[40] P. Healey, "Creativity and Urban Governance," *Policy Studies*, 25, no. 2 (2004): 87-102.

[41] P. Healey, "Creativity and Urban Governance," *Policy Studies*, 25, no. 2 (2004): 87-102.

[42] L. Lebel, J. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. Hughes, and J. Wilson, "Governance and the capacity to manage resilience in regional social-ecological systems," *Ecology and Society*, 1, no. 1 (2006): 19.

[43] For more background on performance management in public administration see G.A. Brewer. "Building Social Capital: Civic Attitudes And Behavior of Public Servants." *Journal of Public Administration Research and Theory* 13 (2003):5–26.; H. Hatry. 1999. *Performance Measurement: Getting Results*. (Washington, DC: Urban Institute, 1999).; E.T. Jennings, M. Patrick Haist. "Putting Performance Measurement in Context." In *The Art Of Governance*, eds. P.W. Ingraham and L.E. Lynn, 173–194. (Washington, DC: Georgetown Univ. Press, 2006).; J. Melkers and K. Willoughby. "Models of Performance-Measurement Use in Local Governments: Understanding Budgeting, Communication, and Lasting Effects." *Public Administration Review* 65(2005):180–90.; and T.H. Poister and G. Streib. 1999. "Performance Measurement in Municipal Government: Assessing the State of the Practice." *Public Administration Review* 59 (1999):325–335.