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Urban Hazard Mitigation: Creating Resilient Cities

Dr. David R. Godschalk
Stephen Baxter Professor
Department of City and Regional Planning
University of North Carolina CB# 3140
Chapel Hill, NC 27599-3140

Local resiliency with regard to disasters means that a locale is able to withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life and without a large amount of assistance from outside the community.
(Mileti 1999, pp.32-33)

Hazard mitigation is action taken to reduce or eliminate long-term risk to people and property from hazards and their effects. It is the cornerstone of the approach of the Federal Emergency Management Agency (FEMA) to reducing the nation's vulnerability to disasters. Its long-term focus and proactive nature distinguish hazard mitigation from the more immediate and reactive activities taken during disaster preparedness, response, and recovery. Hazard mitigation is the only phase of emergency management dedicated to breaking the cycle of damage, reconstruction, and repeated damage from disasters (FEMA 2000a). Hazard mitigation includes measures ranging from structural engineering and building code standards to land use planning and property acquisition (Schwab 1998).

Urban hazard mitigation seeks to develop *resilient cities*. Such cities are capable of withstanding severe shock without either immediate chaos or permanent deformation or rupture. Designed in advance to anticipate, weather, and recover from the impacts of natural or technological hazards, resilient cities are based on principles derived from past experience with disasters in urban areas. While they may bend from hazard forces, they do not break. Composed of networked social communities and lifeline systems, they are able to adapt and rebound to new levels of sustainability. As we know from recent disasters, the ability to rebound from a major impact without falling into chaos is increasingly important for American urban areas.

Godschalk and his colleagues (1999, p. 531) propose a sustainable mitigation policy system whose goal is developing resilient communities, capable of managing extreme events. As shown in the figure below, they envision an intergovernmental system in which federal sustainable development policy is implemented through a national at-risk report and FEMA regions helping to create state and local mitigation commitment and capacity. These actors prepare mitigation plans and carry out mitigation projects and actions aimed at building resilient communities.

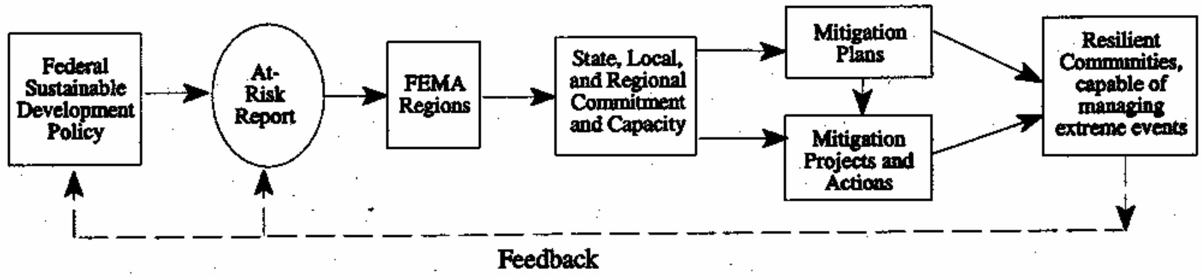

Figure 13.2. A Sustainable Mitigation Policy System.

Many other recent disaster studies also call for the development of resilient communities. Mileti (1999) recommends developing model resilient communities to further a shift in national thinking about hazards and commends the Institute for Business and Home Safety's (IBHS) Showcase Communities Project and FEMA's Project Impact as nationwide initiatives aimed at disaster resilience. Beatley (1998) notes that a sustainable community is resilient— seeking to understand and live with the physical and environmental forces present at its location.

Despite such support for the concept of resilient communities, few studies have formulated systematic principles of resilience and applied them at the city scale. This paper delves beneath the surface of the concept of resilience[1] to uncover its key principles, and then to apply these principles to develop best practices in urban hazard mitigation. I start by asking what is a resilient city and why is resilience important. I then cull resilience principles from the urban systems and disaster mitigation literature. Next I relate these principles to best hazard mitigation practice and experience. Finally, I suggest reforms in hazard mitigation policy that will promote more resilient cities.

1.0 What is a Resilient City?

A resilient city is a sustainable network of physical systems and communities. Physical systems are the constructed and natural environmental components of the city. They include its roads, buildings, infrastructure, communications facilities, soils, topography, geology, water ways, and the like. In sum, the physical systems act as the body of the city, its bones, arteries, and muscles. During a disaster, the physical systems must be able to survive and function under extreme stresses. If enough of them suffer breakdowns that can not be repaired, losses escalate and recovery slows. A city without resilient physical systems will be extremely vulnerable to disasters.

Communities are the social and institutional components of the city. They include the formal and informal, stable and ad hoc human associations that operate in an urban area: neighborhoods, agencies, organizations, enterprises, task forces, and the like. In sum, the communities act as the brain of the city, directing its activities, responding to its needs, and learning from its experience. During a disaster, the communities must be able to survive and function under extreme and unique conditions. If they break down, decision making falters and response drags. A city without resilient communities will be extremely vulnerable to disasters.

Traditional hazard mitigation programs have focused on making physical systems resistant to disaster forces. This is reasonable, since immediate injury and damage results from their failure. However, future mitigation programs must also focus on teaching the city's social communities and institutions to reduce hazard risks and respond effectively to disasters, since they will be the ones most responsible for building ultimate urban resilience.

Resilient cities are constructed to be strong and flexible, rather than brittle and fragile. Their lifeline systems of roads, utilities, and other support facilities are designed to continue functioning in the face of rising water, high winds, shaking ground, and terrorist attacks. Their new development is guided away from known high hazard areas, and their vulnerable existing development is relocated to safe areas. Their buildings are constructed or retrofitted to meet code standards based on hazard threats. Their natural environmental protective systems are conserved to maintain valuable hazard mitigation functions. Finally, their governmental, non-governmental, and private sector organizations possess accurate information about hazard vulnerability and disaster resources, are linked with effective communication networks, and are experienced in working together.

2.0 Why is Resilience Important?

Resilience is an important goal for two reasons. First, because the vulnerability of technological, natural, and social systems cannot be predicted completely, resilience-- the ability to accommodate change gracefully and without catastrophic failure, is critical in times of disaster (Foster 1997).

Second, people and property fare better in resilient cities struck by disasters, than in less flexible and adaptive places faced with uncommon stress. In resilient cities fewer buildings collapse. Fewer power outages occur. Fewer households and business are put at risk. Fewer deaths and injuries occur. Fewer communications and coordination breakdowns take place.

By positing resilience as a goal, we create a model against which decisions and actions can be measured, and plans and policies evaluated. We also create an image that decision-makers and the public can understand and act to achieve.

3.0 Resilience and Terrorism

What is the relationship of resilience and terrorism? Has the terrorist attack on the World Trade Center on September 11, 2001, forever changed the goals and practice of urban hazard mitigation, which has focused primarily on natural hazards?

One goal of natural hazard mitigation has been to influence the physical form of cities in order to separate hazardous areas and development. This goal has been viewed as consistent with contemporary urban planning precepts, such as sustainable development (Berke 1995) and smart growth (Godschalk 2001). Sustainable development seeks to meet present needs without compromising the ability of future generations to meet their needs, but it can not be successful without enabling societies to be resilient to natural hazards and ensuring that future development does not increase vulnerability (UN Commission on Sustainable Development 2002). Smart growth calls for compact cities and high density to combat urban sprawl, similar to the aims of new urbanism (Duany, Plater-Zyberk, and Speck 2000; Katz 1994).

However, in the wake of the attacks on New York, some urbanists have called for a return to the dispersed urban patterns promoted by the U.S. government to reduce vulnerability to nuclear attack in the 1950s. Others have proposed an emphasis on substitution of communications technology for physical interaction and transportation systems, in order to reduce urban concentrations, which is only an option in developed countries.

An advantage of the goal of urban resilience is that it is not tied to a specific pattern of urban form or development. This flexibility allows it to respond to the unique conditions of different cities and development plans. It encourages creative thinking about various ways to achieve resilience, without taking sides in the concentration/dispersal debate.

The practice of traditional natural hazard mitigation has focused on wide sharing of information about risks and safety measures in order to build public commitment to, and participation in, mitigation programs. However, those responsible for combating terrorism and technological hazards operate under conditions of secrecy to prevent terrorists from using public information, such as the vulnerability of public water sources or nuclear power plants. They also restrict access to decision making to a limited set of officials. This raises questions about whether we need two types of mitigation practice, one for natural hazards and one for terrorist hazards.

It may well be that there can be no all-hazards practice that spans both natural and technological/terrorism risks. However, I believe that the principles of disaster resilience are the same for both types of practitioners. The city that is resilient to natural disasters is equally resilient to terrorism, despite a different disaster catalyst. Both types of practitioners should seek to build physical and social resilience.

4.0 Disaster Resilience Principles

Cities are complex and dynamic systems in which technological, natural, and social components interact. Disaster resilience requires combinations of apparent opposites: redundancy and efficiency, diversity and interdependence, strength and flexibility, autonomy and collaboration, planning and adaptability.

Foster (1997) has identified thirty-one principles for achieving resilience. He organizes them according to several categories: general systems, physical, operational, timing, social, economic, and environmental. According to Foster, resilient general systems are independent, diverse, renewable, and functionally redundant, with reserve capacity achieved through duplication, interchangeability, and interconnections.

Resilient physical systems are dispersed rather than site specific, are composed of small, semi-autonomous units, employ standardization, are mobile, require no esoteric parts or unique skills, are stable and use fail-safe design, and can conduct early fault detection. Resilient operating systems are efficient, reversible, autonomous, and incremental. Their timing includes short lead times and rapid response to stimuli, as well as an open-end life span.

Resilient social systems are compatible with diverse value systems, can satisfy multiple goals at the same time (like a multi-purpose reservoir), distribute benefits and costs equitably, generously compensate major losers, and have high accessibility. Resilient economic systems employ incremental funding, provide a wide range of potential financial support, enjoy a high benefit-cost ratio, give an early return on investments, and divide benefits and costs equitably. Resilient environmental systems minimize adverse impacts, and have a replenishable or extensive resource base.

Authors who have studied the response of resilient systems to disasters find that they tend to be (Victoria Transport Policy Institute 2001; Foster 1997; Comfort 1999):

- Redundant--with a number of functionally similar components so that the entire system does not fail when one component fails, as in a spacecraft.
- Diverse--with a number of functionally different components in order to protect the system against various threats, as in a diversified investment portfolio.
- Efficient--with a positive ratio of energy supplied to energy delivered by a dynamic system, as in the reduction of waste.
- Autonomous--with the capability to operate independently of outside control, as in self-government.
- Strong--with the power to resist attack or other outside force, as in healthy organisms.
- Interdependent--with system components connected so that they support each other, as in engineered structures.
- Adaptable--with the capacity to learn from experience and the flexibility to change, as in inquiring organizations.
- Collaborative--with multiple opportunities and incentives for broad stakeholder participation, as in public private partnerships.

The resulting resilient city both plans ahead and acts spontaneously. It has strong central governance, as well as vital private sector and non-governmental institutions. It is aware of the hazards it faces, but not afraid to take risks. It eschews simple command and control leadership, preferring to develop networks of leadership and initiative. It sets goals and objectives, but is prepared to adapt these in light of new information and learning. It recognizes that the quest for resiliency is an ongoing long-term effort.

5.0 Best Hazard Mitigation Practices

Hazard mitigation encompasses the range of advance measures taken to avoid, reduce, or eliminate the long-term risk to human life and property from natural or technological hazards (FEMA 2000). Mitigation is proactive, rather than reactive. Rather than simply waiting for an extreme event and then trying to respond, mitigation planners estimate vulnerability to hazards and take anticipatory actions to lessen risk and exposure.

5.1 Traditional Hazard Mitigation

Traditional hazard mitigation has protected people, property, and the environment from the destructive impacts of hazards in a number of ways (Godschalk et. al, 1999):

- Planning--identifying hazards and vulnerability and making and carrying out smart growth and hazard mitigation plans before disasters occur
- Avoiding hazard areas--directing new development away from hazardous locations and relocating existing structures and land uses to safer areas,
- Strengthening buildings and public facilities--flood-proofing and wind-proofing existing and new structures and public facilities through building codes and engineering design,
- Conserving natural areas--maintaining and enhancing the functions of wetlands, dunes, and forests that reduce hazard impacts through acquiring property or development rights in hazard areas, and limiting development in these areas,
- Controlling hazards--using structural approaches such as flood control works, slope stabilization, and shoreline hardening to attempt to reduce risks from hazardous natural systems.
- Limiting public expenditures--withholding subsidies for roads, sewage treatment systems, and other public facilities that could induce development in hazard areas,
- Communicating the mitigation message--educating developers about mitigation techniques and notifying the public about the existence of hazard areas and the consequences of locating there.

Mitigation is a growing element of state budgets. In fiscal 1999, states spent $498 million on mitigation projects, or an average of about $10 million per state (National Emergency Management Association 2001). Mitigation has had a number of successes in reducing hazard impacts (FEMA 2001a; NC DEM 1999). Since the 1993 Midwest Floods deluged nine states leaving $12 billion of damage in their wake, more that 20,000 buildings have been cleared from the floodplain. Iowa has removed more than 1,000 properties from flood hazard areas and protected over 20 critical facilities, such as hospitals. During repeat floods in 1999, the state of Iowa projects the benefit from just one project in Cedar Falls to be over $6.6 million in avoided damages (FEMA 2001a).

Lifelines and businesses also have been made more resilient. The seismic retrofitting of the Davis Water Pumping Station in Memphis will prevent an estimated loss of $1.4 million in services per day in the event of an earthquake (FEMA 1998). As a result of Hewlett-Packard's comprehensive seismic mitigation program, including evaluation and retrofit of vulnerable facilities worldwide, the HP office building suffered only nonstructural cosmetic damages while surrounding buildings were destroyed or severely damaged in the 1995 Kobe, Japan earthquake (FEMA 1998a).

5.2 Community Mitigation Capacity

Building a disaster resilient city goes beyond changing land use and physical facilities. It must also build the capacity of the multiple involved communities to anticipate and respond to disasters. Based on her decade-long study of eleven earthquakes in nine countries, Comfort (1999) argues that because all those in a risk-prone community share both risk exposure and mitigation responsibility, effective threat reduction and disaster response require collective action. She believes that advances in information processing and dissemination will facilitate collective learning and self-organization. By linking information technology to organizational learning, we can create a "sociotechnical system" able to solve shared risk problems.[2]

Comfort (1999, p. 64) identifies a condition called the ‘"edge of chaos." This is a threshold point at which an earthquake stricken community either absorbs the shocks and forms a new, more effective mode of operation, or it dissipates its energies in unproductive efforts to maintain its previous pattern of operations. The less resilient community’s operation is seriously disrupted. Destructive consequences multiply, and the whole community slides toward chaos. Eventually, a new order is restored, but at substantial cost to the community, its residents, and the wider society that sends resources and personnel to assist. Places most successful in avoiding chaos were those most able to learn from, and adapt their mitigation practices to, the lessons of their disaster experience.[4]

An important limit on the adaptability of communities is their vulnerability to disaster. In his analysis of the 1994 Northridge earthquake, Bolin (1998) focuses on the social and political-economic factors that make people vulnerable to disasters. He argues that looking only at the physical aspects of a disaster produces a one-sided engineering-oriented, "technocratic fix" perspective. In his view, disasters develop out of the interaction of extreme event forces with human settlements. Their impacts are mitigated through the capacities of the people in those settlements to anticipate disasters, adjust appropriately, and deal with the consequences of those disasters that occur.

The most vulnerable are those whose lives are the most constrained, such as the poor who have the least access to coping resources. Thus, Bolin (1998, p. 236) sees disasters as fundamentally social phenomena: "To reduce vulnerability requires expanded understanding of the ways societies unevenly allocate the environmental risks and the social and political commitments to promote greater economic equity and environmental justice." In effect, the poorest and most vulnerable communities within a city are the weakest links in its mitigation capacity. Here is an important opportunity to integrate hazard mitigation with economic development and social justice, achieving the multiple objectives needed for a resilient system.

5.3 Mitigating for Resilience

Clearly, to achieve the goal of a resilient city, urban hazard mitigation best practices must include both technical and social approaches.[3] Unfortunately, the best example of such a sociotechnical approach, FEMA's Project Impact, recently was threatened with extinction on the grounds that its benefits are not tangible enough to measure. Yet without strong public policy promoting community involvement, many places will continue to view hazard mitigation as a technical program with little salience to their needs. Burby (2001) has characterized hazard mitigation as a "policy without a public," based on studies that found a little public concern for natural hazards or efforts by government to mitigate their adverse effects.

In addition to traditional physical system hazard mitigation functions, a resilient city that seeks to mitigate social community hazards would aim for:

- *Ongoing Vulnerability Reduction.* Prepare, publish, and update regularly a detailed vulnerability analysis that describes and maps potential hazards and their probable impacts on a neighborhood and block basis. Include a vulnerability reduction objective in the comprehensive plan and the capital improvements program. Set annual vulnerability reduction targets with special attention to disadvantaged populations, and budget funds and program resources to meet these targets. Include vulnerability reduction in neighborhood plans and social programs.

- *Distributed Hazard Capability.* Provide hazard awareness information, funding and training to new and existing neighborhood and community organizations so that they can develop capable leaders and carry out hazard mitigation as one element of their program activities. Look for opportunities to combine hazard mitigation with other functions, such as environmental conservation, economic development, community facilities, and historic preservation.
- *Broad Hazard Commitment*. Work with public and private decision-makers, non-governmental organizations, neighborhoods, and households to develop a hazard mitigation ethic. Use incentives and sanctions to move mitigation onto the public agenda. Keep hazards issues before the community and hold leaders accountable for hazard mitigation actions.
- *Networked Communications*. Establish and operate a multi-purpose community communications system and network with a number of media and channels to reach all levels from the individual household to the neighborhood, community, region, and state. Publish geographic information system maps of hazard areas, programs, contacts, lifelines, and the like. Use the network for a variety of public purposes, including announcements, plan reviews, information exchange, and hazard mitigation.
- *Recognized Equity Standards*. Adopt standards and benchmarks for achieving equity in hazard vulnerability. Set aside additional resources to make poor neighborhoods safer from hazards, recognizing that their residents will be the least likely to be able to recover on their own from disasters. Work with residents to determine needs and appropriate mitigation programs to remedy inequitable vulnerability situations.
- *Social System Safety Net.* Provide resources and assistance to threatened neighborhoods and vulnerable populations to enhance their survival during and after a disaster. Operate housing relocation programs to move households out of hazard areas and into safe neighborhoods. Enlist neighborhood leaders in safe neighborhoods programs. Combine community learning and improvement efforts with mitigation and vulnerability reduction efforts. Adopt mitigation policies that respond to organizational and social diversity, rather than insisting on one-size-fits-all approaches.
- *Economic System Safety Net*. Prepare businesses and financial institutions to cope with disasters by building capability to respond to potential scenarios in which business is interrupted following a disaster. Establish procedures for providing loans, and deferring financial obligations following a disaster. Create emergency support programs for out-of-work employees. Enlist business leaders in private sector mitigation initiatives.
- *Natural System Safety Net*. Restore the functions of degraded natural environmental systems so that they can become part of the protective system of the city. Enlist environmental and neighborhood organizations in restoration campaigns. Incorporate hazard mitigation into plans and programs to manage urban storm water and restore wetlands and natural drainage systems. Adopt mitigation policies that recognize the role of extreme events in preserving ecological resiliency.

6.0 Disaster Policy Reforms

The Disaster Mitigation Act of 2000 takes an important step toward wise federal disaster policy. Its title signals an increased emphasis on proactive mitigation as opposed to reactive preparedness, response, and recovery. It changes the existing 1988 Stafford Disaster Relief and Emergency Assistance Act's post-disaster approach to a pre-disaster mitigation planning approach. It establishes new requirements for local mitigation plans, authorizes the use of Hazard Mitigation Grant Program (HMGP) funds for mitigation planning, and provides states with approved mitigation plans with additional HMGP funds.

FEMA's (2001) draft criteria for implementing the 2000 Act require states and localities to prepare and maintain risk assessments and mitigation strategies. Risk assessments must map areas threatened by particular hazard types and estimate structures at risk and potential disaster losses for each hazard type. Mitigation strategies must set mitigation goals and policies, prioritize cost effective mitigation projects, and identify funding for implementation.

However, the Disaster Mitigation Act of 2000 and the FEMA 2001 implementation criteria do not go far enough. If we are to take achievement of urban resilience seriously, then we need even bolder policy and implementation--both technical and social (Mileti 1999; Burby 1998; Godschalk et al 1999).

Among the new elements that might be included in a model Resilient Cities policy are:

- Mitigation impact assessments: all federal assistance programs for housing, infrastructure, economic development, community development, and the like would include standards and provisions for assessing their impact on hazard mitigation achievement.
- Hazard mitigation corps: Congress would create a corps of hazard mitigation agents based in state universities to work with urban communities to provide hazard information and mitigation assistance, similar to the agricultural extension service model.
- Mitigation assistance loans: state and federal agencies would establish low interest mitigation loan programs for households and communities that undertake to reduce hazard risks according to standard criteria.
- Mitigation land use standards: federal and state governments would set hazard mitigation standards and take an active role in guiding local land use planning toward effective hazard mitigation, rather than the hands-off approach of the past.
- At risk reports: federal and state governments would compile, map, and publish vulnerability analyses and risk assessments by localities and regions to assist decision-makers in designing resiliency strategies, including an annual "at risk" report to Congress and the American people
- Incentives for state building code hazard standards: Congress would provide incentives for states to adopt national building code hazard safety standards, similar to those for provided for adoption of energy code conservation standards.

We have come a long way in this country toward reducing injury and damage from disasters, but we still have not managed to create truly resilient cities. For a long time, we treated hazard mitigation as a technical problem to be solved, rather than a complex challenge of building social learning systems that could respond creatively to the unpredictable stresses of disasters.[5]

The time is right to begin a resilient cities campaign. That could be one of our signal achievements of the twenty first century.

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End Notes

[1] Resilience is defined in the dictionary in two ways: 1) the ability to recover quickly from illness, change, or misfortune; buoyancy; 2) the property of a material that enables it to resume its original shape after being bent, stretched, or compressed; elasticity. My use incorporates both the meaning to recover quickly and the meaning to resume its original shape.

[2] According to Comfort (1999, p. 363):

> A sociotechnical approach requires a shift in the conception of response systems as reactive, command-and-control driven systems to one of inquiring systems, activated by processes of inquiry, validation, and creative self-organization. Inquiring systems function best with an appropriate investment in information infrastructure and organizational training that enables the system to assess accurately the conditions in a community that precipitate risk and to act quickly to reduce threat or minimize the consequences when destructive events occur. Combining technical with organizational systems appropriately enables communities to face complex events more effectively by monitoring changing conditions and adapting its performance accordingly, increasing the efficiency of its use of limited resources. It links human capacity to learn with the technical means to support that capacity in complex, dynamic environments.

[3] For example, Comfort (1999) shows how emergency managers in California learned how to adapt and improve their disaster response activities over the course of three earthquakes: Whittier Narrows, Loma Prieta, and

Northridge. Following each disaster, their response management improved as they adapted their community practices. But other places facing a single large earthquake were not as successful. After earthquakes in Ecuador in 1987 and Armenia in 1988, there was little change in community mitigation practices. Comfort (1999, p. 81) calls these non-adaptive systems, low on technical structure, flexibility, and openness to new information and methods.

[4] The new FEMA Emergency Management Institute course, Building Disaster Resilient Communities (EMI 2001) lays out a syllabus to train emergency managers to create plans and programs aimed at achieving both technical and social resilience. The course structure covers best hazard mitigation practices across the various functions affecting disaster resilience. After each of its four modules, students report on critical factors. They are required to analyze community building and governance processes, to describe how hazard resilience is incorporated into local comprehensive and small area plans, to assess resilience-building tools and processes, and to devise and defend a hazard resilience strategy for a particular community.

[5] Over 95 percent of the expenditures for the Hazard Mitigation Grant Program (HMGP) under the Stafford Act between 1988 and 1995 went for physical projects, leaving less than 5 percent for planning, education and training, and administration (Godschalk et al 1999, p. 411).

Author Biography

David R. Godschalk , FAICP, is Stephen Baxter Professor of City and Regional Planning, at the University of North Carolina at Chapel Hill. His degrees include: BA, Dartmouth College; B. Architecture, University of Florida; Master of Regional Planning and Ph.D. in Planning, University of North Carolina. A city and regional planning teacher, scholar, and consultant, and a Fellow of the American Institute of Certified Planners, Dr. Godschalk is a member of board of directors of the Multihazard Mitigation Council of the National Institute of Building Sciences, and the Mitigation Committee of the National Hurricane Conference. His most recent book, *Natural Hazard Mitigation: Recasting Disaster Policy and Planning* (Island Press, 1999), assesses the effectiveness of intergovernmental policy and planning for hurricane, flood, and earthquake hazard mitigation.