Urban Hazard Mitigation: Creating Resilient Cities

David R. Godschalk[1]

Abstract: Cities are complex and interdependent systems, extremely vulnerable to threats from both natural hazards and terrorism. This paper proposes a comprehensive strategy of urban hazard mitigation aimed at the creation of *resilient cities*, able to withstand both types of threats. The paper reviews hazard mitigation practice, defines a resilient city, considers the relationship between resilience and terrorism, and discusses why resilience is important and how to apply its principles to physical and social elements of cities. Contending that current hazard mitigation policy, practice, and knowledge fail to deal with the unique aspects of cities under stress, the paper recommends a major *resilient cities initiative*, including expanded urban systems research, education and training, and increased collaboration among professional groups involved in city building and hazard mitigation.

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Introduction

Cities are complex and interdependent systems, extremely vulnerable to threats from both natural hazards and terrorism. The very features that make cities feasible and desirable—their architectural structures, population concentrations, places of assembly, and interconnected infrastructure systems—also put them at high risk to floods, earthquakes, hurricanes, and terrorist attacks. This paper issues a call for advance planning and action to reduce those risks through the development of resilient cities. While the paper's policy recommendations are geared to the United States context, the basic concepts also apply worldwide, where urban vulnerability is often even higher than in this country.

Annual losses from natural hazards are staggering. A recent review of worldwide natural hazard losses during 2001 identified 700 natural disasters, resulting in 25,000 deaths, $36 billion in economic losses, and $11.5 billion in insured losses (Munich Re Group 2001). Most of these losses occurred at locations where vulnerable urban settlements were developed near known hazard areas, such as floodplains, earthquake fault zones, and hurricane-prone shorelines. Must we continue to accept these losses, or can we find a way to mitigate their impacts?

The United Nations background paper on natural disasters and sustainable development stated the issue clearly:

> Can sustainable development, along with the international instruments aiming at poverty reduction and environmental protection, be successful without taking into account the risks of natural hazards and their impacts? Can the planet afford to take the increasing costs and losses due to natural disasters? The short answer is no.
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> Disaster reduction policies and measures need to be implemented, with a two-fold aim: to enable societies to be *resilient to natural hazards* while ensuring that development efforts do not increase the vulnerability to these hazards (U.N. Commission on Sustainable Development 2001). (Emphasis added.)

Hazard mitigation is action taken to reduce or eliminate long-term risk to people and property from hazards and their effects. In the United States, hazard mitigation is the cornerstone of the approach taken by the Federal Emergency Management Agency (FEMA) to reduce the nation's vulnerability to disasters from natural hazards. 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 phase of emergency management dedicated to breaking the cycle of damage, reconstruction, and repeated damage from disasters (FEMA 2000b). Hazard mitigation includes measures ranging from structural engineering and building code standards to land use planning and property acquisition (Schwab 1998). However, hazard mitigation guidelines typically have not focused on or identified the unique needs and characteristics of cities under stress, as opposed to more generic hazard situations.

Since the September 11, 2001, terrorist attacks on the United States, concern with natural hazard threats has been joined with concern for strengthening homeland defenses against terrorism threats. In response, the National Research Council (2002) has called for a broad program of technical approaches to mitigate the vulnerability of key infrastructures—including transportation, information and telecommunications systems, health systems, the electric power grid, emergency response units, food and water supplies, among others. Their report focuses on the contribution of science and technology to counter terrorist threats to particular functional systems. While it discusses the need for new ways of understanding and modeling complex, adaptive systems, the National Research Council report does not specifically identify the need for research on strengthening cities, as metasystems vulnerable to terrorist threats.

I argue that *urban hazard mitigation* is a particular branch of hazard mitigation practice, and that its overriding goal should be to develop resilient cities. Such cities would be capable of withstanding severe shock without either immediate chaos or permanent harm. Designed in advance to anticipate, weather, and re-

[1]Dr., Stephen Baxter Professor, Dept. of City and Regional Planning, Univ. of North Carolina, Chapel Hill, NC 27599-3140. E-mail: dgod@email.unc.edu

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cover from the impacts of natural or terrorist hazards, resilient cities would be built on principles derived from past experience with disasters in urban areas. While they might bend from hazard forces, they would not break. Composed of networked social communities and lifeline systems, resilient cities would become stronger by adapting and learning from disasters. As we know from recent events, the ability to withstand a major shock without long-term, debilitating physical, social, or economic damage is increasingly important for cities everywhere.

Moor (2001) pointed out that cities, as the most complex of human creations, are at great risk both from a wide range of hazards and from their own multiple vulnerabilities. As he noted, points of urban vulnerability are everywhere from infrastructure systems and buildings to telecommunications, transport, and energy and resource supply lines. And reduction of vulnerability at the city scale is not simply a matter of stronger structures. Urban risk reduction mechanisms include police and fire forces, planning and building inspection departments, health services, families, schools, and the media.

Increasing support for the notion of resilient cities is found in the hazard mitigation literature. Godschalk et al. (1999) proposed a sustainable mitigation policy system whose goal is developing resilient communities, capable of managing extreme events. They envisioned 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. State and local agencies prepare mitigation plans and carry out mitigation projects and actions aimed at building resilient communities.

Many other recent disaster studies also call for the development of resilient communities. Mileti (1999) recommended 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) noted that a sustainable community is resilient—seeking to understand and live with the physical and environmental forces present at its location. The educational course materials prepared by Burby et al. (2002), ''Building Disaster Resilient Communities,'' view disaster resilience as a primary goal of emergency management. And the analyses of disaster-stricken cities by Vale and Campanella (2002) explore the historic meanings of resilience and urban trauma.

Despite such interest in 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 to uncover its key principles, then begins to apply these principles to develop best practices in urban hazard mitigation. I ask what constitutes a resilient city and why is resilience important. I raise questions about, and make recommendations concerning, the objectives of resilience and antiterrorism. I then cull general resilience principles from the urban systems and disaster mitigation literature. Next, I relate these principles to best hazard mitigation practice and experience. Finally, I propose a national campaign of research, education and training, and professional collaboration to increase knowledge and awareness of resilient city planning and design.

What is a Resilient City?

''*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).

A resilient city is a sustainable network of physical systems and human communities. Physical systems are the constructed and natural environmental components of the city. They include its built roads, buildings, infrastructure, communications, and energy facilities, as well as its waterways, soils, topography, geology, and other natural systems. 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.

Human 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: schools, 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 community networks must be able to survive and function under extreme and unique conditions. If they break down, decision making falters and response drags. Social and institutional networks exhibit varying degrees of organization, identity, and cohesion. Just as engineers analyze the fragility of physical structures under stress, social scientists seek to develop ''fragility curves'' for organizations under stress (Zimmerman 2001). 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, because they will be the ones most responsible for building ultimate urban resilience. Geis (2000) argued that the term disaster resistant is both more fitting and more marketable than disaster resilient, but he also stressed the need for a holistic and integrated approach that is concerned with connections and relationships and not just the structural integrity of buildings. While in the final analysis the term chosen is less important than what it encompasses, many contemporary writers use resiliency to indicate concern with the linkage of physical and social systems (Olshansky and Kartez 1998; Tobin 1999; van Vliet 2001).

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, nongovernmental, and private sector organizations are prepared with up-to-date information about hazard vulnerability and disaster resources, are linked with effective communication networks, and are experienced in working together.

Why Is Resilience Important?

Resilience is an important goal for two reasons. First, because the vulnerability of technological 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). If we knew exactly when, where, and how disasters would occur in the future, we could engineer our systems to resist them. Since hazard planners must cope with uncertainty, it is necessary to design cities that can cope effectively with contingencies.

Second, people and property should fare better in resilient cities struck by disasters than in less flexible and adaptive places faced with uncommon stress (Bolin and Stanford 1998; Comfort 1999). In resilient cities, fewer buildings should collapse. Fewer power outages should occur. Fewer households and business should be put at risk. Fewer deaths and injuries should occur. Fewer communications and coordination breakdowns should take place.

Some skeptics argue that the pursuit of community resilience is laudable but impractical. Using a conceptual framework based on theoretical models of mitigation, recovery, and structural-cognitive interaction, Tobin (1999) examined data from the state of Florida to assess the possibility of developing sustainable, resilient communities. Analyzing the state as a whole rather than any individual cities, Tobin concluded that major (unlikely) changes in political awareness and motivation would be necessary to overcome obstacles to resiliency and sustainability from Florida's existing demographic traits, spatial patterns, and hazard conditions.

Is the resilient community thus simply a utopian ideal, or can we find examples in the real world? I believe that systematic research on natural hazard mitigation—the field where we have the most experience—would discover considerable progress toward the goal of resiliency. Two American cities appear to be well on their way toward physical and social resilience in the face of natural hazards. Berkeley, Calif., and Tulsa, Okla., exemplify long-term persistence and innovation in risk-reduction policies and programs, with strong champions to lead community efforts and consistent attention to the political and social, as well as the physical, aspects of hazard mitigation.

Following the 1989 Loma Prieta earthquake and the 1991 East Bay Hills wildfire, Berkeley crafted a community safety strategy to make itself economically and socially sustainable within a high-risk environment (Chakos et al. 2002). Berkeley voters have approved five local ballot measures to fund the seismic retrofit of municipal facilities and school buildings totaling over $390 million, and the city has invested $2 million annually for seismic subsidies and safety programs. Its City Council adopted a transfer tax rebate program and a permit fee rebate program for homeowner seismic safety actions, and the city operates a loan program and a free home repair program for low income seniors or disabled people. Its rate of retrofit is the highest in the San Francisco Bay area. Designated as a "Project Impact Community," the City of Berkeley has used that program's seed money to build partnerships within the community and the region.

Faced with tornadoes, violent thunderstorms, and flooding from the Arkansas River, Tulsa instituted an outstanding community hazard mitigation program (Patton 1993; Conrad et al. 1998). Spurred to action by a long series of repetitive floods during the 1970s and 1980s, Tulsa began a community debate on how to deal with flood control. Shocked by a national study that showed that Tulsa led the nation in numbers of federally declared disasters, city leaders recognized that they must establish a comprehensive flood management program with political and fiscal continuity. They established a floodplain clearance effort that removed some 875 buildings by 1993, stable program funding through a stormwater utility fee that brings in $8 million per year, watershed-wide development regulations, an aggressive public awareness program, master drainage plans supported with a capital funding program, and floodplain recreation and open space areas. As a result, Tulsa has reduced losses from repeated flooding, enhanced quality of life by expanding open space recreation areas, and created a better environment by returning floodplains to wetlands and reclaiming wildlife habitat.

By positing physical and social resilience as a goal, city leaders create a model against which decisions and actions can be measured and plans and policies can be evaluated. They create an image that decision makers and the public can understand and act to achieve. They create a goal that all hazard mitigation organizations can share.

Bridging between Natural Hazard Mitigation and Antiterrorism

"*Science can play a role in helping with prevention and mitigation as well as recovery and repair. It will make its greatest contribution if we consider our vulnerability to terror attacks and to natural disasters jointly rather than separately. Because our social and economic arrangements have made us vulnerable to both, we can gain from working on them together with a program that involves the social sciences as deeply and as actively as the natural sciences*" (Kennedy 2002, p. 405).

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 hazard mitigation, which has focused primarily on natural hazards in years past?

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), smart growth (Godschalk 2001), and new urbanism (Katz 1994; Duany et al. 2000). 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 cities to be resilient to natural hazards and ensuring that future development does not increase vulnerability (U.N. Commission on Sustainable Development 2001). Smart growth calls for compact cities and high density to combat urban sprawl; many smart growth policies include the goal of hazard resilience. New urbanism advocates traditional architectural design principles to foster community, while reducing urban sprawl.

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.

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 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 hazards and terrorism risks. However, I believe that the principles of disaster resilience are the same for both types of practitioners. The goal of the resilient city could become a bridging concept between the two fields. The city that is resilient to natural disasters is also resilient to terrorism, despite a different disaster catalyst. Both types of practitioners should seek to build physical and social resilience.

Disaster Resilience Principles

Hazards researchers and system theorists have identified a number of characteristics found in complex, resilient systems, such as cities, in which technological components and social components interact. They have pointed out that resilience requires combinations of apparent opposites, including redundancy and efficiency, diversity and interdependence, strength and flexibility, autonomy and collaboration, and planning and adaptability (Zimmerman 2001; Bell 2002; Tierney 2002).

Futurist theorist Harold Foster (1997) has proposed 31 principles for achieving resilience. He organized 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, semiautonomous 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 multipurpose 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.

Researchers who have studied the response of resilient systems to disasters find they tend to be

- *Redundant*—with a number of functionally similar components so that the entire system does not fail when one component fails.
- *Diverse*—with a number of functionally different components in order to protect the system against various threats.
- *Efficient*—with a positive ratio of energy supplied to energy delivered by a dynamic system.
- *Autonomous*—with the capability to operate independently of outside control.
- *Strong*—with the power to resist attack or other outside force.
- *Interdependent*—with system components connected so that they support each other.
- *Adaptable*—with the capacity to learn from experience and the flexibility to change.
- *Collaborative*—with multiple opportunities and incentives for broad stakeholder participation.

[For example, see Comfort (1999), Foster (1997), Tierney (2002), Victoria Transport Policy Institute (2001), and Zimmerman (2001).]

The public and private organizations of a resilient city would both plan ahead and act spontaneously. The city would have strong central governance, as well as vital private sector and nongovernmental institutions. Its leaders would be aware of the hazards it faces, but not afraid to take risks. They would eschew simple command and control leadership, preferring to develop networks of leadership and initiative. They would set goals and objectives, but be prepared to adapt these in light of new information and learning. They would recognize that the quest for resiliency is an ongoing long-term effort.

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 2000a). 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.

Traditional Hazard Mitigation

Traditional hazard mitigation protects people, property, and the environment from the destructive impacts of hazards in a number of ways (Godschalk et al. 1999). Hazard mitigation activities include planning—i.e., identifying hazards and vulnerability, carrying out smart growth and hazard mitigation plans before disasters occur, and avoiding hazard areas—directing new development away from hazardous locations, and relocating existing structures and land uses to safer areas. Mitigation activities also include strengthening buildings and public facilities—flood-proofing and wind-proofing existing and new structures through building codes and engineering design, and 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.

Hazard mitigation also seeks to control hazards, using structural approaches such as flood control works, slope stabilization, and shoreline hardening to attempt to reduce risks from hazardous natural systems, and to limit unwise public expenditures—e.g., withholding subsidies for roads, sewage treatment systems, and other public facilities that could induce development in hazard areas. Finally, it aims to communicate 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 year 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 2000a; NC DEM 1999). Since the 1993 Midwest floods deluged nine states, leaving $12 billion of damage in their wake, more than 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 2000a).

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 11 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.

For example, Comfort (1999) showed how emergency managers in California learned 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) called these ‘‘nonadaptive’’ systems, low on technical structure, flexibility, and openness to new information and methods.

An important limit on the adaptability of communities is their vulnerability to disaster. In their analysis of the 1994 Northridge earthquake, Bolin and Stanford (1998) focused on the social and political-economic factors that make people vulnerable to disasters. They argued that looking only at the physical aspects of a disaster produces a one-sided engineering-oriented, technocratic fix perspective. In their 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 and Stanford (1998) perceived 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.

Mitigating for Social and Institutional Resilience

Clearly, to achieve the goal of a resilient city, urban hazard mitigation best practices must include both technical and social approaches. Unfortunately, the best example of such a sociotechnical approach, FEMA’s Project Impact, has been criticized 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 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 city that seeks social and institutional resiliency would monitor vulnerability reduction, build distributed hazard mitigation capability, develop broad hazard mitigation commitment, operate networked communications, adopt recognized equity standards, assist threatened neighborhoods and populations, and mitigate business interruption impacts.

Monitor Vulnerability Reduction

To track and disseminate progress toward resiliency, city planners and emergency managers would prepare, publish, and update regularly a detailed vulnerability analysis that describes and maps potential hazards and their probable impacts on a neighborhood basis. They would include a vulnerability reduction objective in the comprehensive plan and the capital improvements program, as well as in neighborhood plans and social programs. City elected officials would set annual vulnerability reduction targets with special attention to disadvantaged populations, and would allocate budget funds and program resources to meet these targets.

Build Distributed Hazard Mitigation Capability

To create a broad base of mitigation capability, city planners and emergency managers would provide hazard awareness information, funding, and training to new and existing neighborhood and community organizations to enable them to develop capable leaders and carry out hazard mitigation as one element of their program activities. The city government would seek out opportunities to combine hazard mitigation with other functions, such as environmental conservation, economic development, community facilities, and historic preservation.

Develop Broad Hazard Mitigation Commitment

City staff and leaders would work with public and private decision makers, nongovernmental organizations, neighborhoods, and households to develop a hazard mitigation ethic. They would use incentives and sanctions to move mitigation onto the public agenda, keeping hazards issues before the community and holding leaders accountable for hazard mitigation actions.

Operate Networked Communications

City officials would establish and operate a multipurpose community communications system and network with a variety of media and channels to reach all levels from the individual household to the neighborhood, community, region, and state. They would use the network for public announcements, plan reviews, information exchange, and hazard mitigation programs. The network would publish geographic information system maps of hazard areas, programs, contacts, and lifelines.

Adopt Recognized Equity Standards
The city government would adopt standards and benchmarks for achieving equity in hazard vulnerability. They would 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. City staff would work with residents at the neighborhood level to determine needs and appropriate mitigation programs to remedy inequitable vulnerability situations.

Assist Vulnerable Neighborhoods and Populations
The city government would provide resources and assistance to threatened neighborhoods and vulnerable populations to enhance their survival during and after a disaster. They would operate relocation housing programs to move households out of hazard areas and into safe locations, enlist neighborhood leaders in safe neighborhood programs, and combine community learning and improvement efforts with mitigation and vulnerability reduction efforts.

Mitigate Business Interruption Impacts
Planners and emergency managers would prepare businesses and financial institutions to cope with disasters by describing potential scenarios in which business is interrupted following a disaster and enlisting business leaders in private sector mitigation programs. The government would establish procedures for providing loans and deferring financial obligations following a disaster, as well as programs to assist workers during periods of business closure due to disasters.

This paper has gleaned a number of useful insights about resilient cities from the systems and hazards literature and from disaster recovery experience. However, there is still much to be learned and applied if we are to move toward urban resiliency on a wide front. The concluding section proposes a multifaceted campaign to build urban resiliency as a major national priority.

Conclusion: Building Resilient Cities as a National Priority

Cities are complex and dynamic metasystems in which technological components and social components interact. They are made up of dynamic linkages of physical and social networks. Planning for resilience in the face of urban disaster requires designing cities that combine seemingly opposite characteristics, including redundancy and efficiency, diversity and interdependence, strength and flexibility, autonomy and collaboration, and planning and adaptability. We are just beginning to realize the scope and magnitude of the challenges inherent in making our cities resilient to threats from natural hazards and urban terrorism.

To meet these challenges, I propose a national resilient cities initiative, aimed at the vision of the resilient city as the goal that bridges natural hazard mitigation and counterterrorism practice. To succeed, this initiative will require changes in national disaster policy, funding for basic and applied urban systems research, support for advanced education programs, and active collaboration among the city planning, design, and construction professions.

National Disaster Policy

National disaster policy has been greatly strengthened in recent years. The Disaster Mitigation Act of 2000 increased funding for proactive hazard mitigation by states and local governments to act in concert with the important functions of preparedness, response, and recovery. The Act changed the existing 1988 Stafford Disaster Relief and Emergency Assistance Act's postdisaster approach to a predisaster mitigation planning approach. It established new requirements for local mitigation plans, authorized the use of Hazard Mitigation Grant Program (HMGP) funds for mitigation planning, and provided states with approved mitigation plans with additional HMGP funds.

FEMA's (2001) draft criteria for implementing the 2000 Act required 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.

The Disaster Mitigation Act of 2000 and the new FEMA criteria are major advances. However, they do not distinguish the necessary elements of urban hazard mitigation from mitigation in general, nor do they anticipate the threat of terrorism hazards. As Robert Prieto (2002), chairman of the major engineering firm of Parsons Brinkerhoff, has stated: "Unlike many past events, both natural and man-made, the events of September 11 were attacks on an 'engineered,' built environment, a hallmark of our society, which thrives on human proximity, connectivity, interaction, and openness. The very fabric of our 'civil' society is tightly woven."

Further changes in disaster policy are clearly needed to respond to the unique aspects of urban hazard mitigation. These should be incorporated in the forthcoming programs of the new Department of Homeland Security, as well as in the existing FEMA programs.

Basic and Applied Research

While we have learned a great deal about the behavior of various urban systems in recent years, there are still many gaps in our knowledge about how physical and social systems within cities respond to extreme stress. Homeland Security Department legislation under consideration by Congress includes a program of focused research. A national program of basic and applied research on this topic could generate valuable contributions to our understanding of how to plan and design resilient cities.

The National Research Council (2002) report *Making the Nation Safer* calls for a broad government-industry dialogue on counterterrorism research agendas and lists a number of critical long-term research needs. It notes the need for developing new ways of understanding and modeling complex, adaptive systems. Urban planning researchers have made a promising start in this direction by using geographic information systems (GIS) to analyze, model, and visualize dynamic and interdependent urban systems, such as linkages between land use and transportation (Brail and Klosterman 2001). The new GIS contingency models are able to respond to what if questions that ask about potential system responses to future changes of various types. The GIS-based HAZUS model, developed by the National Institute of Building Sciences with funding from FEMA, estimates losses from future earthquakes of varying intensities (Miletti 1999). Models of this type could be extremely valuable in analyzing the potential responses of physical and social urban systems to disaster scenarios.

Already, the terrorist attack on New York has spurred a number of studies on the vulnerability of organizational and social systems as well as infrastructure systems (Zimmerman 2001;

Tierney 2002). The National Science Foundation has provided initial research grants. While their results are not yet complete, these studies promise to be very useful in planning for resiliency.

We need to build on these initial studies with a full-blown national research program on urban systems resiliency, similar to what the nation did earlier in responding to international space exploration challenges fueled by the Russian space satellite Sputnik. This program should include funds for sponsored basic and applied research in urban systems engineering, modeling, and design, as well as social science and planning studies.

Education Programs

In concert with the research campaign, we need to strengthen education and training in designing and managing resilient urban systems. The goal here is to increase our pool of human resources to prompt future engineers, scientists, planners, and emergency managers to enter practice and become educators and researchers.

The National Research Council (2002) report recommends a human resource development program aimed at producing a sustained increase in baccalaureate and doctoral degrees in fields consistent with long-term priorities for homeland security. Such a program should include support for university training for students in disciplines that can contribute to urban resiliency. These would include the physical science, social science, planning, design, engineering, and management fields.

Professional Collaboration

If we are to take the achievement of urban resilience seriously, we need to build the goal of the resilient city into the everyday practice of city planners, engineers, architects, emergency managers, developers, and other urban professionals. This will require a long-term collaborative effort to increase knowledge and awareness about resilient city planning and design.

Prieto (2002) notes that, because engineering tends toward specialization, engineers often have difficulty translating lessons learned to a broad range of disciplines; he suggests that the National Academy of Engineering could play an important role in deriving and disseminating lessons from disasters. Other professions face similar difficulties and would benefit from both intraprofessional and interprofessional collaboration. Such an effort could start with a summit conference to convene leaders of all the professions concerned with city design and development to develop resilient city practice guidelines. This could be kicked off by a national conference on Planning and Building Resilient Cities, sponsored by the National Research Council.

The objective of the conference would be to discuss principles for building resilient cities and ways of incorporating these principles into the practice of engineers, planners, architects, administrators, developers, and other city designers, builders, and managers. The program would look at both physical systems and social systems, and their linkages. It would include sessions on urban vulnerability analysis, urban hazard mitigation, and resilient city building.

Call to Action

If this resilient cities initiative sounds too ambitious, think back to what is at stake—thousands of deaths and injuries and billions of dollars in damage every year from natural hazards alone, not to mention the added terrorism threat risk. We have come a long way in 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 urban systems that could respond creatively to the unpredictable stresses of disasters. Increased public awareness of urban vulnerability resulting from the attack on the World Trade Center has opened a window of opportunity. Now is the time to kick off a resilient cities campaign aimed at maintaining the security of our urban civilization during the 21st century.

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