16

Resiliency to Disasters

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Key Points

- The levels of physical and mental harm to persons and physical damage to property occurring during and after natural and manmade disasters are influenced by community design.
- Community resilience, the ability to bounce back after a disaster, is influenced by preparedness planning, community design, and social networks.
- Community design features that enhance resilience include siting critical facilities such as wastewater treatment plants away from floodplains, adopting and enforcing seismic codes for structures such as buildings and bridges, burying utility lines underground, and protecting natural systems such as wetlands.
- Passive survivability is the ability of a building to maintain critical life support functions in the absence of power, water, and heating and cooling.

Introduction

August 29, 2005: A monstrous storm, Hurricane Katrina, barreled toward New Orleans on Sunday with 160-mph wind and a threat of a 28-foot storm surge, forcing a mandatory evacuation of the below-sea-level city and prayers for those who remained to face a doomsday scenario. . . . "It's capable of causing catastrophic damage," [National Hurricane Center Director Max] Mayfield said. "Even well-built structures will have tremendous damage. Of course, what we're really worried about is the loss of lives. New Orleans may never be the same." . . . As many as 100,000 inner-city residents didn't have the means to leave and an untold number of tourists were stranded by the closing of the airport, so the city arranged buses to take people to 10 last-resort shelters, including the Superdome.

Despite the dire predictions, a group of residents in a poor neighborhood of central New Orleans sat on a porch with no car, no way out. . . . "We're not evacuating," said Julie Paul, 57. "None of us have any place to go. We're counting on the Superdome. That's our lifesaver." The 70,000-seat

> Superdome, the home of football's Saints, opened at daybreak Sunday, giving first priority to frail, elderly people on walkers, some with oxygen tanks. They were told to bring enough food, water and medicine to last up to five days. . . .
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> But the evacuation was slow going. Highways in Louisiana and Mississippi were jammed all day as people headed away from Katrina's expected landfall. All lanes were limited to northbound traffic on Interstates 55 and 59, and westbound on I-10. At the peak, 18,000 vehicles an hour were streaming out of southeastern Louisiana [report by the Associated Press 2005].

During Hurricane Katrina the greatest human and property impacts in New Orleans occurred in the newer and poorest parts of the city (Figure 16.1). Many of the older homes had been built on higher land, had elevated floor plates, and had window shutter and roofing designs that made them more resilient to extreme weather events. Response to and recovery from this disaster have been slow and troubled, leading to new attention on how places and communities can become more resilient to disaster.

Risks from natural hazards are ubiquitous throughout the United States and in most areas of the world. American communities face threats from hazards including hurricanes, forest fires, earthquakes, tsunamis, floods, tornadoes, severe drought, and heat waves. The mix of hazards a community might encounter depends on its location, and these hazards will be made more serious by changing climate conditions.

Figure 16.1 When the levees failed during Hurricane Katrina in 2005, impacts were highest in the poorest parts of New Orleans (photo: Jocelyn Augustino, FEMA).

Researchers at the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA) have mapped the last three decades of weather events that resulted in $1 billion or more worth of damage. Figure 16.2 provides a snapshot of the range and severity of these extreme weather events facing American communities. Moreover, the frequency and economic impacts of such events are increasing. In 2009, there were five weather events in the United States that caused more than $1 billion in damages each. Although loss of life from disasters in the United States has been low compared with losses in the developing world (the 2010 Haiti earthquake, for example, resulted in more than 300,000 deaths, whereas fewer than 2,000 persons died due to Hurricane Katrina), human suffering and property losses are nevertheless significant concerns.

Many urban population centers, including major cities such as Los Angeles and Seattle on the West Coast and Charleston, South Carolina, and Boston on the East Coast, face severe seismic hazards. Coastal communities, especially along the Atlantic and Gulf coasts, face increased frequency of hurricanes and coastal storms and long-term sea level rise (Beatley 2009). Pilkey and Young (2009) suggest coastal communities should plan for a minimum two-meter rise in sea level by the end of the twenty-first century, a prediction that portends serious flooding and an adaptation challenge.

The health impacts of natural disasters extend beyond the immediate mortality and injury. Often, surviving families and individuals are displaced and face substantial physical and psychological stresses. Following Hurricane Katrina, such conditions included inadequate housing (including formaldehyde-emitting FEMA trailers), inadequate access to food, and unemployment.

The long-term health implications of climate change are creating new challenges for communities and local governments. Rising urban temperatures and future heat waves are threats for all, but especially for vulnerable populations such as the elderly and socially isolated (Chapter 9). By the 2080s, average daily high temperatures that today are 80 to 85 degrees Fahrenheit may rise to 90 to 95 degrees, and in late summer they could rise to 100 to 110 degrees (Lynn, Healy, and Druyan 2007). The 2003 heat wave in Europe is estimated to have resulted in as many as 80,000 excess deaths, mostly among older residents, and heat-related mortality can be expected in North America as well. Although a few cities have developed policies for sheltering residents in air-conditioned public buildings in such emergency heat conditions (Figure 16.3), most cities have relatively limited plans or capabilities for addressing such a problem.

Vulnerability is also a function of other social and community variables. Social vulnerability varies over space and time and depends on interactions of social, economic, and biophysical factors (Cutter, Boruff, and Shirley 2003).

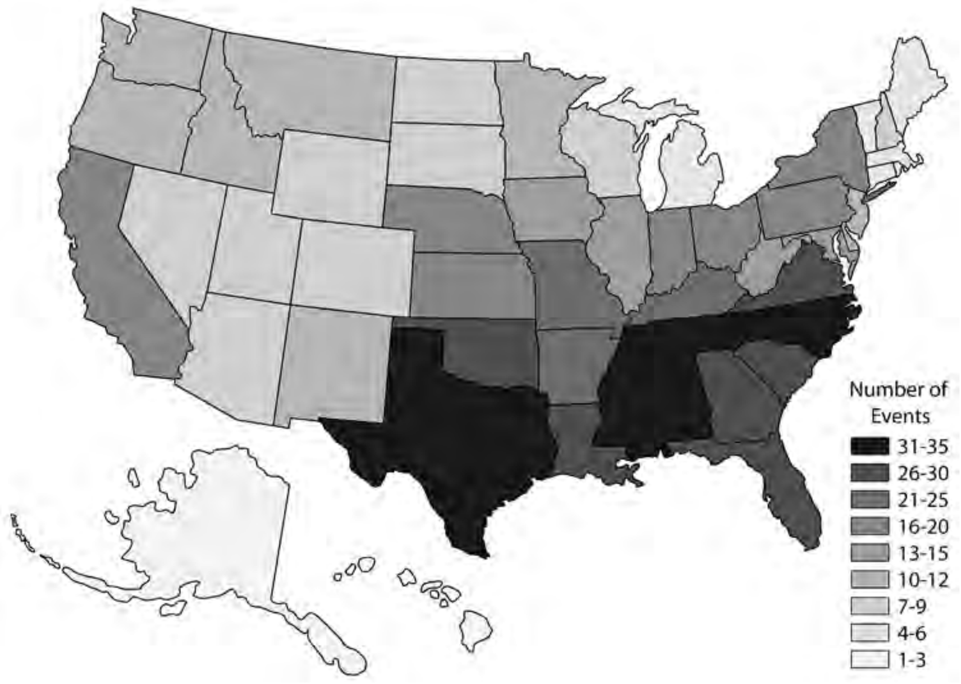

Figure 16.2 Nearly 100 weather disasters—hurricanes and other severe rain storms, floods, blizzards, fires, ice storms, heat waves, and freezes—each with costs exceeding \$1 billion, have affected all regions of the United States between 1980 and 2010. A single event may affect multiple states (data from NOAA, National Climatic Data Center, n.d.).

Indicators of social vulnerability include age, income and poverty, housing stock, race, and presence or absence of social support networks that could help in a disaster.

Each of these demographic and social categories suggests special vulnerability in the face of a natural disaster. Elderly residents with limited mobility may have difficulty evacuating in advance of an oncoming storm. The poorest members of the community have the fewest resources with which to prepare for or respond to a disaster event. In New Orleans the absence of cars among poor residents and minimal public transit infrastructure meant many residents had difficulty leaving the city before or after Hurricane Katrina. Other ethnic and demographic variables, such as having lived only a short time in a community or being unable to speak English, may be impediments to preparing for a disaster event and to accessing disaster recovery services and benefits.

The degree of social isolation in a neighborhood influences vulnerability. Trends in the United States suggest that Americans exhibit a greater degree of social isolation today than they did two decades ago (McPherson, Smith-Lovin,

Figure 16.3 Residents of New York's Lower East Side neighborhood escape the heat in one of the city's designated cooling centers during the July 2010 heat wave (photo: AP Images, David Goldman).

and Bashears 2006). Another significant dimension of community vulnerability is economic condition. Weak local economies are likely to have less resilient responses and slower recoveries from a major hurricane or earthquake. The challenge for American communities is to address the physical, social, and economic factors that make them vulnerable to future disasters.

Planners and health professionals need to work toward the design and planning of more resilient communities—cities, towns, neighborhoods, and homes that can more effectively withstand physical, social, and economic shocks. This will require strengthening and enforcing building codes, steering development and infrastructure into safer locations, protecting and restoring natural systems, and building **social resilience**.

Community Resilience as a Primary Goal

In the face of current threats, resilience should be an organizing concept and primary goal for future planning and development. Early work on resilience by C. S. Holling focused on **ecological resilience**, defined as "the capacity of a system to absorb and utilize or even benefit from perturbations and changes that attain it, and so persist without a qualitative change in the system's structure" (Holling 1973).

The word *resilient* comes from Latin *resiliere*, meaning "jump back"; so a resilient person or community is one able to bounce back from a disturbance or crisis (Paton 2006). Godschalk describes resilient cities as ones "capable of withstanding severe shock without either immediate chaos or permanent harm. Designed in advance to anticipate, weather, and recover 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 be able to adapt and would not break. Composed of networked social communities and lifeline systems, resilient cities would become stronger by adapting and learning from disasters" (Godschalk 2003, 137). In resilient cities, buildings, major roads, utilities, and other support facilities are designed to continue functioning during disasters. Allowing residents to safely *shelter in place* is preferable to trying to quickly move millions of people, including many who are in weakened condition, under austere circumstances. Existing residential and commercial development will need to be relocated to safer areas and future development guided toward less hazard-prone areas. Government and community organizations must have good communication links, current hazard vulnerability and disaster resource information, and experience in working together.

Resilience is closely related to other concepts in community planning, including sustainability and hazard mitigation. Implicit in the notion of resilience is an emphasis on taking actions and steps to build *adaptive capacity*, to be ready ahead of a crisis or disaster. Resilience is anticipatory and intentional in its outlook. Planning ahead is a key aspect of resilience.

Community Resilience: Key Planning Dimensions

Community resilience is a woven network. Its interconnected strands are the inherent resilience of buildings; robustness of infrastructure; existing and future land use; compatibility with ecosystems and natural environments; economic, financial, and insurance resources; governmental capacity; and social capital (Box 16.1). Changes in community land-use patterns and urban form, for example, can reduce exposure to natural hazards such as floodplains and also promote social interaction, thereby enhancing social resilience. Actions to strengthen economic resilience may ensure that companies can reopen quickly following a storm or other natural event, in turn helping to buffer the families

Box 16.1

Elements of Community Resilience

Buildings

- Structural soundness
- Roof design, tie-downs
- Earthquake bolts
- Window shutters
- Elevated first floor
- Mold and fire resistance
- Daylit interior and natural ventilation
- Prepositioning of emergency supplies
- Food and water resources
- On-site power generation

Neighborhood

- Levees
- Swales and water retention areas
- Underground utilities
- Large and robust civic buildings
- Tree management
- Hazard-resistant landscaping
- Edible landscaping
- Prepositioning of emergency supplies

City

- Functional governance, including emergency services
- Emergency plans
- Functional communication systems
- Training
- Distributed energy systems
- Enforced building codes requiring resiliency
- Local government rainy-day funds

Financial

- Robust, diverse economy
- Business continuity plans
- Insurance coverage of individual and community assets
- Off-site storage of copies of key business records

Social

- Knowledge and concern about neighbors
- Active neighborhood associations

Regional

- Preservation of natural systems, such as wetlands
- Evacuation and sheltering plans

who depend on the jobs, income, and services these companies provide. Limiting such business disruptions helps to enhance social resilience.

Building and Structural Resilience

Designing the stock of buildings in a community—its homes, businesses, offices—to withstand the physical forces likely to occur contributes to community resilience. Building codes and construction standards are a common method for ensuring resilience and a cost-effective tool for advancing community health and safety. For example, the California Building Code (www.bsc.ca.gov/default.htm) mandates extensive design and construction standards for seismic safety, ensuring new buildings are likely to be survivable for occupants during earthquakes.

To strengthen construction, the Institute for Business and Home Safety (IBHS), an insurance industry–funded nonprofit group that promotes hazard mitigation, created the "Fortified . . . for safer living" program to encourage homebuilders to build stronger structures and homebuyers to seek them out (IBHS 2007). IBHS established additional construction standards, generally above those required by code, for hurricane winds, flooding, and wildfires. Once these standards are met, the home or structure is awarded a "fortified" certificate, valued by homebuyers and rewarded in the marketplace.

Although adoption of a strong building code is necessary, enforcement of that code is equally important. In collaboration with IBHS, the International Organization for Standardization (ISO) has implemented a Building Code Effectiveness Grading Schedule (www.floir.com/BCEGS/index.aspx) that rates communities according to the strength and enforcement of their codes. A result of the experiences encountered during and after Hurricane Andrew, the grading schedule allows communities to be scored against objective measures, and these scores support lower insurance rates for communities with effective codes (ISO, n.d.).

In a broader context, there is value in structures that reduce demands on the environment while providing healthier indoor and outdoor living conditions. Buildings with reduced energy consumption help reduce the size and vulnerability of local and regional energy systems (reducing the need for additional power plants and transmission lines and thus reducing exposures to future natural disasters), enabling communities to spring back more easily from disasters. High energy demand coupled with increasingly severe weather often results in energy blackouts and service disruptions. Designing homes and buildings that require less energy helps to reduce the impacts and severity of these outcomes. Local energy generation and *smart metering* (use of meters that provide real-time usage details and allow consumers to selectively use electricity at times of lowest cost) would help to offer these benefits.

Hurricane Katrina stimulated discussion of how homes and buildings could be designed to ensure livable conditions for occupants following events that disrupt public services. **Passive survivability** is the "ability of a building to maintain critical life-support conditions for its occupants if services such as power, heating fuel, or water are lost for an extended period" (Wilson 2006). A house or building might be hot or uncomfortable but still survivable. Many of the building features needed for passive survivability are consistent with energy conservation and the other benefits associated with green buildings, such as passive solar design, daylighting, natural ventilation, and rooftop photovoltaic panels to supply electricity during power outages.

Several high-profile green projects in New Orleans have emphasized passive survivability and demonstrate the ability to respond to natural hazards and create healthier home living environments. For example, the Holy Cross project, planned and funded by Global Green in the lower Ninth Ward, includes design features for passive survivability. Among other features of these homes, they are located on higher ground, living spaces are elevated above the height required by code, and materials used include rigid foam insulation that dries quickly and paperless drywall that limits the formation of mold.

Berlin, Maryland, is located in a coastal area at risk for hurricanes. One development in Berlin, Hilltop at Walnut Hill, features passive survivability at both the home and neighborhood levels: the houses have been built in a compact, walkable, infill location and include passive heating and cooling, paints with few or no volatile organic compounds (VOCs), natural materials, and disaster preparedness features such as a two-month supply of food (Beatley 2009).

Landscape and Site Design

Many landscape and site features can build resilience, such as enhancing permeability to absorb rainfall or providing opportunities for neighborhood food production. Neighborhood greening efforts can assist in addressing the **urban heat island** problem. Green rooftops and green walls, urban tree planting, rain gardens, and permeable paving materials are valuable in controlling storm water runoff (Chapter 6) and in reducing urban temperatures. Such neighborhood-based storm water features are types of **low-impact development** (LID) and are encouraged or mandated by some communities.

Reducing the extent of impervious cover in a neighborhood can reduce the risk of flooding, especially downstream. This can be accomplished by reducing the extent of paved surfaces, through designing shared driveways and roadway space and by using permeable asphalt and pavers that allow percolation of storm water and the growing of grass and vegetation. Preserving forest cover and greenery on a site can also enhance resilience. Good examples exist of new coastal developments and redevelopments that seek to preserve and protect the integrity of the onsite vegetation and natural environment. For example, in the new Oak Terrace neighborhood in North Charleston, South Carolina, the majority of the site's live oak trees have been preserved through sensitive subdivision design and orientation of homes.

At the site level, other steps can enhance the resilience of a home or neighborhood to wind and water. To promote wind- and flood-resistant landscaping, Charleston County, South Carolina, advises homeowners that trees with greater wind resistance, such as live oaks, sabal palmetto, longleaf pine, southern magnolia, and dogwood, should be planted near houses. Vegetated buffers around streams and riparian areas can further protect against floodwaters and also provide important habitat and other ecological benefits.

Resilient Community Land Use

Avoidance of natural hazards is an effective resilience strategy that can be accomplished by steering development away from high-risk locations, such as floodplains and seismic fault zones. Communities can undertake the following:

- Prepare comprehensive plans or community land-use plans that guide future growth away from risky locations.
- Update land-use regulatory tools, such as zoning, to keep the extension of density and development away from high-risk locations.
- Impose performance standards to reduce exposure (for instance, by requiring new development to be set back a minimum distance from high-erosion shorelines).
- Focus local and regional land acquisition efforts on setting aside high-hazard locations and on ensuring a healthy regional ecosystem that preserves the mitigative features of the natural environment.
- Create hazard mitigation and recovery plans that specify areas where, in the event of future destruction, rebuilding will be prohibited or restricted.

There are many good examples of communities in the United States that have incorporated natural hazards and risks into their comprehensive plans and development regulations and are attempting to minimize risks by steering development away from high-risk locations. Box 16.2 and Plate 13 present the example of one coastal community, Crisfield, Maryland, that is incorporating sea level rise into its community plan.

Resilient Lifelines and Infrastructure

Lifelines are "systems or networks which provide for the circulation of people, goods, services and information, upon which health, safety, comfort and economic activity depends" and "are the means whereby a community supports its day-to-day activities and include mechanisms used to respond to emergencies" (Johnston, Becker, and Cousins 2006, 40). They include community infrastructure providing water; wastewater collection and treatment; police and fire services; roads, bridges, and transport; and communication, power supply, and transmission facilities. Robust and connected communication systems for

Box 16.2

Crisfield, Maryland: A Community Plan for Coastal Retreat

The town of Crisfield, Maryland, with a population of about 2,700, lies adjacent to Chesapeake Bay and faces some stark realities: virtually the entire locality, including its commercial downtown, is located on a 100-year floodplain, and almost all its land has an elevation less than three feet above sea level (Plate 13). The prospects for further flooding and the potential impact of likely future sea level rise have inspired the city to develop and adopt an unusual community comprehensive plan, one that places flooding and sea level rise at the center and calls for managing future development and growth to minimize long-term exposure to these coastal hazards.

The heart of the plan is a "comprehensive land use" map and a "land use/natural area compatibility" chart. The former divides the town into various use zones, while the latter presents an unusual suitability matrix, arranging suitable uses according to how sensitive the land or area is. Land in the city at 3.1 feet in elevation or higher is indicated as suitable for development, while land at less than 2 feet is suited to water-dependent, passive recreation, and resource conservation uses only. Areas designated as "eco-residential" areas, an example of the land-use map, are infill sites subject to flooding. Redevelopment here is permissible only "if it restores natural functions and open spaces, links isolated wetlands and natural areas together to provide flood protection and aesthetic benefits, improves infrastructure to benefit living conditions; and provides a broad mix of housing across the affordability range." The plan recognizes the importance of preserving the extensive coastal marshes that lie to the north and west (including Janes Island State Park) and to the south. The plan states that these wetlands represent "important resources that protect the city against storm surge and excessive flooding." Under the land-use map, most of these wetland areas are designated "resource protection" and are off-limits to future development. Perhaps the most interesting element of the plan is the section discussing future expansion and extension of the city. The plan includes an "urban growth sustainability area" map that indicates specific areas where, through municipal annexation, the city prefers to expand. This preferred future growth area lies completely outside the 100-year flood zone (adapted from Beatley 2009).

responders are essential. For example, a serious problem during the response to the September 11, 2001, World Trade Center disaster in New York City was that police and fire personnel lacked common communication capability.

Lifelines should be designed to withstand the range of physical forces expected. Examples include designing bridges to withstand earthquakes, elevating roads above potential flood levels, and placing utility lines underground where they are less susceptible to damage.

Critical facilities should be located outside high-risk hazard zones or in areas expected to experience lower magnitude forces. For instance, fire stations, schools, and hospitals should be located or relocated outside tsunami hazard zones, as has been done in Cannon Beach, Oregon. Worcester County, Maryland, has undertaken an inventory of critical facilities, and most, including municipal sewage treatment plants, are well away from floodplains and are located on upland, in-town sites. Ocean City, Maryland, has gradually placed power and telephone lines underground (Beatley 2009). Following the 1991 fires in Oakland, California, utility services were put underground—a task easier in a devastated community than in one that is built-out.

Community infrastructure must be rethought and reconceptualized in an expanded way to include, for example, consideration of local food and energy sources, ecological services from wetlands, and evacuation capabilities. A major trend in communities is to establish decentralized forms of infrastructure. Communities that have experienced damage and loss of service from natural disasters are at the forefront in investing in a new approach to infrastructure. For example, after Houston experienced significant damage and a long electrical service disruption from Hurricane Ike in 2008, a mayoral task force recommended moving toward more resilient distributed energy systems, such as solar power and combined heat and power production, as well as investments in a more intelligent grid (City of Houston, Texas 2009). The task force concluded that developing a master list of vulnerable populations and critical facilities in the city and region, encouraging personal readiness (including personal investments in solar panels and the possibility of plug-in hybrids along with two-way inverters helping to power homes in the aftermath), and promoting smart vegetation management would pay dividends in future hurricanes and would make the city safer, more sustainable, and better able to adapt to future circumstances.

Ecological Resilience: Conservation and Restoration of Natural Systems

The ecosystems and natural environments in which communities are embedded are subject to impacts of natural events such as hurricanes and wildfires but also to moderators of the impacts of these forces on people and built form. Examples of planning actions to support ecological resilience include actions that ensure sufficient wetlands buffers and permit coastal wetlands to migrate landward in response to long-term sea level rise. Conserving and restoring natural systems will also deliver significant resilience benefits to communities and built environments, such as when wetland systems absorb flood waters and sand dunes act as natural sea walls.

Hurricane Katrina stimulated new appreciation for the natural mitigative value of wetlands and other natural ecosystems. Costanza, Mitsch, and Day (2006) argue that a major focus in rebuilding New Orleans must be on restoring "natural capital," especially the region's coastal wetlands system that provides extensive flood protection and other natural services of high economic value.

The economic value of the flood protection services alone provided by these wetlands has been estimated at $375 per acre per year. These authors believe that "had the original wetlands been intact and levees in better shape, a substantial portion of the US$100 billion plus damages from this hurricane probably could have been avoided" (Costanza, Mitsch, and Day 2006, 319).

One challenge for community planners is to find ways to restore and repair ecosystems, and there are good examples of such efforts. The new sustainable coastal community of Loreto Bay, in Baja California Sur, Mexico, for instance, is placing much emphasis on restoring its estuary, including replanting native vegetation and mangrove forests that will eventually expand the capability of absorbing flood waters and provide protection from storms.

Social and Economic Resilience

Communities are not made up simply of buildings and infrastructure but also of people—individuals, families, and social groups for whom resilience efforts should be developed. Communities that have nurtured certain social qualities and conditions and social relationships will be more resilient in the face of natural disasters and other disruptions. A community cannot achieve resilience without adequate attention to the social realm. In times of stress and crisis, strong social networks can provide important buffering opportunities. Research shows the value of extensive friendship patterns in recovering from disease (for example, lower mortality and higher recovery rates for cancer patients with more extensive friendship patterns). Friendships, knowing one's neighbors, and having well-developed patterns of community and neighborhood socializing and sharing significantly prepare communities to cope with disasters.

Strengthening the social capital of a community may be as important in enhancing resilience as strengthening the homes and buildings. There are many programs, strategies, and tools available to assist communities in building social capital. As described in Chapter 8, such approaches as compact design that encourages walking and social interaction can help to strengthen social resilience. A robust set of social networks and institutions will both help in effective recovery and allow a community to weather the event. It may also inoculate a community against the most severe impacts. Extensive and healthy social capital is valuable before, during, and after a disaster event. For example, if communication and social networks are strong among neighbors, evacuation may be more effectively managed in a disaster.

One of the most effective approaches to enhancing overall community resilience is to take actions to support a more sustainable and resilient local and regional economy. Local and regional economies are more resilient when they are diverse (they do not rely on a single or just a few specific employers or economic sectors), prepared (businesses in the community have planned for natural hazards and other disrupting events), sustainable and green (businesses build on the qualities and resources of place and employ local supply chains), and community connected (well embedded in the community).

There are many examples of communities that are planning ahead to facilitate effective business recovery from disaster. In Florida, Palm Beach County's postdisaster recovery plan identifies specific measures to encourage business to remain in the county rather than relocating following a major disaster event and generally to strengthen the resilience of businesses located there (Palm Beach County 2006). In Hawaii, Maui County has adopted a community plan that seeks greater self-reliance and self-sufficiency and also less dependence on materials and goods coming from the US mainland (Maui County 2010).

Summary

This chapter has examined the promise of resilience as a central organizing concept for guiding community planning. Resilience offers a relevant and useful perspective on how to design, plan, and manage communities. Although the term *resilience* has various definitions, its intuitive essence—the concept of designing and living in places that can effectively adapt to and bounce back from natural disasters—has much appeal.

Community resilience requires action at a number of design scales. Much can be accomplished at the level of building design as well as at the city and regional levels, including land-use planning that keeps development out of high-hazard areas and actions that preserve a green infrastructure. The stories of how communities have adapted in the face of previous catastrophes emphasize that in planning for resilience, the social and cultural aspects of a community are as important as the physical ones. Much of the interpersonal and neighborhood resilience needed will require a sense of commitment to community and place that is absent in some US communities today, especially those with mobile populations. How to rebuild a network of helping, caring citizens embedded in places in which they are committed to stay is a major community planning challenge.

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