



PLANNING RESILIENT INFRASTRUCTURE

Planning more resilient infrastructure systems is significantly advanced by communities when they engage in continuous resilience planning, as capsulized below:

- Create a continuing planning and development process that will shift the way in which infrastructure services are designed and implemented, to consider more resilient protection for existing and future infrastructure systems
- Create a resilience program and recovery plan for post-disaster implementation that considers the types of risks that threaten critical systems, assesses vulnerable infrastructure, and identifies priorities for improving resilience, based on an assessment of multicomponent and life-cycle costs and project benefit.

KEY POINT #1

Understand the risks to infrastructure. Communities should perform in-depth risk analysis for all key infrastructure systems, assessing a full range of hazards and severity of risk, using root-cause analysis.

KEY POINT #2

Identify projects to reduce risk. For critical infrastructure assets at greatest risk, identify mitigation actions and study their implementation feasibility to understand functional benefits, costs, and impacts.

KEY POINT #3

Seek out funding opportunities for mitigation planning and projects. For projects that can demonstrably mitigate risk, seek funding opportunities under state and federal grants programs and seek cooperative partnerships with utilities.

KEY POINT #4

Achieving infrastructure resilience is a continuous learning process. Reducing infrastructure risk requires ongoing initiative to refine and adjust mitigation actions to be increasingly effective and reliable, recognizing that hazards are variable and mitigation technologies are evolving.



KEYPOINT #1:
**Understand
the risks to
infrastructure.**

Who is responsible for increasing the resilience of our infrastructure systems? This is a complex question, because infrastructure systems are owned and operated by a wide range of agencies. Water and sewer systems are owned by municipalities, authorities, private companies, and individuals. Roads and rail systems are typically

operated by public transportation and transit agencies. Electric systems are usually owned by private power companies, but occasionally municipalities operate local power distribution grids. Communications including telephone, cable, Internet, and cellular systems are mostly owned by private companies.

The result of this mixed ownership is that the planning, engineering, operation, and disaster-recovery functions for these wide-ranging systems are distributed among multiple owners and agencies. These multiple parties have not traditionally coordinated closely with one another. To begin the process of achieving more resilient communities, it is critical that local leaders engage representatives of vulnerable infrastructure systems in a “resiliency roundtable” to explore mitigation approaches. The purpose is to explore how resilience could be improved through planning, engineering, and disaster-response functions, as implemented on both public and private property.

Many issues typically converge during roundtable discussions: Power and water/sewer utilities need access for disaster recovery via the transportation/road network. However, implementing underground power for critical network segments, or providing natural barriers to flooding near water/wastewater treatment facilities can keep these infrastructure elements in operation, but can require joint public/private action. Creating an appropriate mix of public, private, and utility actions, and leveraging the expertise and authority of land-use and resiliency planning, zoning, code enforcement, engineering, landscape design, and emergency response systems, provides a great opportunity for improvement.

Communities should perform risk analysis for all key infrastructure systems, assessing the full range of likely

hazards and the severity of risk. When assessing risk from natural hazards, it is imperative that natural hazard risks are effectively evaluated and understood in order to formulate a comprehensive approach to resilient infrastructure. There are a number of resources available to evaluate risk based on hazard type (see Resources/References), most of which are based on statistical analysis of historical events and modeling. Where relevant, it is also useful to establish a history of past damages and the severity of the event that caused those damages to facilitate identifying the root cause. Risk assessment for resilience should take future conditions into consideration.

ASSETS AT RISK

Once risk from natural hazards is identified, it is necessary to evaluate the infrastructure assets that would be at risk from those hazards. The following analyses are recommended:

- Inventory, map, and analyze data relating to population, buildings, and critical facilities (e.g., hospitals) within high-risk areas. Essentially, identify the vulnerable built environment and determine the connectivity of vulnerable infrastructure systems serving the built environment to prioritize potential risk-reduction projects. Identifying key infrastructure is critical in understanding which human activities will be affected by interruptions to these facilities. Include an evaluation of the age of infrastructure relative to its useful life.
- Evaluate the vulnerability of the critical infrastructure in current and future hazard areas to determine potential damages. Include all hazards in the evaluation, including risk from floods, severe winter storms, hurricane and tornado winds, wildfire, and earthquakes. Use scenario-planning approaches, applying information such as flood inundation elevation or wind speeds that cause damage. Create a potential damage curve by comparing the costs to repair damage to the probability of occurrence of the hazard (e.g., flood level and recurrence interval, such as a 100-year flood level). Include scenarios with irreparable damage that result in costly replacement of the infrastructure. Facilities that result in larger amounts of risk during frequent events should be prioritized for mitigation actions. The

Federal Emergency Management Agency's (FEMA) Hazus provides a tool to identify risk by quantifying potential damages and averaging annualized losses due to floods, earthquakes, and hurricane winds.

- Evaluate the level of service of flood control structures (e.g., levees, berms, detention facilities), and reassess whether the level of service needs to be recalculated given changes in climate. Compare historic event return periods to current return periods. Evaluate a new probability of exceeding the capacity of flood control structures and protections.
- Inventory and determine the connectivity of vulnerable infrastructure systems as a means to prioritize potential projects.
- Visualize potential impacts to infrastructure from coastal development or sea-level rise using tools such as CanVis and the National Oceanic and Atmospheric Administration's Sea Level Rise Viewer, and consider usability of infrastructure at varying flood depths and event return intervals.

Data to support these activities can be accessed through sites such as the Federal Emergency Management Agency (FEMA) Map Service Center for flood hazards, the National Oceanic and Atmospheric Administration's National Weather Service for wind hazards, the U.S. Geological Survey for earthquake hazards, and LANFIRE for wildfire information. State and local agencies often have more robust information at the local level. Groups such as the Silver Jackets (a collaboration of state and federal agencies forming a state-based interagency team) or local universities may be able to provide technical assistance, as well as groups such as the Silver Jackets (a collaboration of state and federal agencies forming a state-based interagency team), and local universities.

KEYPOINT #2: Identify Projects to Reduce Risk.

For those critical infrastructure assets at greatest risk, identify potential mitigation projects and study implementation feasibility. Future funding may depend on the value of the functional benefits, costs, and impacts, and how those characteristics are expressed. Upon identifying susceptible infrastructure, communities

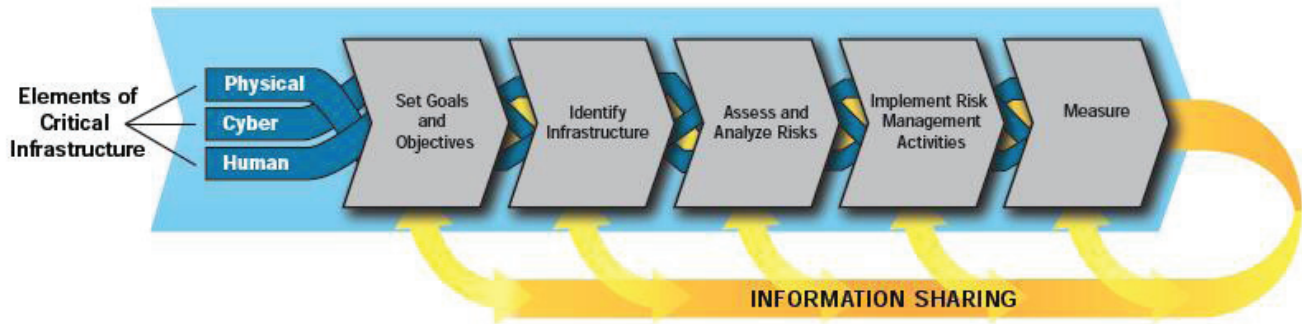
should complete vulnerability assessments to quantify the risk, call out those assets that are at greatest risk, and help prioritize mitigation and resilience improvements.

Comparing the cost of repair and recovery against the cost of creating long-term protection designs for vulnerable infrastructure systems, over a range of threats and outcomes (i.e., scenario planning), is very useful in evaluating the life-cycle costs and benefits of alternative resiliency improvements.

One resource for conducting a vulnerability assessment is the Department of Homeland Security's Integrated Rapid Visual Screening Methodology. Upon identifying vulnerabilities, communities then need to identify alternative measures to reduce the risk to susceptible infrastructure. FEMA's Risk Management Series (RMS) is a series of publications directed at providing design guidance to architects and engineers, building owners/operators/managers, and state and local government officials, toward the goal of mitigating multihazard events. FEMA's Public Assistance Program has mitigation handbooks for public facilities for flood, hurricane, and seismic events.

In addition, FEMA's Building Science Branch develops and produces multihazard mitigation guidance that focuses on creating disaster-resilient communities to reduce loss of life and property. It offers publications, guidance materials, and tools that can improve resiliency of new construction and the repair of existing buildings, including structures associated with infrastructure. Projects involving federal funding must comply with federal environmental laws and regulations; be feasible and cost-effective, and consistent with program eligibility requirements (e.g., FEMA Hazard Mitigation Assistance Unified Guidance).

Figure 1: Critical Infrastructure Risk Management Framework



Vulnerability assessment resources can assist in identifying alternative measures to reduce risk to a community's existing infrastructure. When evaluating alternatives it is important to consider the following:

- **Consequences**—the estimated damages and effects of losing infrastructure services essential to public health and safety, both during and following a disaster.
- **Effectiveness**—the level of protection provided by the proposed alternative, description of how the activity will mitigate future losses, and any level of risk that might remain after implementation of the mitigation.
- **Benefit-Cost Analysis**—assesses the cost-effectiveness of a mitigation measure by comparing avoided future damages to the cost of a project.

FEMA'S BUILDING SCIENCE PROGRAM

Building Science takes a lead role in developing publications, guidance materials, tools, technical bulletins, and recovery advisories that incorporate the most up-to-date building codes, floodproofing requirements, seismic design standards and wind design requirements.

In addition to providing technical support for model building codes and standards, the Building Science Branch provides technical support for the National Flood Insurance Program for public and private sector stakeholders, the National Earthquake Hazards Reduction Program, the National Windstorm Impact Reduction Program.

Source: www.fema.gov/building-science

This analysis should not only include future avoided physical damages, but also quantify the estimated loss of function that occurs during repair and restoration of the damaged public infrastructure. Resilience projects can also include long-term environmental and business continuity benefits. Too often only the cost of the infrastructure repair is considered, and not the losses from workforce displacement, interruption to education, and health impacts.

- **Environmental Planning and Historic Preservation (EHP)**—evaluate any potential effects to environmental and historic resources associated with infrastructure repair versus mitigation/resilience improvements, to demonstrate that prioritized actions will comply with environmental laws and regulations (also to meet grant and subsidy requirements).
- **Resilience Execution**—establish clear procedures to implement the mitigation measures. Some communities utilize local universities to provide technical assistance to evaluate resilience actions, document lessons learned, and monitor best resilience practices.

State and local governments with detailed and proactive hazard mitigation and resilience programs in place before a disaster are the most effective at securing federal funding after a disaster, and implementing needed projects within federal timelines. The projects and procedures must consider the eligibility limitations associated with the source of funding. Some projects may require using multiple sources of funding to complete all aspects. This is especially true where a combination of municipal and private/utility actions result in the greatest gains in resil-

ience, but the projects in the resilience portfolio are not all eligible for the same funding and grants. *Creating an integrated mosaic of funding and grant opportunities, from among the broad array of funding sources, provides a clear pathway to the fastest and most comprehensive recovery program.* It is also often useful to establish contractor and restoration procurement procedures in advance that comply with the federal funding requirements. Creating this mosaic in advance significantly speeds response after a disaster occurs.

It is also worth noting that the U.S. Department of Homeland Security (DHS) has established the Critical Infrastructure Partnership Advisory Council (CIPAC) to facilitate effective coordination between federal infrastructure protection programs with the infrastructure protection activities of the private sector and of state, local, territorial, and tribal governments. The National Infrastructure Protection Plan (NIPP)—NIPP 2013: Partnering for Critical Infrastructure Security and Resilience—outlines how government and private-sector participants in the critical infrastructure community can work together to manage risks and achieve security and resilience outcomes.

This Critical Infrastructure Council program is designed more for protection from intentional human-motivated threats to infrastructure, but the program specifically recognizes the importance of achieving improved resilience against natural threats. The CIPAC provides a forum in which infrastructure system representatives can engage in a broad spectrum of activities to support and coordinate critical infrastructure protection. See www.dhs.gov/critical-infrastructure-partnership-advisory-council.

Further, the DHS National Protection and Programs Directorate (NPPD) Office of Infrastructure Protection (IP) Regional Resilience Assessment Program (RRAP) is a voluntary, nonregulated interagency assessment of critical infrastructure resilience in designated geographic regions. Most regions have had planning initiatives under way. Each year, NPPD/IP, with input and guidance from federal and state partners, selects several RRAPs focusing on specific infrastructure sectors within defined geographic areas to address all-hazard threats that could result in regionally and/or nationally significant consequences.

KEYPOINT #3:
Seek out funding opportunities for mitigation planning and projects.

By developing and evaluating alternative approaches to improving resilience and comparing costs and benefits, communities and utilities can prioritize projects for implementation, as well as compile and prepare needed project information when additional funding is available. FEMA's National Mitigation Framework pro-

vides guidelines for how to develop, employ, and coordinate mitigation capabilities through individuals; businesses; nonprofit organizations; and local, state, tribal, territorial and federal governments.

FEMA's Hazard Mitigation Assistance (HMA) program funds multihazard mitigation plans, which are the basis of a community's long-term strategy to reduce disaster losses and break the cycle of repeated damage due to disasters. *The planning process creates a framework for risk-based decision making.* It also facilitates more cost-effective decision making among stakeholders and the public. A FEMA-approved plan must be in place before obtaining HMA funds for a hazard mitigation project, which is a sustained action taken to reduce or eliminate long-term risk to people and their property from hazards. FEMA evaluates all proposed hazard mitigation projects for cost effectiveness, technical feasibility, and compliance with EHP statutory, regulatory, and executive order requirements prior to funding.

The HMA program includes two annual, congressionally appropriated grants, including the Pre-Disaster Mitigation (PDM) program and the Flood Mitigation Assistance (FMA) program. While the PDM grant can be used to address all types of natural hazards, the FMA grant provides funds for projects to reduce or eliminate risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program.

Following a Presidential Disaster Declaration, there are two primary sources of FEMA funding to improve the disaster resilience of a community's infrastructure, as authorized through Sections 404 and 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act.

- Section 404 authorizes the Hazard Mitigation Grant Program (HMGP), a grant source managed under the HMA program. Similar to PDM, the grant provides funding to help protect against all types of natural hazards, regardless of the hazard that caused the disaster declaration. The states administer the HMGP by establishing mitigation priorities based on FEMA-approved hazard mitigation plans, and selecting and reviewing projects located anywhere in the state (not restricted to the declared disaster area) for submittal to FEMA.
- Section 406 of the Stafford Act authorizes funding of mitigation measures in conjunction with the permanent repair of the disaster-damaged components that are eligible for funding under the Public Assistance (PA) program. Under the PA Program, the subgrantee can request hazard mitigation funding in accordance with FEMA Recovery Policy 9526.1, which is usually available only during the repair efforts, and consistent with approved work. (See Appendix A of that policy for potential mitigation measures that are predetermined to be cost-effective, and which include a wide range of protections for infrastructure (e.g., drainage/crossings and bridges, sanitary and storm sewer systems, wastewater treatment plants, potable water, and electric power distribution). FEMA evaluates the proposed hazard mitigation projects for cost effectiveness, technical feasibility, and compliance with EHP statutory, regulatory, and executive order requirements prior to funding.

Community Development Block Grants (CDBG) provided by the U.S. Department of Housing and Urban Development (HUD) address critical social, economic, and environmental problems, including the threat of natural hazards. CDBGs can be used in conjunction with FEMA funding (even acting as a funding match) to holistically address mitigation in a post-disaster environment. Other federal agencies have post-disaster programs that incorporate mitigation, including betterments to permanent repairs under the Federal Highway Administration Emergency Relief Program and the U.S. Department of Agriculture's Natural Resource Conservation Service Emergency Watershed Protection Program. A community can access FEMA's National Disaster Recovery Framework through the state to help coordinate federal funding opportunities.

The ability for a community to obtain funding and implement mitigation projects in a post-disaster environment is greatly improved if proper planning has been completed and projects are properly identified and vetted before the disaster strikes. Pre-planning should also include the identification of methods for communities to finance mitigation projects internally through sewage disposal or other fees to generate funding for resilience efforts versus solely relying on federal and state grants.

KEYPOINT #4:
Achieving infrastructure resilience is a continuous learning process that requires community engagement.

Reducing infrastructure risk requires that communities focus on refining and adjusting mitigation actions so resiliency actions are increasingly effective and reliable, recognizing that hazards are variable and mitigation technologies are evolving. This is especially true with respect to infrastructure systems, which

almost universally seek to achieve more energy-efficient and environmentally friendly operation. New Low Impact Design options are being created, proposed, and tested almost daily, from self-sufficient, off-the-grid approaches to systems that rely on renewable materials and energy sources.

Communities have many options, alternatives, and strategies for being served by lower-risk infrastructure systems and higher-resiliency systems. The process must inherently start with land-use planning, because land development creates demand for infrastructure systems to service new development and redevelopment. The cost of sprawl has become apparent to community decision makers, especially in terms of energy cost, and as resource availability becomes scarcer in many part of the country (e.g., potable water). The need to consider energy, water, and waste disposal system impacts, and to consider the vulnerability of such systems (and the human populations they serve) to climatic and other natural disasters, should become part of the decision-making process in approving all new land for development. When local

communities understand the connectivity between land use, infrastructure system resource requirements and vulnerabilities, and attendant impacts to natural resources from land development and infrastructure, they are better prepared to create a more resilient and sustainable future. Adopting the latest codes and properly enforcing them is equally important in achieving resilience.

When the emergence of new technologies for infrastructure systems is coupled with new developments in understanding the variability of climate change, and the vulnerabilities that result from past land-use practices, a need emerges to create a continuous learning process. In this continuous learning process, past lessons learned and new information become the basis of improved planning for infrastructure resiliency. Because land-use decision making is dynamic, and because our understanding of natural systems and infrastructure technologies is expanding, the planning process for infrastructure resiliency needs to be an ongoing process—one that is inherently linked to community master planning, zoning, and code development, and the need to update and re-strategize resiliency approaches in those planning guidance documents regularly.

Also, many communities, through their own utility departments, and via interaction with utility agencies serving the community (e.g., water, sewer, transportation, power, etc.) are creating more robust *asset management programs* that inventory, map, assess condition, and determine the vulnerability of infrastructure assets. Asset management systems and asset management strategies are valuable tools in helping to understand and respond to the vulnerability of infrastructure to hazards and risk. The information contained in computer-based asset management systems illuminates the condition, cost of replacement, and service restoration options, and supports informed decision making during disaster events. Such systems are also useful in supporting review of land development proposals, helping to evaluate whether supporting infrastructure systems are sufficiently resilient to future disaster scenarios.

With respect to the role of the community in achieving infrastructure resiliency, and hazard mitigation, FEMA recognizes that a government-centric approach is not sufficient to meet the challenges posed by a catastrophic event. FEMA has published two guidance documents that outline in detail how to connect

hazard mitigation and resilience improvement with local planning. *Integrating Hazard Mitigation Into Local Planning* (2013) and *A Whole Community Approach to Emergency Management* (2011) both reinforce the fact that FEMA is only one part of the nation's emergency management team, and that all of the resources of the community should be leveraged in preparing for, protecting and mitigating against, responding to, and recovering from natural threats to infrastructure and communities. The larger collective resilience improvement team should include not only FEMA and its partners at the federal level, but also local, tribal, state, and territorial partners; nongovernmental organizations (such as faith-based and nonprofit groups and private-sector industry); and individuals, families, and communities. That brings us back to the resilience roundtable recommended to begin the planning process for risk reduction.

Readers should also be aware of the Community Recovery Management Toolkit which is provided by FEMA's Community Planning Capacity Building (CPCB) Program. CPCB offers a compilation of guidance, case studies, tools, and training to assist local communities in managing long-term recovery following a disaster. The materials provided in the toolkit are aimed at helping local officials and community leaders to lead, organize, plan for, and manage the complex issues of post-disaster recovery, including improving infrastructure resilience.

Communities should also look into APA's Community Planning Assistance Team initiative, whereby a multidisciplinary team of expert planning professionals works with community members, key stakeholders, and relevant decision makers to foster community education, engagement, and empowerment. Each team is selected for the specific expertise needed on the project to offer pro bono assistance in developing a framework or vision plan that promotes a sustainable, livable, economically vibrant, and healthy community. Projects focus on localities with a demonstrated need for assistance, where planning resources and expertise may not otherwise be available.

RESOURCES/REFERENCES

State, federal, and other organizations offer a broad array of disaster resilience planning and infrastructure protection programs, guidance, funding support, and expertise. Helpful links and links related to programs and publications mentioned in this briefing paper are below.

State

<http://floodready.vermont.gov>
http://accd.vermont.gov/strong_communities/opportunities/planning/resilience
http://hazardmitigation.calema.ca.gov/plan/local_hazard_mitigation_plan_lhmp
<http://stormrecovery.ny.gov/community-reconstruction-program>
<http://la.stormsmart.org/before/emergency-services/creating-a-post-disaster-recovery-plan>
<http://www.nfrmp.us/state/>

FEMA

<http://emilms.fema.gov/IS0913a/indexMenu.htm>
<http://training.fema.gov/EMIWeb/IS/courseOverview.aspx?CODE=IS-913.a>
<http://www.dhs.gov/critical-infrastructure-sector-partnerships>
http://www.dhs.gov/sites/default/files/publications/CIPAC_2013_annual_report.pdf
http://www.fema.gov/pdf/rebuild/ltrc/fema_apa_ch5.pdf
<http://www.fema.gov/national-disaster-recovery-framework/community-recovery-management-toolkit>
<http://www.fema.gov/hazus/hazus-multi-hazard-overview>
<https://msc.fema.gov/portal>
<https://www.fema.gov/what-mitigation/security-risk-management-series-publications>
<https://www.fema.gov/media-library/assets/documents/16572>
<https://www.fema.gov/media-library/assets/documents/16562>
<https://www.fema.gov/media-library/assets/documents/16491>
<http://www.fema.gov/building-science>
<http://www.fema.gov/media-library/assets/documents/33634>
<https://www.fema.gov/national-mitigation-framework>

<https://www.fema.gov/hazard-mitigation-assistance>
<https://www.fema.gov/multi-hazard-mitigation-planning>
<https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit/hazard-mitigation-funding-under-section-406-0>
<http://www.fema.gov/national-disaster-recovery-framework>
http://www.fema.gov/media-library-data/20130726-1908-25045-0016/integrating_hazmit.pdf
http://www.fema.gov/media-library-data/20130726-1813-25045-0649/whole_community_dec2011__2_.pdf

Other Government Resources

<http://coast.noaa.gov/digitalcoast/tools/canvis?redirect=301ocm>
<http://coast.noaa.gov/digitalcoast/tools/slr>
<http://www.nhc.noaa.gov>
<http://earthquake.usgs.gov/hazards/products>
<http://www.landfire.gov>
<http://www.nfrmp.us/state>
<http://www.dhs.gov/building-and-infrastructure-protection-series-tools-0>
<http://www.dhs.gov/critical-infrastructure-partnership-advisory-council>
<http://www.dhs.gov/regional-resiliency-assessment-program>
<https://www.hudexchange.info/community-development/cdbg-laws-and-regulations>
<http://www.fhwa.dot.gov/programadmin/erelief.cfm>
<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewppp>

American Planning Association

<https://www.planning.org/communityassistance/teams>

This briefing paper was written by Sherry Crouch, Manuel Perotin, and William Cesanek, AICP, of CDM Smith. Contact Crouch at crouchsc@cdmsmith.com; Perotin at perotinma@cdmsmith.com; and Cesanek at CesanekWE@cdmsmith.com.

Cover photo: James Schwab, AICP

Copyright © 2014 by the American Planning Association, 205 N. Michigan Ave., Suite 1200, Chicago, IL 60601-5927. www.planning.org