3. Community Disaster Resilience for the Built Environment

3.1. Community Level Disaster Resilience

Communities come in varying sizes and with varying cultures; and they all face a wide range of opportunities, challenges, and hazards. A community can be defined in many ways, from a single neighborhood to a nation. For purposes of this framework, a community is defined as "people who live, work, learn, and/or play together under the jurisdiction of a governance structure, such as a town, city or county."

Community disaster resilience is best addressed by plans based on the available social services, supported at the neighborhood level, organized around a well-orchestrated community effort, and functional physical infrastructure. As described in Chapter 2, community disaster resilience planning should begin by defining the needs of the community's citizens, which are supported by a community's social institutions, prior to hazard events and during recovery. Those needs provide the basis for establishing performance goals for the built environment. The built environment is an essential part of community disaster resilience. A strong foundation provides the building clusters (buildings of similar function) and infrastructure systems needed by the people, businesses and government to restore the neighborhoods, care for vulnerable populations, and restore the community's economy. Chapter 2 defines how the social institutions are linked to and rely on building clusters and infrastructure systems during the recovery. To understand what is needed from the building clusters and infrastructure systems during recovery, desired performance levels (functionality) and associated restoration times need to be defined for each with the expectation that temporary measures will be provided in the interim. Those definitions, which become the metrics for resilience, are compared to the existing conditions to define gaps that represent opportunities for improvement.

Every community is different and will approach development of a community resilience plan from a different perspective, tolerance for risk, expectation of services to be provided, and planning process. The vitality and usability of the plan depends of its unique adaptation to its community. The plan development and iimplementation will require a broad base of support.

3.1.1. Community Disaster Resilience for the Built Environment

The term "resilience" means the ability to prepare for and adapt to changing conditions, and withstand and recover rapidly from disruptions. As related to the built environment, resilience means the ability of identified buildings and infrastructure systems to return to full occupancy and function, as soon as they are needed, to support a well-planned and expedited recovery. After identifying the social services to be provided and the necessary building clusters and infrastructure systems, the next step is to identify how soon each is required after a hazard event occurs. Timing will depend on both the type and intensity of the event, the age and composition of the community, and available assistance from neighboring communities, regions, and state.

Achieving and maintaining community resilience is an ongoing effort that involves planning and will benefit from mitigation before the hazard event, followed by emergency response, restoration and long-term reconstruction after the event. This framework defines a process for developing a community plan that will inform actions before, during, and after an expected hazard event occurs.

As outlined in Chapter 1, a variety of efforts were initiated in the past 15 years related to community resilience. Beginning in 2007, the San Francisco Planning and Research Association (SPUR) pioneered this style of resilience planning. Their work's, focus was at the community level, specifically considering what San Francisco needed from policies and programs to become a Disaster Resilient City (www.spur.org). SPUR's work produced multiple policy papers and recommendations covering broad issues of disaster resilience. Their policy recommendations focused on what is needed before the disaster, for disaster response, and after the disaster (see Table 3-1).

The Oregon Seismic Safety Policy Advisory Commission led a planning effort in 2012 to 2013 that followed the SPUR concepts and defined actions from Oregon communities needed to survive and rebound from a magnitude 9.0 Cascadia earthquake and tsunami (http://www.oregon.gov/OMD/OEM/osspac/docs). The plan determined the impacts of the earthquake statewide, defined acceptable time frames to restore functions needed to accelerate statewide recovery, and recommended changes in practices and policies, that if implemented over the next 50 years, the plans will allow Oregon to reach desired resilience targets.

Communities benefit from determining the levels of disaster resilience required for their physical infrastructure. This is best done for several levels of each prevalent hazard. Accordingly, each individual building or system will derive its resilience goals and performance levels from those defined by the community for its cluster and function.

Table 3-1: The SPUR Plan for San Francisco (SPUR 2009).

SPUR's Resilient City Initiative	
Before the Disaster	Our Before the Disaster work has focused on key questions related to disaster planning. What do we need to be doing now to make sure that our built environment can recover quickly from a major earthquake? Which existing buildings need to be retrofitted, and to what standard of performance? How do we encourage better performance from new buildings? How do we strengthen our infrastructure so that our buildings are serviceable after an earthquake? SPUR addresses these and other questions in four Before the Disaster papers published in the February 2009 edition of the *Urbanist*.
Disaster Response	Disaster Response focuses on activities during the days and weeks following a catastrophic event, including damage assessment, ensuring the safety of responders, communications and control, evacuation, public health and safety and restoration of vital systems. SPUR has recently completed a paper on the culture of preparedness, which focuses on disaster planning and preparedness in San Francisco's neighborhoods.
After the Disaster	Our After the Disaster task force is asking several key questions: After a catastrophe, are we prepared to rebuild our city to a state even better than it was before? What plans and systems of governance does San Francisco need if it is to be effectively positioned to rebuild? What lessons can be learned from recovery experiences in lower Manhattan, New Orleans, Haiti, Chile, China, and beyond? This task force will be working to complete major papers on long-term recovery, covering the topics of transportation, governance, planning, and housing.

3.1.2. Contributing Factors to Resilience

Just as the prevalent hazards are different across the country, so are the communities with respect to their age, composition, capabilities, and values. The initial process of developing a community disaster resilience plan requires an estimation of how quickly a community needs to recover from each prevalent hazard to maintain its population, workforce, and economic viability given its current built environment and planned development. Hurricane Katrina demonstrated that New Orleans was not resilient for flood events because of the impact of flood damage on housing of the workforce. Other communities may be resilient for all but extreme events, because of their location, inherently resilient government, ability to meet social needs, and redundancy in their built environment. The impact of the 1994 Northridge earthquake on the cities in the San Fernando Valley was a good example of inherent resilience. Decades of good building codes prevented all but a few casualties, yielded a rapidly repairable physical infrastructure, and the availability of housing just outside the damage zone, which allowed the workforce to return quickly.

From among the many metrics that give communities their distinguishing characteristics, the following discussion illustrates how they may inform development of a resilience plan. Our discussion is organized around Social Systems, Political Systems, Economic Systems and the Built and Natural Environment. Each characteristic needs to be considered by community resilience planners as they seek to identify their strengths and adapt ideas from other communities.

Social Systems

- ***Attitudes.*** Communities that have experienced a disaster learn from the experience. If the resulting recovery effort is orderly and successful, they may develop a sense of contentment with their status quo, even if the experience was based on a moderate event. If the resulting recovery was challenging, drawn out and less than successful in the short term, they may move more aggressively toward a resilient state in the reconstruction process. A window of opportunity opens for 1 to 2 years, during which people are interested in resilience activities and making big changes to their planning processes and codes. Communities that have not experienced a damaging hazard event are unlikely to be proactive and develop disaster resilience plans.

- ***Age of the Community.*** Age brings mature and sophisticated social institutions, efficient and informed governance, historically significant landmarks, deep-rooted cultural values, and more. It also brings an aging physical infrastructure that contributes to resilience gaps. With more and larger gaps comes the challenging task of determining priorities for closing the gaps in an orderly manner.
- ***Social Vulnerability and Inequity.*** Not all people use and/or have access to a community's buildings and infrastructure systems in the same ways. These systems typically reflect the people who created them, and may not address the needs of everyone likely to be affected in a hazard event (or on a day-to-day basis) such as the elderly, people living in poverty, racial and ethnic minority groups, people with disabilities, and those suffering from chronic and/or mental illness. Others that may not be adequately represented are renters, students, single-parent families, small business owners, culturally diverse groups, and historic neighborhoods. Moreover, hazard events tend to create settings in which populations on the margins of vulnerability become vulnerable, increasing the number of people in this category.

Built and Natural Environment

- ***Natural Capital.*** Each community has a unique location, topology and green infrastructure that contribute to its culture, vitality, and vulnerability to hazards. For example, a dense tree canopy increases the vulnerability to severe weather; hills and mountains contribute to landslide vulnerability; flat ground or locations near rivers, lakes, or other bodies of water may be susceptible to flooding and liquefaction vulnerability. Community resilience planning must take these features into account in assessments and mitigation plans.
- ***Codes, Standards, Administration, and Enforcement.*** Local building codes and enforcement are key tools for building physical infrastructure that performs as anticipated and for retrofitting at opportune times. To achieve resilience, local codes may need to be more stringent than national model standards. A community's history with adoption, administration, and enforcement of codes will significantly influence the degree of inherent resilience present in the physical infrastructure. There must be a commitment to funding these activities for the resilience plan to be effective.
- ***Architecture and Construction*** – Not all buildings and systems are built alike. Vulnerability to damage depends on the construction materials and their combustibility, structural and non-structural systems, quality of construction, size and shape of the building or systems, codes and practices in place during construction, and the building's current condition. The hundreds of permutations of architecture and construction styles vary by community and impact the communities' resilience. For example, in San Francisco, the multi-family apartment buildings of the 1920s and 1930s are a unique construction style particularly vulnerable to moderate and larger earthquakes. The over 6,000 buildings represent a significant amount of housing that will be uninhabitable after a moderate or large seismic event and will create a demand for interim housing that cannot be provided within the city limits. As a result, one of San Francisco's first resilience programs is a mandatory program to retrofit these buildings to a shelter-in-place level.

Economic Systems

- ***Economic Drivers***. The financial health of a community depends largely on the availability of jobs and a strong set of economic drivers. The vulnerability of the economy to a hazard event depends on the transportability of its industries. Knowledge-based industries can relocate if the workforce or needed physical infrastructure is not quickly restored; research and development industries are more rooted, because of the related laboratory and test facilities; manufacturing is deeply rooted and hard to move; most tourism is permanent and only needs to be restored. The restoration times and priorities built into a community's disaster resilience plan need to recognize the mobility of the key industries that support their economy.

- ***Financial Conditions***. Communities are typically faced with broad-ranging financial demands for expanded governance and new programs aimed at addressing deficient conditions. Each program requires staff support and funds to achieve the desired outcome. Disaster resilience, which is one of many community needs, requires financial support for emergency responders, planners, and building officials, and funds to develop and implement disaster resilience plans. The speed of recovery depends on those plans and the ability to implement them under recovery conditions.
- ***Resources***. Ongoing efforts to encourage development and achieve sustainability through energy efficiency and alternate energy generation have created a variety of new funding mechanisms. Community-backed bonds, locally-crafted loan programs, taxes, and FEMA mitigation grants are being used to finance mitigation projects. Tax incentives can also be enacted as a means to underwrite activities that are needed for community resilience. A lack of immediate funding should not overly influence the content of the disaster resilience plan. The plan should point to the need for new funding solutions.

Political Systems

- ***Priorities for Emerging Public Policies***. Communities face multiple opportunities that bring new public policies and priorities. A transparent and holistic community disaster resilience plan, with informed recovery plans and prioritized mitigation options, offers the opportunity for a community to balance the cost and benefit of becoming more resilient with other competing opportunities and demands.
- ***Governance Structure***. While resilience planning begins at the neighborhood level, the process and structure needed to build up to a community-level resilience plan will depend on the community governance structure. For a community that is an incorporated city, the plan will be self-contained and represent the needs of multiple neighborhoods served by the city departments and agencies. If the community is an unincorporated portion of a county, the plan will benefit from the capabilities of multiple neighborhoods and the interaction, interdependence, and mutual assistance inherent in the other communities that form the unincorporated areas of the county. In both cases, communities will need to look outside their jurisdictions to understand and plan for their dependence on others in their region.
- ***Hazard Mitigation Planning***. The Disaster Mitigation Act of 2000 specifically addresses mitigation planning and requires state and local governments to prepare multi-hazard mitigation plans as a precondition for receiving FEMA mitigation project grants. Many communities have produced such plans and update them every 5 years. This Community Disaster Resilience Framework can significantly inform the Community Capabilities, Risk Assessment, and Mitigation Strategy included in the FEMA Mitigation Plan. An existing Mitigation Plan can provide much of the planning information needed for identifying assets, resources, and stakeholders. Hazard Mitigation Plans are not regulatory, and if these plans are to have a measured impact to promote resilience activities, they should be formally adopted into compliance with the community's land use, zoning, and building code regulations (APA 2010).

3.1.3. Acceptable Risks

Acceptable risk can be defined "as the level of human and/or material injury or loss…. that is considered to be tolerable by a society or authorities in view of the social, political, and economic cost-benefit analysis" (Businessdictionary.com, 2015). Risk is often defined and interpreted differently by engineers, laypeople, community leaders, and other stakeholders, based on their level of understanding and expectations. Risks to the built environment are affected by land use planning, possible hazard events, adoption and enforcement of codes and standards, and maintenance and operation of physical infrastructure. Risk levels currently embodied in the built environment can be inferred from the national model building codes, standards, and guidelines. The consensus process of codes and standards provides the best mechanism for defining minimum levels of acceptable risk for the built environment. The risks in the codes and standards account for hazard levels, performance of various types of construction, and the consequences of damage or failure. Standards and guideline writers bring their personal experiences to the development process. They normalize the experience for application to other vulnerable regions via various metrics and formulations, and develop guidance for designing to an equivalent acceptable level. Codes, standards, and guidelines also provide minimum design criteria for many natural hazards and building and infrastructure performance.

Each community's current land use policies and construction standards are an inherent measure of the risk they have accepted with regard to the built environment. This decision is often influenced by other factors such as costs, politics, and desire for growth. For this reason, construction practices and the degree of compliance with current national standards varies dramatically across the nation. It is common for local jurisdictions to amend the national standard and eliminate provisions they deem unnecessary. The lack of personal experience with a damaging hazard event and the lack of understanding about the level of damage expected when a significant hazard event occurs often lead to misconceptions of a community's vulnerability. Communities should recognize their vulnerabilities based on national experience, not just local events, by adopting and enforcing the current national land use policies (e.g., flood zones) and model codes. The cost of compliance for new construction is minor compared to future savings.

The resilience planning process needs to consider the performance expectations eimbedded in adopted design codes as an indicator for the community's existing physical infrastructure, as outlined in Chapters 5 through 9. Since the performance expectation is focused at the community level, the plan does not insist that all buildings meet the same performance level. Instead, selected building clusters and infrastructure systems with specific functions for community recover should meet the needed performance. A community's decisions for damage levels and required functionality in the built environment defines their level of acceptable risk.

3.1.4. Implementing Community Resilience Planning

A community resilience plan should be developed through a collaborative arrangement between the Chief Executive's office (e.g., Mayor), community departments and key stakeholders, including representatives of the community's social institutions (e.g., community organizations, nongovernmental organizations, business/industry groups, health care, education, etc.), representatives of the physical infrastructure systems, and interested community members. Because of the holistic nature of the plan and the need to be fully supported during implementation, a public-private partnership is the best mechanism to develop the resilience plan. Guidance related to building a planning team is well documented in the FEMA Local Mitigation Planning Handbook. FEMA suggest beginning with existing community organizations or committees and involving all agencies and organizations involved in hazard response and mitigation planning.

The Community Resilience Planning Team will vary in size and breadth depending on the community. The following organizations that include elected officials, Departments, Businesses and Service Professionals and volunteer organizations, are examples those that should be considered for inclusion in the team depending on the size and makeup of the community.

Elected Officials

- ***The Office of the Chief Executive (e.g., Mayor)*** provides leadership, encourages collaboration between departments, and serves as the link to the stakeholders in organizing, compiling, and vetting the plan throughout the community. The office also serves as the point of contact for interactions with neighboring communities within the region and the State. A Chief Resilience Officer or other leader within the office should lead the effort.

- ***City Council or Board of Supervisors*** represents the diversity of community opinion, adopts the needed plans, and enacts legislation for needed mandatory mitigation efforts.

Departments

- The ***Department of Building and Safety*** identifies appropriate codes and standards for adoption; provides plan check and inspection services as needed, to assure proper construction; provides post event inspection services aimed at restoring functionality, as soon as possible. The department should also develop and maintain a GIS-based mapping database of all community physical infrastructure, and social institutions and their relationship to the physical infrastructure.
- The ***Department of Public Works*** is responsible for publicly owned buildings, roads, and infrastructure, and identifies emergency response and recovery routes.
- ***Fire Departments/Districts*** are responsible for codes and enforcement of construction standards related to fire safety and brings expertise related to urban fires, wild fires, and fire following hazard events.
- ***Parks and Recreation*** identifies open spaces available for emergency or interim use for housing and other neighborhood functions**.**
- The ***Public Utilities Commission*** is responsible for overseeing publicly owned utility systems and assists in developing recovery goals.
- The ***Planning Department*** identifies pre-event land use and mitigation opportunities and post-event recovery opportunities that will improve the city's layout and reduce vulnerabilities through repair and reconstruction projects and future development.
- The ***Emergency Management Department*** identifies what is needed from the physical infrastructure to streamline response and recovery of the social structure of the community, including defining a set of standardized hashtags to facilitate community-wide information transfer

Business and Service Professionals

- ***Chambers of Commerce, Community Business Districts, Building Owners, and Managers*** provide the business perspective on resilience planning and recovery in terms of their needs for workforce, buildings, utilities, and other infrastructure systems, as well as how their needs should influence the performance levels selected.
- ***Service and Utility Providers*** hold the keys to rapid recovery of functionality and should work together to understand the community needs and priorities for recovery, as well as the interdependencies they share.
- ***Architects and Engineers*** help determine the design and performance capabilities for the physical infrastructure and assist in the development of suitable standards and guidelines. They can help establish desired performance goals and the actual performance anticipated for the existing built environment.

Volunteer Organizations

- ***Nongovernment Organizations*** (NGO) consist of any non-profit, voluntary citizens' groups that are organized on a local, national or international level and is task-oriented. NGOs perform a variety of service and humanitarian functions, bring citizen concerns to Governments, advocate and monitor policies and encourage political participation through provision of information. Within the Community Service social institution (See Chapter 2), NGOs provide support to other social institutions, especially those that provide services to vulnerable and at-risk populations
- ***National Voluntary Organizations Active in Disaster*** (VOADS) is a nonprofit, nonpartisan, membership-based organization that helps to build resiliency in communities nationwide. It serves as the forum where organizations share knowledge and resources throughout the disaster cycle — preparation, response, recovery and mitigation — to help disaster survivors and their communities.

- ***Community Service Organizations (CSOs)*** are volunteer, membership based groups that provide service to the community's social institutions and will have a role in the post-disaster environment.

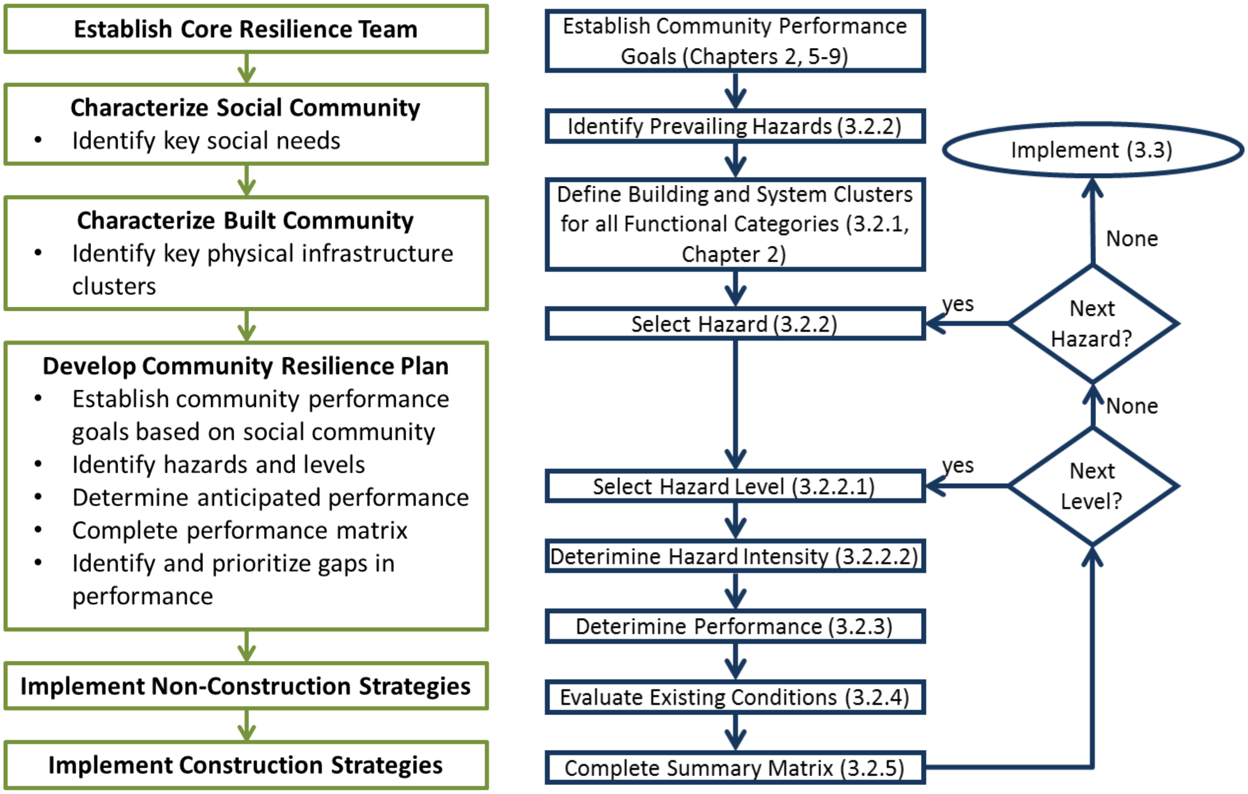
Implementing a resilience plan for the built environment is a long-term effort that requires constant attention, monitoring, and evolution. Because of the cost and the need to transform the governance systems, real estate, and construction cultures, it can easily take up to 50 years or more to fully implement. Once the resilience performance goals for buildings and systems are adopted, all new construction can be built in compliance at very little additional cost. Studies, such as FEMA 313 (1998), show that the increased costs range from 0 to 5 %. Unfortunately, this alone will only have a long-term impact, since the vast majority of buildings and systems will not conform until replaced or retrofitted. Retrofitting existing facilities to achieve new performance goals are generally considered to be cost prohibitive. However, the resilience plan allows resilience gaps related to clusters of buildings or infrastructure systems to be judged in terms of relative importance to the community, mitigated as appropriate, and can provide short-term interim, post recovery strategies.

3.2. Pathway to Community Resilience

Figure 3-1 shows a flow chart of the Community Resilience Planning process. First steps include establishing the core resilience planning team, determining social assets and identifying key social needs for community recovery, and determining physical infrastructure assets and natural resources that support these key social needs. With this community information, the community resilience plan is developed with the following steps: 1) establish community-level performance goals, 2) determine anticipated performance of infrastructure clusters; 3) complete the performance matrix, and 4) identify and prioritize gaps between the desired and anticipated performance for the clusters and each hazard. Once the gaps are prioritized, the community can develop strategies to mitigate damage and improve recovery of functions across the community. This path is compatible with the FEMA Mitigation Plan (FEMA 2013), which many communities are using. However, the plan to community resilience goes a step farther to envision and plan for recovery of functionality across the community.

When a hazard occurs, each building and infrastructure system should protect the occupants from serious injury or death. This goal can be achieved by adopting and enforcing current building codes. In addition to safety, communities need to determine how soon their buildings and infrastructure systems will need to be functional to support community recovery. The desired recovery times will depend on the needs of the social institutions, the size of the area affected during the hazard event, and the anticipated level of disruption in terms of affected area (e.g., local vs. widespread) and loss of functionality. The outcome of planning is summarized in a *Summary Resilience Matrix*, as defined in Section 3.2.5.

Given this set of performance goals organized around hazards, physical infrastructure system clusters, and anticipated levels of disruption, communities can develop and implement a resilience plan and strategies to improve the anticipated performance. Anticipated performance measures include safety, functionality, and recovery times. Comparing the performance of the existing built environment to the performance goals identifies opportunities for mitigation or other plans, such as relocation either before or after a hazard event.



a. Core Activities for Developing a Resilient Community

b. Flow Chart for Developing a Community Resilience Plan

Figure 3-1: Flow Chart for Developing Resilience Plan

3.2.1. Identify Clusters of Buildings and Infrastructure Systems

Clusters of buildings and supporting infrastructure systems that support social needs and emergency response efforts after a hazard event need to be identified. The cluster ensures that all supporting systems are functional so that the buildings and infrastructure systems can operate as intended. Chapters 5 through 9 provide specific guidance on how to define the clusters of facilities and support systems needed for each phase of recovery, short term, intermediate, and long term. Table 3-2 lists the buildings that are likely needed during each recovery phase within a cluster. Refer to Chapter 4 for guidance on considering the interdependencies between physical infrastructure systems.

Table 3-2: Buildings and Facilities in Clusters by Recovery Phase

Recovery Phase	Buildings in Clusters
1. Short Term	**Critical Facilities**
	1. Hospitals and Essential healthcare facilities 2. Police and Fire Stations 3. Emergency Operations Centers 4. Disaster Debris and Recycling Centers
	Emergency Housing
	1. Public Shelters 2. Residential Shelter-in-Place 3. Food Distribution Centers 4. Nursing Homes, Transitional Housing 5. Animal Shelters 6. Faith and Community-Based Organizations 7. Emergency Shelter for Emergency Response and Recovery Workers 8. Gas Stations (location known by community) 9. Banking Facilities (location known by community)
2. Intermediate	**Housing/Neighborhoods/Business**
	1. Essential City Services Facilities 2. Schools 3. Medical Provider Offices 4. Neighborhood Retail Stores 5. Local Businesses 6. Daycare Centers 7. Houses of Worship, Meditation, and Exercise 8. Buildings or Space for Social Services (e.g., Child Services) and Prosecution Activities 9. Temporary Spaces for Worship 10. Temporary Space for Morgue 11. Temporary Spaces for Bath Houses 12. Temporary Spaces for Markets 13. Temporary Spaces for Banks 14. Temporary Spaces for Pharmacies 15. Local Grocery Stores (location known by community)
3. Long Term	**Community Recovery**
	1. Residential Housing 2. Commercial and Industrial Businesses 3. Non-Emergency City Services 4. Resilient Landscape Repair, Redesign, Reconstruction, and Repairs to Domestic Environment

3.2.2. Hazard Events

This framework is based on resilience planning for three levels of a hazard events that are referred to as routine, expected, and extreme. The definition of each level depends on the characterization of the hazard and a community's tolerance for damage or loss of function.

Communities should select the prevailing hazards that may damage physical infrastructure, which may include:

- ***Wind* –** storms, hurricane, tornadoes
- ***Earthquake* –** ground shaking, faulting, landslides, liquefaction
- ***Inundation* –** riverine flooding, coastal flooding, tsunami
- ***Fire* –** urban/building, wildfire, and fire following a hazard event
- ***Snow or Rain* –** freeze or thaw
- ***Human-caused* –** blast, vehicular impact, toxic environmental contamination as a result of industrial or other accidents as well as due to clean-up/disposal methods after a hazard event

3.2.2.1. Hazard Levels for Resilience Planning

For each hazard selected, communities should determine the three levels of hazard intensity or magnitude for use in the framework. Each should be defined in the same terms that are used for design.

- ***Routine –*** Hazard level is below the expected (design) level and occurs more frequently. Buildings and infrastructure systems should remain fully functional and not experience any significant damage that would disrupt the flow of normal living.
- ***Expected –*** Design hazard level, where the design level is based on codes, may be greater than the minimum required by codes, or may be set for the building or infrastructure system based on other criteria. Buildings and systems should remain functional at a level sufficient to support the response and recovery of the community. This level is based on the design level normally used for buildings.
- ***Extreme –*** Hazard level is above the expected (design) level and may be referred to as the maximum considered occurrence based on the historic record and changes anticipated due to climate change. However, this hazard level should not need to be the largest possible hazard level that can be envisioned, but rather one that the community wants to be able to recover from, though it will take longer than for an expected hazard event. Critical facilities and infrastructure systems should remain functional at this level. Other building and infrastructure systems should perform at a level that protects the occupants and allows them to egress without assistance. In addition, emergency response plans should be based on scenarios that represent this hazard level.

As an example, Table 3-3 contains the definitions that SPUR used for the three levels of seismic hazard they recommended for San Francisco resilience planning.

Table 3-3: Sample Hazard definition for earthquakes developed by SPUR for San Francisco

Routine	***Earthquakes that are likely to occur routinely.*** Routine earthquakes are defined as having a 70% probability of occurring in 50 years. In general, earthquakes of this size will have magnitudes equal to 5.0 – 5.5, should not cause any noticeable damage, and should only serve as a reminder of the inevitable. San Francisco's Department of Building Inspection (DBI) uses this earthquake level in their Administrative Bulletin AB 083 for purposes of defining the "service level" performance of tall buildings.
Expected	***An earthquake that can reasonably be expected to occur once during the useful life of a structure or system.*** It is defined as having a 10% probability of occurrence in 50 years. San Francisco's Community Action Plan for Seismic Safety (CAPSS) assumed that a magnitude 7.2 earthquake located on the peninsula segment of the San Andreas Fault would produce this level of shaking in most of the city.
Extreme (Maximum Considered Earthquake)	***The extreme earthquake that can reasonably be expected to occur on a nearby fault.*** It is defined as having a 2% probability of occurrence in 50 years. The CAPSS defined magnitude 7.9 earthquake located on the peninsula segment of the San Andreas Fault would produce this level of shaking in most of the city.

The American Society of Civil Engineers (ASCE) Standard 7-10 *Minimum Design Loads for Buildings and Other Structures* defines minimum hazard levels for design nationwide. Table 3-4 presents suggested design hazard levels for buildings and facilities based on ASCE 7-10. Communities may define the size of a hazard they wish to consider for each level, based on the table or based on other available information. It is important that hazard levels are selected and characterized in a manner that can be used by design professionals in design and retrofit of facilities.

Table 3-4: Design Loads for Buildings and Facilities (ASCE 7-10)

Hazard	Routine	Expected	Extreme
Ground Snow	50 year	300 to 500 year[1]	TBD
Rain	[2]	[2]	[2]
Wind – Extratropical	50 year	700 year	3,000 year[3]
Wind – Hurricane	50 to 100 year	700 year	3,000 year[3]
Wind – Tornado	[3]	[3]	[3]
Earthquake[4]	50 year	500 year	2,500 year
Tsunami	50 year	500 year	2,500 year
Flood	100 year	100 to 500 year	TBD
Fire – Wildfire	[4]	[4]	[4]
Fire –Urban/Manmade	[4]	[4]	[4]
Blast / Terrorism	[5]	[5]	[5]

[1] For the northeast, 1.6 (the LRFD factor on snow load) times the 50-year ground snow load is equivalent to the 300 to 500 year snow load.

[2] Rain is designed by rainfall intensity of inches per hour or mm/h, as specified by the local code.

[3] Tornado and tsunami loads are not addressed in ASCE 7-10. Tornadoes are presently classified by the EF scale. Tsunami loads are based on a proposal for ASCE 7-16.

[4] Hazards to be determined in conjunction with design professionals based on deterministic scenarios.

[5] Hazards to be determined based on deterministic scenarios. Reference UFC 03-020-01 for examples of deterministic scenarios.

3.2.2.2. Hazard Intensity

The impact of hazards depends on more than just size and frequency. The impact also depends on the size of the area affected, the extent of civilization in the affected area, the impact of the damage, and the community's ability to respond. The size of the affected area depends on the particular hazard, as does the geographic distribution of the intensity. A wildfire in the wilderness areas of the California Sierra Nevada Mountains, where there is little population, can burn many square miles of forest with little disruption. On the other hand, the 1992 Oakland Hills firestorm covered only 1520 acres, but killed 11, destroyed nearly 4,000 homes and apartments, and caused $1.5 billion in damage. The affected area was relatively small compared to other wildfires; but the disruption to the affected population and built environment was severe.

For purposes of this framework, the terms *affected area* and *anticipated disruption level* are defined in terms of the Community and the impacts of a hazard event at the present time.

Table 3-5: Affected Area and Anticipated Disruption Level

	Category	Definition
Affected area	Localized	Damage and lost functionality is contained within an isolated area of the community. While the Emergency Operations Center (EOC) may open, it is able to organize needed actions within a few days and allow the community to return to normal operations and manages recovery. Economic impacts are localized
	Community	Significant damage and loss of functionality is contained within the community, such that assistance is available from neighboring areas that were not affected. The EOC opens, directs the response and turns recovery over to usual processes once the City governance structure takes over. Economic impacts extend to the region or state.
	Regional	Significant damage occurs beyond community boundaries. Area needing emergency response and recovery assistance covers multiple communities in a region, each activating their respective EOCs and seeking assistance in response and recovery from outside the region. Economic impacts may extend national and globally.
Anticipated Disruption Level	Minor	All required response and recovery assistance is handled within the normal operating procedures of the affected community agencies, departments, and local businesses with little to no disruption to the normal flow of living. Critical facilities and emergency housing are functional and community infrastructure systems are functional with local minor damage.
	Moderate	Community EOC activates and all response and recovery assistance is orchestrated locally, primarily using local resources. Critical facilities and emergency housing are functional and community infrastructure systems are partially functional.
	Severe	Response and recovery efforts are beyond the authority and capability of local communities that are affected and outside coordination is needed to meet the needs of the multiple jurisdictions affected. Professional services and physical resources are needed from outside of the region. Critical facilities and emergency housing have moderate damage but can be occupied with repairs, community infrastructure systems are not functional for most needs.

3.2.3. Community Performance Goals

Performance goals for buildings, building clusters and infrastructure systems are a combination of performance levels during the hazard event and recovery times. Standard definitions for performance levels that cover safety and functionality assure uniform development of community plans and the codes, guidelines, manuals of practice, and analytical tools that support them. Recovery times are needed to identify the extent of temporary facilities and systems that will be needed, as well as for prioritizing repair and reconstruction that recognizes local, regional, and possibly national and international implications of damage due to a hazard event. For instance, if a production plant in a community is the national supplier for a particular good, the impact of damage to the plant extends well beyond the community.

3.2.3.1. Performance Levels for Buildings

To assure that a community framework is compatible with codes and standards, and other guidance documents for physical infrastructure, common definitions of performance are needed for facilities and infrastructure systems. Setting performance goals for both safety and functionality informs plans for new construction and any needed retrofitting of existing buildings and infrastructure systems. For new construction, such performance goals help improve a community's resilience over time. For existing construction, performance goals help identify clusters of buildings and infrastructure systems that may benefit retrofitting or other measures to provide the needed performance. Table 3-6 provides standard definitions for building performance levels that are used for seismic performance of buildings, but are adopted here for general application to performance for all hazards.

Table 3-6: Performance Definitions for Buildings

Category	Performance Standard
A. Safe and operational	These are facilities that suffer only minor damage and have the ability to function without interruption. Essential facilities such as hospitals and emergency operations centers need to have this level of function.
B. Safe and usable during repair	These are facilities that experience moderate damage to their finishes, contents and support systems. They will receive green tags when inspected and will be safe to occupy after the hazard event. This level of performance is suitable for shelter-in-place residential buildings, neighborhood businesses and services, and other businesses or services deemed important to community recovery.
C. Safe and not usable	These facilities meet the minimum safety goals, but a significant number will remain closed until they are repaired. These facilities will receive yellow tags. This performance may be suitable for some of the facilities that support the community’s economy. Demand for business and market factors will determine when they should be repaired or replaced.
D. Unsafe – partial or complete collapse	These facilities are dangerous because the extent of damage may lead to casualties.

3.2.3.2. Performance Recovery Levels for Building Clusters and Infrastructure Systems

Performance levels for building clusters and infrastructure systems are defined in terms of the time needed to restore the cluster or system to full functionality. Recovery times will vary with the hazard under consideration. Early in the planning process, generalized time frames such as days, weeks, and months are sufficient. Disaster response and recovery traditionally is organized around sequential recovery stages or phases. Recovery phases are defined in a variety of ways by deferent programs, but generally have common goals. The Department of Homeland Security (DHS) National Disaster Response Plan defines them as short, intermediate and long term as shown in Figure 3-2 with a series of activities defined in each. While each begins early in the recovery time frame, the bulk of effort follows sequential stages.

Figure 3-2: National Disaster Recovery Framework (NDEF) Recovery Continuum (NDRF 2014)

The three recovery phases use the terms in the NDRF and are defined in Table 3-7. While discrete time frames are designated, it is recognized and expected that there will be considerable overlap in their imitation and completion, and each recovery phase could conceivably start shortly after the hazard event. The time frames shown are suggestions related to expected hazard events and may not be applicable for all plans.

Table 3-7: Recover Phases

Phase	Name	Time Frame	Condition of the built environment
I	Short Term	0 to 3 days	Initial emergency response and staging for recovery
II	Intermediate	1 to 12 weeks	Housing restored and ongoing social needs met
III	Long Term	4 to 36+ months	Reconstruction in support of economic recovery

For Buildings in Clusters. While individual buildings are assigned performance levels that reflect their role in the community, as noted above, the performance of a cluster with multiple buildings depends on how many of the buildings are restored and functioning. For purposes of planning, it is helpful to set goals for three levels of cluster recovery for the percentage of buildings recovered.

Table 3-8: Building Performance Recovery Levels

Category	Performance Level
30% Restored	Minimum number needed to initiate the activities assigned to the cluster
60% Resorted	Minimum number needed to initiate usual operations
90% Restored	Minimum number needed to declare cluster is operating at normal capacity

For Infrastructure Systems. The recovery of infrastructure systems needs to be measured in terms of its ability to restore service as a percentage of full capacity. While the components of the system are measured and rated in terms of the performance levels defined above, the overall performance of the system needs a system-wide categorization based on restoration of service.

Table 3-9: Infrastructure Performance Recovery Levels

Category	Performance Level
I	Resume 90% service within days and 100% within weeks
II	Resume 90% service within weeks and 100% within months
III	Resume 90% service within months and 100% within years

3.2.4. Anticipated Performance of the Physical Infrastructure Clusters

The majority of buildings and infrastructure systems in service today have been designed to serve their intended functions on a daily basis under the normal environmental conditions. Buildings and other structures are also designed to provide occupant safety during an expected (design) level hazard event, but they may not continue to be functional. The design of buildings and physical infrastructure systems are provided by experienced architects and engineers following their community codes and standards of practice. The codes and standards of practice are continually evolving due to changing technology, changing needs, and to address observed performance issues during hazard events. Current design practices related to predicting performance for the expected or extreme hazard event are uneven, and may be based on expert judgment or past experience of other communities. The technologies needed to estimate the anticipated performance of existing buildings and infrastructure systems are constantly being improved. Technologies related to building evaluation for seismic conditions is maturing and is in its third generation. On the other hand, methods are just emerging for estimating infrastructure system performance and restoration times. Chapters 5 through 9 provide guidance on how to estimate the performance of existing buildings and infrastructure systems.

Architects and engineers generally design or evaluate buildings and infrastructure systems one building or system at a time without considering community-level functions or dependencies on other systems. Under a community resilience plan, each design should be compatible with the goals of the community resilience plan.

While it would be ideal to retrofit or replace all buildings and systems that do not meet the community resilience goals, it is neither necessary nor practical. As a starting point, a community should focus on having a critical mass of buildings and infrastructure systems to support short term recovery

The next step is to evaluate each of its designated clusters of buildings and infrastructure systems and estimate its anticipated recovery time for its current condition for each level of the hazard. This information, when compared to the performance goals previously set, defines the gaps that need to be addressed.

3.2.5. Summary Resilience Matrix

A matrix-based presentation of the many facets of a community resilience plan has been developed for use with this framework. It includes a Detailed Resilience Matrix for buildings and infrastructure systems. Example detailed matrices for the fictional community Centerville, USA are developed and shown in each of the infrastructure system chapters that follow and they include the recovery times for each recovery phase and estimated levels defined in Table 3-7 for each of the three hazard levels. The detailed example matrices for Centerville, USA are summarized in three Resilience Matrices, as shown in Table 3-10 through Table 3-12, to provide an overview of the desired and anticipated recovery goals estimated for the built environment. For purposes of providing a general overview, the summary matrix only shows the 90% restoration time needed for all elements within each phase for each infrastructure system.

Table 3-10: Example Summary Resilience Matrix for a Routine Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Routine Event	Localized
	Disruption Level	Minor

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	Overall Recovery Time for Hazard and Level Listed								
	Routine Hazard Level								
	Phase 1 – Short-Term			Phase 2 -- Intermediate			Phase 3 – Long-Term		
	Days	Days	Days	Wks	Wks	Wks	Mos	Mos	Mos
	0	1	1-3	1-4	4-8	8-12	4	4-24	24+
Critical Facilities									
Buildings	90%	X							
Transportation	90%	X							
Energy	90%	X							
Water	90%		X						
Waste Water		90%	X						
Communication	90%		X						
Emergency Housing									
Buildings	90%		X						
Transportation	90%	X							
Energy	90%	X							
Water	90%		X						
Waste Water		90%	X						
Communication	90%			X					
Housing/Neighborhoods									
Buildings	90%		X						
Transportation		90%	X						
Energy		90%	X						
Water		90%		X					
Waste Water			90%	X					
Communication		90%		X					
Community Recovery									
Buildings		90%	X						
Transportation			90%	X					
Energy		90%	X						
Water			90%	X					
Waste Water			90%	X					
Communication		90%		X					

Footnotes:

1 Specify hazard being considered
Specify level – Routine, Expected, Extreme
Specify the size of the area affected – localized, community, regional
Specify severity of disruption – minor, moderate, severe

2 30% 60% 90% Restoration times relate to number of elements restored within the cluster

3 X Estimated 90% restoration time for current conditions based on design standards and current inventory

Table 3-11: Example Summary Resilience Matrix for an Expected Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Expected Event	Community
	Disruption Level	Moderate

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	Overall Recovery Time for Hazard and Level Listed								
	Expected Hazard Level								
	Phase 1 – Short-Term			Phase 1 – Short-Term			Phase 1 – Short-Term		
	Days	Days	Days	Wks	Wks	Wks	Mos	Mos	Mos
	0	1	1-3	1-4	4-8	8-12	4	4-24	24+
Critical Facilities									
Buildings	90%							X	
Transportation		90%	X						
Energy		90%	X						
Water			90%		X				
Waste Water				90%				X	
Communication		90%		X					
Emergency Housing									
Buildings				90%					X
Transportation			90%	X					
Energy			90%	X					
Water			90%		X				
Waste Water				90%				X	
Communication				90%	X				
Housing/Neighborhoods									
Buildings						90%			X
Transportation			90%	X					
Energy			90%	X					
Water				90%				X	
Waste Water					90%			X	
Communication				90%			X		
Community Recovery									
Buildings								90%	X
Transportation				90%	X				
Energy			90%	X					
Water				90%				X	
Waste Water							90%	X	
Communication				90%			X		

Footnotes: See Table 3-10, page 16

Table 3-12: Example Summary Resilience Matrix for an Extreme Event in Centerville, USA

Disturbance		
(1)	Hazard	Any
	Affected Area for Extreme Event	Regional
	Disruption Level	Severe

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	Overall Recovery Time for Hazard and Level Listed								
	Extreme Hazard Level								
	Phase 1 – Short-Term			Phase 1 – Short-Term			Phase 1 – Short-Term		
	Days	Days	Days	Wks	Wks	Wks	Mos	Mos	Mos
	0	1	1-3	1-4	4-8	8-12	4	4-36	36+
Critical Facilities									
Buildings						90%			X
Transportation			90%		X				
Energy				90%					
Water							90%	X	
Waste Water					90%			X	
Communication	90%			X					
Emergency Housing									
Buildings						90%			X
Transportation				90%		X			
Energy				90%					
Water					90%		X		
Waste Water					90%			X	
Communication				90%			X		
Housing/Neighborhoods									
Buildings							90%		X
Transportation				90%		X			
Energy				90%	X				
Water					90%			X	
Waste Water						90%		X	
Communication					90%		X		
Community Recovery									
Buildings								90%	X
Transportation				90%		X			
Energy				90%	X				
Water							90%		X
Waste Water								90%	X
Communication					90%			X	

Footnotes: See Table 3-10, page 16

3.3. Mitigation and Recovery Strategies

Community disaster resilience planning provides a comprehensive picture of the gaps between desired and anticipated performance of the physical infrastructure to support recovery for the hazards and hazard levels considered. This information provides communities with the opportunity to develop short term plans for covering the most urgent gaps with emergency/interim facilities and supporting infrastructure systems as well as a comprehensive community-level basis for long term strategies that will eventually close the gaps.

Mitigation to derive long term solutions before the event costs money, but reduces demands during recovery and can speed up the overall recovery process. Streamlining recovery processes can also reduce the need for mitigation.

Mitigating the gaps can be addressed in a number of ways, from altering the expectations to relying on more external assistance, to adding redundancies, to retrofit and/or reconstruction programs that add robustness. For some hazards, such as flooding, the threat can be redirected.

Mitigation also provides the opportunity to build-back better. When a hazard event occurs, there is significant pressure to quickly restore the built environment to its pre-event condition. With advanced planning, reconstruction can be done to a "new normal" that includes addressing the needs of the social institutions and also improving sustainability, and resilience.

Cost is always an issue with regard to funding mitigation activities. While the initial planning is comprehensive and requires the interaction of a large number of people, it is the first and most cost effect step in the process, carrying out the needed retrofits before the hazard event occurs has significant long term benefits. A study of grants awarded by FEMA indicates "a dollar spent on disaster mitigation saves society an average of $4." (MMC 2005) It is noteworthy that this study is being revisited as the benefit for investment is presumed to have increased dramatically since the study was last completed.

Unfortunately, most communities wait until after a hazard event occurs before they become serious about mitigation planning. This is not the most appropriate time to implement criteria to achieve a more resilient community. At this point the stressors on the community are overwhelming. Communities need to implement criteria for enhanced resiliency prior to any hazard event to achieve effective change and to achieve an acceptable level of community continuity should a hazard event occur. Fortunately, the FEMA requirements for mitigation planning are an incentive to initiate the process and this NIST Disaster Resilience Framework yield actionable information that can be implemented in the long term.

Once the plan is in place, a number of non-construction activities can be done at low cost for significant long-term benefit. There is also a series of construction related activities that can significantly improve community resilience in the long term.

3.3.1. Non-Construction Strategies

Implementing a community's disaster resilience plan related to the physical infrastructure should begin with evaluating and validating the following activities or initiating them as needed. Each is a low-cost activity that is best done as an extensions to existing programs.

1. Organize and maintain a resilience office lead by a Chief Resilience Officer that collaborates with and learns from the Rockefeller 100 Resilience Cities program. Orchestrate community engagement through this office and solicit buy-in.
2. Incorporate the resilience plan in the Community Safety Element of the General Plan.
3. Incorporate the resilience plan in the communities FEMA Mitigation Plan
4. Adopting the latest national model building codes and standards for the physical infrastructure.
5. Insist on the development of codes and standards that are compatible with resilience planning and set transparent performance goals.

6. Adopt appropriate land use planning regulations that manage the green infrastructure, limit urban sprawl, and set design standards for construction in high hazard zones such as flood plains, coastal areas, areas susceptible to liquefaction, etc.
7. Assure the effectiveness of the building department in enforcing current codes and standards during permitting and construction inspection to assure that the latest processes are being followed.
8. Develop processes and guidelines to be deployed for post-event assessments and repairs.
9. Collaborate with adjacent communities to promote common understanding and opportunities for mutual aid during response and recovery.
10. Elevate the level of inter-system communication between the infrastructure community's providers and incorporating the interdependencies in their response and recovery plans.
11. Lobby for State and Federal owned and leased properties to be built and upgraded to resilient standards.
12. Develop and implement education and awareness programs for all stakeholders in the community to enhance understanding, preparedness, and opportunities for mitigation.

3.3.2. Construction-Related Strategies

1. Using the tools provided in Chapter 10, prioritize gaps identified between the desired and anticipated performance of infrastructure clusters, as summarized in the Resilience Matrix for the prevailing hazards.
2. Identify and implement opportunities for natural systems protection including sediment and erosion control, stream corridor restoration, forest management, conservation easements, and wetland restoration and preservation.
3. For each built environment gap, identify the guidelines and standards used to assess deficiencies in individual public and private buildings and infrastructure systems. Define the gap in a transparent and publicly available method and announce the result. This will trigger voluntary actions on the part of building owners and infrastructure system operators.
4. Include retrofitting of public buildings to achieve the resilience goals in the capital planning process and make it a part of the prioritization process.
5. Develop incentives to encourage new construction be built to the resilient standards and for deficient existing construction to be retrofitted as needed.
6. Support national efforts to improve code-based design standards that match the resilience metrics defined in this framework.
7. Identify building and infrastructure system clusters that need to be retrofitted under mandatory programs and implement the retrofitting through local ordinances. Develop and announce viable funding opportunities and include some level of public funding.

3.4. REFERENCES

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