10. Community Resilience Metrics

10.1. Background

Community resilience metrics or indicators come in a wide variety of types. They can be descriptive or quantitative; they can be based on interviews, expert opinion, engineering analysis, or pre-existing datasets. They can also be presented as an overall score or as a set of separately reported scores across a broad spectrum of physical, economic, and social dimensions. Regardless of the methodologies used to develop and summarize the results, effective community resilience metrics must address two questions (National Academies 2012a):

1. *How can community leaders know how resilient their community is?*
2. *And how can they know if their decisions and investments to improve resilience are making a significant difference?*[1]

In 2012, the National Academies Committee on Increasing National Resilience to Hazards and Disasters and the Committee on Science, Engineering, and Public Policy evaluated 17 approaches to measuring various aspects of resilience. The authors concluded that none of the 17 existing methodologies satisfactorily addressed the two basic questions posed above. As a result, one of the six main recommendations coming out of the report was the development of a "national resilience scorecard, from which communities can then develop their own, tailored scorecards" (National Academies 2012b). Similar recommendations can be found in other recent reviews of disaster risk reduction and disaster resilience (Government Office for Science 2012; UNISDR 2012). The need for a tailorable or locally relevant scorecard recognizes that a single prescriptive scorecard is unlikely to be appropriate for communities of all sizes and types (e.g., from small tourism- or agriculture-centric communities to large financial- or industrial-centric cities) and for all planning scenarios (e.g., from preliminary scoping studies to comprehensive planning with ongoing follow-up assessments).

10.2. Desirable Characteristics for Community Resilience Metrics

From the community perspective, effective community resilience metrics should be accurate, reliable, comprehensive, scalable, affordable, and actionable indicators of the community's capacity to respond to and recover from a specified disaster scenario. Cutter (2014) suggests that communities seek a resilience measurement tool that meets the following criteria:

- Open and transparent
- Aligns with the community's goals and vision
- Measurements…
    - are simple, well documented
    - can be replicated
    - address multiple hazards
    - represent community's areal extent, physical (manmade and environmental) characteristics, and composition/diversity of community members
    - are adaptable and scalable to different community sizes, compositions, changing circumstances

For purposes of this framework, we are specifically interested in community resilience metrics or tools that will reliably predict the physical, economic, and social implications (either positive or negative) of community decisions (either active or passive) made with respect to planning, siting, design, construction, operation, protection, maintenance, repair, and restoration of the built environment.

[1] As stated in (National Academies 2012b), "measuring resilience is challenging but essential if communities want to track their progress toward resilience and prioritize their actions accordingly."

10.3. Types of Metrics

As defined in PPD-21 (White House 2013) and emphasized throughout this framework, the concept of disaster resilience extends well beyond the magnitude of direct physical damage sustained by the various components of the built environment under a specified disaster scenario. The centrality of community impacts and community recovery to the concept of community resilience demands that community resilience be evaluated and measured in much broader terms than, for example, critical infrastructure vulnerability.

Looking beyond direct physical damage and direct repair costs for the built environment, at least three broad categories of metrics should be considered by communities: (1) recovery times, (2) economic vitality metrics, and (3) social well-being metrics. A community can use these end result metrics to measure improvements through proactive planning and implementation. Resilience planning and implementation of plans will produce a faster and more robust recovery that avoids or minimizes the expected negative economic and social impacts of hazard scenarios. However, predicting how these end result metrics will be impacted by specific community planning and implementation decisions is a challenging and ongoing area of research.

Many indicators of community resilience may have a direct and quantifiable cause-and-effect influence on resilience; whereas others may either have some postulated influence on resilience or simply be correlated with resilience. Examples of indicators that may influence or correlate with recovery times, economic vitality, and social well-being are provided below.

10.3.1. Recovery Times

Recovery times for the built environment are easy to grasp as resilience goals, but difficult to predict with precision or confidence. Predicting recovery times under different planning scenarios should consider:

- Designated performance level or restoration level for each building cluster and infrastructure system
- Original criteria used in the design of the various components of the built environment and their condition immediately prior to the specified disaster scenario
- Loading conditions applied to the built environment during and after the specified hazard scenario
- Spatial and logical distribution of physical damage to the built environment
- Availability of resources and leadership to strengthen (pre-event) or repair (post-event) the built environment
- Critical interdependencies among the built environment and social structures within a community (See Chapter 2)

Recovery times have a direct bearing on many economic and social functions in a community. As such, explicit estimates (or at least a general sense) of system recovery times become a prerequisite for most, if not all, other measures of community resilience. Due to the large volume of data required and the inherent complexity of “system-of-systems” modeling, recovery times are likely to be estimated based on some combination of simplified modeling, past experience, and/or expert opinion.

Examples of community-level recovery time goals by building cluster and infrastructure system are provided in Table 3-10 through Table 3-12 in Chapter 3. These community-level recovery times are built-up from the buildings and sector-level recovery time examples discussed in Chapters 5 through 9. Each community should define its own set of building clusters, infrastructure systems, and designated performance levels that reflect its makeup and priorities.

10.3.2. Economic Vitality

Economic health and development are major concerns for communities. Economic development concerns include attracting and retaining businesses and jobs, building the tax base, addressing poverty and inequality, enhancing local amenities, and economic sustainability. These factors are discussed below. Further background on economic modeling approaches and issues appears later in Section 10.5.

10.3.2.1. Attracting and Retaining Businesses and Jobs

Attracting and retaining businesses and jobs is a major concern of most communities. A community that cannot attract and retain businesses and jobs is in decline. Communities also prefer businesses that produce high-paying jobs. Metrics for this would include the employment rate, per capita income or, per capital Gross Domestic or Regional Product, and education attainment rate.

Metrics indicative of a community's ability to continue attracting and retaining businesses and jobs through and after a hazard event would include the resiliency of infrastructure systems.

10.3.2.2. Tax Base

For most cities, local revenue sources consist of property tax and/or sales tax. Sales tax revenue is increased by attracting commercial businesses and jobs, and property tax revenue is increased by increasing property values.

Tax base indicators include real-estate prices, rents, and amount of tourism (for hotel tax revenues). Metrics indicative of how a community's tax base would be affected by a hazard event include the extent of property insurance coverage across the community, percent of property in areas susceptible to hazards (like flood plains), adopted building codes, and the number of buildings that fail to meet current codes.

10.3.2.3. Poverty and Income Distribution

Poverty and income distribution are a major concern of local communities. Many projects communities pursue aim to decrease poverty in their neighborhoods, and a significant amount of external funding available to communities aim to alleviate poverty. This concern intersects with community resilience because the disadvantaged are often the most vulnerable to disasters. Metrics of poverty and income distribution include the poverty rate and the Gini coefficient, a measure of income dispersion.[2]

Metrics that indicate or influence how a hazard event might affect poverty and income distribution include the poverty rate itself because poor people tend to fare worse in disasters.

10.3.2.4. Local Services and Amenities

Local services and amenities include the infrastructure systems discussed in Chapters 6-9, but also include a variety of other characteristics and services associated with communities, such as public transportation, parks, museums, restaurants, theaters, etc. Local services and amenities improve the quality of life for local residents. In addition, there is an expectation that improving local amenities will indirectly help attract and retain businesses and jobs. Amenities are provided by multiple sources. Some are provided by local governments, some are privately provided, and some are environmental. Metrics for infrastructure systems are discussed in Chapters 6-9 and in Section 10.3.5 of this chapter. Metrics for amenities will depend on the community.

10.3.2.5. Sustainability

Local communities are interested in ensuring that their community is sustainable. Sustainability includes two distinct ideas: 1) protecting and improving the environment (i.e., being "green" and maintaining a small footprint); and 2) producing a vibrant and thriving economy. It is desirable that a community remain sustainable, even amid disasters. Metrics of economic sustainability include population growth rates and growth rates of Gross Domestic or Regional Product.

[2] http://data.worldbank.org/indicator/SI.POV.GINI

Factors that might affect a community's sustainability in the presence of hazard events include the degree to which the local economy depends on a single industry. Metrics could include percent of jobs in the service industry or percent of jobs in agriculture and mining.

10.3.2.6. Other Economic Indicators

There are a number of economic indicators that are associated with or affect non-economic aspects of community resilience. For example, debt ratios generally impact a community's ability to deal with disasters. Poverty impacts the probability that people will rebound from a disaster, as do ownership of a car or phone. Similarly, job continuity and economic sustainability will strongly influence the continuity of social networks.

10.3.3. Social Well-being

Reflecting the hierarchy of human needs presented in Section 2.3, social metrics should address:

- ***Survival –*** preservation of life and availability of water, food, clothing and shelter
- ***Safety and security –*** personal safety, financial (economic) security, and health/well-being
- ***Sense of belonging –*** belonging and acceptance among family, friends, neighborhoods, and organizations
- ***Growth and achievement –*** opportunities for recognition and fulfillment

The resilience of a community following a hazard event depends on how well these needs are met. Examples of indicators or metrics for each of these needs are provided below. An example of a resilience plan that includes several of these indicators is the Canterbury Wellbeing Index (CERA 2014).

10.3.3.1. Survival

Survival depends on the ability of a community's residents, employees and visitors to possess physical requirements, including water, food, shelter, and clothing. Access to these requirements depends on the functionality of the supporting physical infrastructure, availability of distribution systems, and personnel. These tasks may be performed by the governmental organizations, non-governmental aid organizations, or the private sector. Metrics for survivability could include housing availability and affordability, poverty rates, homeless rates, etc.

Metrics affecting a community member's chance of survival during or after a hazard event include:

- Building code adoption and enforcement history
- Existence and effectiveness of warning systems
- Existence of comprehensive emergency management plans (mutual aid pacts, emergency response resources (e.g., urban search and rescue teams), public shelters)
- Number of community service organizations that assist in distributing water, food, or clothing or providing shelter in the wake of a disaster
- Level of household disaster preparation
- Percentage of homes that are owner occupied (i.e., renters may be more vulnerable in disasters)
- Percentage of insured homes and businesses
- Availability of short- and medium-term accommodation
- Distance to family/friends unaffected by the disaster

10.3.3.2. Safety and Security

Safety and security includes all aspects of personal and financial (economic) security, and health and well-being. People require safety and security in their personal lives from situations of violence, physical or verbal abuse, war, etc., as well as knowing that the safety of their family and friend networks are secure. Individuals also require financial safety, which can include job security, a consistent income, savings accounts, insurance policies, and other safety nets. Finally, people require safety from negative health conditions, so that they can enjoy life and consistent well-being.

Examples of metrics for personal safety evaluated before and after a hazard event could include community statistics on assaults, property offenses, re-offending rates, and reports on child abuse or neglect.

Examples of metrics for financial (economic) security include employment rates (also covered in Section 10.3.2.1 under economic metrics). Additionally, metrics that would be indicative of how a community member's employment would be affected by a hazard event include occupation type (e.g., some occupations, more than others, can be severely affected by a hazard event)[3], education levels, percentage of residents that commute other communities for work, and gender (i.e., women may have a more difficult time than men due to employment type, lower wages, and/or family care responsibilities).

Examples of metrics for health and well-being of community members include acute medical admissions, immunization rates, cancer admissions, substance abuse rates, and blood donor rates. Additionally, metrics that would be indicative of how a community member's health/well-being would be affected by a hazard event include percentage of the population with health insurance, access to health services (e.g., health system demand and capacity indicators: emergency room, in-patient beds, out-patient clinics, community health centers, mental health services, etc.), and community demographics (e.g., age distribution, number of individuals with disabilities or access and functional needs, etc.).

10.3.3.3. Sense of Belonging

Social metrics can also address the belonging need, which can represent belonging and acceptance among various groups of people (e.g., family, friends, school groups, sports teams, work colleagues, religious congregation) or belonging to a place or location. Examples of metrics or indicators related to sense of belonging include:

Civic participation[4]:

- Voter registration or voter participation rates
- Involvement in local action groups
- Perception of being well-informed of local affairs

Social networks:

- Frequency of contact with friends, family, neighbors, etc.
- Number of close friends/family (geographically)

Social participation:

- Membership in (and frequency of involvement in) community-wide social, cultural, and leisure clubs/groups including sports clubs
- Membership in (and frequency of involvement in) religious organizations and other belief systems
- Volunteering

Trust

- Confidence in leadership (at various levels)
- Trust in others (similar or dissimilar to member)

[3]Reference to University of South Carolina – Social Vulnerability Index
[4]Foxton, F. and R. Jones. 2011. *Social Capital Indicators Review*. Office for National Statistics http://www.ons.gov.uk/ons/dcp171766_233738.pdf

10.3.3.4. Growth and Achievement

Humans need to feel a sense of achievement and respect in society, accompanied by the need for continual growth and exploration. Examples of metrics or indicators related to growth and achievement include:

- Education
    - System capacity (sufficient numbers of teachers, classrooms, books, etc.)
    - Graduation rates
    - Memberships to public libraries
    - Education levels
- Participation rates in arts and recreation

10.3.4. Hybrids

Some metrics combine several indicators into an overall score. Often, additional types of metrics, beyond the three broad categories discussed above, are included. These other types of metrics, such as system-specific or ecological/environmental metrics, are discussed below in Section 10.3.5.

Due to the sparsity of data, the unique aspects of each hazard event, and the lack of generally applicable community resilience models, the scaling and weighting schemes used to aggregate disparate metrics into an overall score of community resilience are largely based on reasoning and judgment. A related technique is to attempt to monetize all of the dimensions (e.g., the statistical value of lost lives, lost jobs, lost business revenue, increased healthcare costs, etc.), but this approach cannot adequately address the social dimensions of community resilience.

10.3.5. Other Metrics

Examples of system-specific metrics include indicators such as:

- Temporary shelter demand in the housing sector
- Water pressure level or water quality level in water supply systems
- Vehicles per hour or shipping tonnage capacities in transportation systems
- Percentage of dropped calls or undelivered messages in communications systems
- Percentage of customers without service in electrical power systems

In the context of this framework, these system-level indicators can be thought of as performance levels to gauge recovery time for the built environment.

Ecological or environmental metrics include indicators such as debris and hazardous waste volumes (by which landfill and waste management requirements can be assessed), indicators of water and soil quality (e.g., salinity), and many more. While very important due their impact to public health, wildlife management, etc., these metrics address impacts and planning issues that are, for the most part, outside the scope of this framework.

10.4. Examples of Existing Community Resilience Assessment Methodologies

As discussed in Section 10.1, a variety of community-wide resilience assessment methodologies was presented in the research literature. In this section, we present brief overviews of nine existing methodologies and evaluate their applicability as tools for assessing both current resilience and plans for improved resilience within the context of planning decisions regarding the built environment. Not all of these methodologies were developed to address community resilience, but they are considered as relevant and potentially applicable in whole or part. This list is not meant to be complete and is expected to evolve along with this framework, as additional research and pilot studies are completed.

10.4.1. SPUR Methodology

The SPUR methodology provides "a framework for improving San Francisco's resilience through seismic mitigation policies." The stated goals of the SPUR report (2009) are:

1. *Define the concept of "resilience" in the context of disaster planning,*
2. *Establish performance goals for the "expected" earthquake that supports our definition of resilience,*
3. *Define transparent performance measures that help us reach our performance goals; and*
4. *Suggest next steps for San Francisco's new buildings, existing buildings and lifelines.*

The SPUR methodology focuses on establishing performance goals for several clusters of buildings (i.e., groups of buildings that provide a community service, such as critical response facilities, emergency housing, or neighborhood services) and establishing target recovery times for a specified earthquake scenario in the San Francisco area. While economic and social metrics are not direct outputs of the SPUR methodology, the building clusters selected and recovery time goals provided are clearly intended to improve both the economic and social resilience of San Francisco. Similarly, although SPUR focuses on earthquakes as the primary hazard, the underlying methodology is applicable to other perils.

10.4.2. Oregon Resilience Plan

In 2011, the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) was directed by House Resolution 3 "to lead and coordinate preparation of an Oregon Resilience Plan that reviews policy options, summarizes relevant reports and studies by state agencies, and makes recommendations on policy direction to protect lives and keep commerce flowing during and after a Cascadia earthquake and tsunami." The OSSPAC assembled eight task groups (earthquake and tsunami scenario, business and work force continuity, coastal communities, critical buildings, transportation, energy, information and communications, water and wastewater) and assigned the following tasks to each group:

1. *Determine the* ***likely impacts*** *of a magnitude 9.0 Cascadia earthquake and tsunami on its assigned sector, and estimate the time required to restore functions in that sector if the earthquake were to strike under present conditions;*
2. *Define* ***acceptable timeframes*** *to restore functions after a future Cascadia earthquake to fulfill expected resilient performance; and*
3. *Recommend* ***changes in practice and policies*** *that, if implemented during the next 50 years, will allow Oregon to reach the desired resilience targets.*

The Oregon Resilience Plan (2013) builds on the SPUR methodology and the Resilient Washington State initiative to produce a statewide projection of the impacts of a single earthquake and tsunami scenario. Immediate impacts include lives lost, buildings destroyed or damaged, and households displaced. Moreover, a particular statewide vulnerability identified in the study is Oregon's liquid fuel supply and the resulting cascade of impacts induced by a long-term disruption of the liquid fuel supply. The study includes recommended actions to reduce the impacts of the selected hazard scenario and shorten the state's recovery time.

10.4.3. UNISDR Disaster Resilience Scorecard for Cities

The United Nations International Strategy for Disaster Risk Reduction (UNISDR) Disaster Resilience Scorecard for Cities "provides a set of assessments that will allow cities to understand how resilient they are to natural disasters." The Scorecard is "intended to enable cities to establish a baseline measurement of their current level of disaster resilience, to identify priorities for investment and action, and to track their progress in improving their disaster resilience over time." There are 85 disaster resilience evaluation criteria grouped into the following areas:

- ***Research***, including evidence-based compilation and communication of threats and needed responses

- ***Organization***, including policy, planning, coordination and financing
- ***Infrastructure***, including critical and social infrastructure and systems and appropriate development
- ***Response capability***, including information provision and enhancing capacity
- ***Environment***, including maintaining and enhancing ecosystem services
- ***Recovery***, including triage, support services and scenario planning.

Each evaluation criterion is broken down into the aspect of disaster resilience being measured, an indicative measurement, and the measurement scale (from 0 to 5, where 5 is best practice).

The formal checklist is organized around "10 Essentials for Making Cities Resilient," which were developed to align with the five priorities of the Hyogo Framework (UNISDR 2005). The overall score is the percentage of possible points from each of the 85 measures. It is suggested that cities plan on 2 to 3 people working for a minimum of 1 week to complete an assessment, ranging up to 2 months for a more detailed and comprehensive assessment.

10.4.4. CARRI Community Resilience System

The Community and Regional Resilience Institute's Community Resilience System (CARRI CRS 2013) "is an action-oriented, web-enabled process that helps communities to assess, measure, and improve their resilience to … threats and disruptions of all kinds, and ultimately be rewarded for their efforts. The CRS brings together people, process and technology to improve resilience in individual communities. The system includes not only a knowledge base to help inform communities on their resilience path but also a process guide that provides a systematic approach to moving from interest and analysis to visioning and action planning. It also provides a collaborative mechanism for other interested stakeholders to support community efforts."

The CRS is a DHS/FEMA funded initiative. It began in 2010, convening three working groups: researchers (the Subject Matter Group), community leaders (the Community Leaders Group), and government/private sector representatives (the Resilience Benefits Group). The findings of these working groups culminated in the development of the CRS web-based tool along with pilot implementations in eight communities commencing in the summer of 2011.

The CRS addresses 18 distinct Community Service Areas (CSAs) and is designed specifically for use by community leaders. The web process is a checklist driven approach, with questions tailored for each of the CSAs. The answer to a question may trigger additional questions. For many of the questions, comment fields are provided so that communities may answer the questions as specifically as possible. The CARRI team notes that a facilitated approach (i.e., an outside group coming in, such as CARRI), is most effective. "The CRS process works more productively as a "partially facilitated" model where some supportive expertise assists communities in applying aspects of resilience to and embedding them within their community circumstances and processes."

10.4.5. Communities Advancing Resilience Toolkit (CART)

The Communities Advancing Resilience Toolkit (CART 2012) was developed by the Terrorism and Disaster Center at the University of Oklahoma Health Sciences Center. It was funded by the Substance Abuse and Mental Health Services Administration, U.S. Department of Health and Human Services, and the National Consortium for the Study of Terrorism and Responses to Terrorism, U.S. Department of Homeland Security, and by the Centers for Disease Control and Prevention.

CART is designed to enhance community resilience through planning and action. It engages community organizations in collecting and using assessment data to develop and implement strategies for building community resilience for disaster prevention, preparedness, response, and recovery. The CART process uses a combination of qualitative and quantitative approaches, and it involves the following steps:

1. Generating a community profile (CART Team and Partners)

2. Refine the community profile (Community Work Groups)
3. Develop a strategic plan (Community Planning Groups)
4. Implement the plan (Community Leaders and Groups)

The CART approach is not hazard specific, and it is applicable across communities of varying size and type. It is innovative, providing a complete set of tools and guidelines for communities to assess their resilience across a number of domains. The toolkit includes the CART assessment survey, key informant interviews, data collection framework, community conversations, neighborhood infrastructure maps, community ecological maps, stakeholder analysis, SWOT analysis, and capacity and vulnerability assessment. The focus of the approach is to provide a process that engages communities in thinking about resilience and provide a foundation to move forward into sophisticated activities.

10.4.6. Baseline Resilience Indicators for Communities (BRIC)

The Baseline Resilience Indicators for Communities (BRIC, Cutter et al. 2014) process builds on prior work by Cutter et al., and is based on empirical research with solid conceptual and theoretical underpinnings. BRIC measures overall pre-existing community resilience. The approach provides an empirically based resilience metric for use in a policy context. Using data from 30 public and freely available sources, BRIC comprises 49 indicators associated with six domains:

- Social (10 indicators)
- Economic (8 indicators)
- Housing and infrastructure (9 indicators)
- Institutional (10 indicators)
- Community Capital (7 indicators)
- Environmental (5 indicators)

BRIC is not hazard specific, and it has been implemented at the county level. The 49 indicators were selected through conceptual, theoretical, and/or empirical justification as capturing qualities associated with community resilience. Indicators in the aforementioned domains determine areas that policy makers should invest for intervention strategies to improve resilience scores.

10.4.7. Rockefeller Foundation City Resilience Framework

The City Resilience Framework (CRF 2014) is a framework “for articulating city resilience” developed by Arup with support from the Rockefeller Foundation 100 Resilient Cities initiative. One merit of this framework is that it is based on a very extensive literature review involving cities with different characteristics and a substantial amount fieldwork to collect data and develop case studies. The framework organizes 12 so-called “key indicators” into 4 categories:

- Leadership and strategy
- Health and wellbeing
- Infrastructure and environment
- Economy and social

This organization integrates social and physical aspects, and it considers human-driven processes as inherent components of the system-of-systems, making the community fabric of a city. Economic/financial constraints are also considered in an integral way, providing a realistic setting for its application for planning purposes. In turn, the 12 key indicators span 7 qualities of what is considered a resilient city: being reflective, resourceful, robust, inclusive, redundant, integrated, and/or flexible.

The CRF will serve as the basis for developing a City Resilience Index in 2015. The CRF report states that the CRI will further refine the 4 categories and 12 indicators of the framework into 48 to 54 sub-indicators and 130 to 150 variables or metrics.

10.4.8. NOAA Coastal Resilience Index

The National Oceanic and Atmospheric Administration's Coastal Resilience Index (NOAA CRI 2010) was developed to provide a simple and inexpensive self-assessment tool to give community leaders a method of predicting if their community will reach and maintain an acceptable level of functioning after a disaster. The tool is completed by experienced local planners, engineers, floodplain managers and administrators in less than three hours using readily available, existing sources of information, in a yes/no question format.

The CRI is targeted primarily at coastal storms, particularly hurricanes and other surge or rain induced flooding events with immediate and short-term recovery. More specifically, it focuses on the restoration of basic services and how long a community will take to reach and maintain functioning systems after a disaster. The eight page assessment form addresses six broad areas:

1. Critical facilities and infrastructure
2. Transportation issues
3. Community plans and agreements
4. Mitigation measures
5. Business plans
6. Social systems

The resulting assessment is meant to identify problems (vulnerabilities) that should be addressed before the next disaster – areas in which a community should become more resilient and where resources should be allocated. It also estimates the adaptability of a community to a disaster, but is not meant to replace a detailed study. The authors note that "The Resilience Index and methodology does not replace a detailed study…. But, the Resilience Index resulting from this Community Self-Assessment may encourage your community to seek further consultation."

The authors also state that the tool should not be used to compare one community to another. Rather, they recommend using it as an approach to internal evaluation to identify areas in which a given community might increase its resilience. As part of its development process the NOAA Community Resilience Index (CRI) was pilot tested in 17 communities in five states (Alabama, Florida, Louisiana, Mississippi, and Texas). In addition to developing their community indices, these pilot tests were also used to further refine and improve the assessment methodology.

10.4.9. FEMA Hazus Methodology

The Federal Emergency Management Agency's Hazus tool (FEMA 2014) "is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods and hurricanes. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane and floods. Users can visualize the spatial relationships between populations and other fixed geographic assets or resources for the specific hazard being modeled – a crucial function in the pre-disaster planning process."

The Hazus methodology and data sets cover the entire United States, and the study region (i.e., community) can be defined as any combination of US Census tracts. The specific hazard models included are earthquake (including fire following), flood (riverine or coastal) and hurricane (wind and storm surge). The focus of the model is on immediate physical, economic and (to a lesser degree) social impacts. But, the model does produce outputs on expected loss of use for buildings, loss of use for infrastructure (earthquake and flood only), shelter requirements, casualties (earthquake only), building contents and inventory losses, lost wages and income and indirect economic losses (earthquake and flood only). Estimated repair times are explicitly considered in economic loss estimates produced by the model, but the economic outputs are not tabulated or viewable as a function of time. While Hazus can be used to assess losses avoided through some mitigation measures, it does not estimate mitigation costs and therefore does not output estimates of return on investment.

There are gaps between the results produced by Hazus and the information required for a community-level resilience assessment methodology, particularly in the areas of interdependencies, social impacts and recovery times. However, many of the Hazus methodologies and the types of results they produce could become portions of a larger framework.

10.4.10. Comparison Matrix

A summary comparison of the nine example methodologies discussed in the preceding sections is provided in Figure 10-1. As noted earlier, not all of these methodologies address community resilience, but were evaluated to identify relevant and potentially applicable methods, indicators, or processes.

Each methodology was assessed on five broad dimensions: (1) comprehensiveness, (2) utility, (3) impacts assessed, (4) techniques used, and (5) overall merit with respect to the maturity, innovativeness, objectivity, and scientific merit of the methodology. Assessments were made in the context of community resilience planning and assessment, specifically as it pertains to the built environment.

Consistent with the findings of previously published assessments, none of the nine methods reviewed is strong in all five dimensions. However, it may be possible to combine the strongest features of existing and emerging methodologies to produce a new community resilience assessment methodology that addresses the needs identified in this chapter.

			Existing Assessment Methodologies								
Group	**Category**	**Sub-Category**	**SPUR**	**Oregon Res. Plan (ORP)**	**UNISDR Scorecard**	**CARRI CRS**	**CART**	**BRIC**	**Rockefeller CRF & CRI**	**NOAA CRI**	**FEMA Hazus**
1	Comprehensiveness	Community size	•	•	+	+	+	+	+	•	+
		Hazards	•	•	+	+	+	+	+	-	-
		Recovery time scales	+	+	?	?	?	?	+	•	-
		Systems	+	+	?	+	-	-	+	•	•
		Interdependencies	•	•	?	+?	-	-	+?	-	-
2	Utility	User friendliness	•	•	+	+	+	+	•	+	•
		Utility without hired or volunteer SMEs	-	-	+	•?	•?	•?	•	•?	•?
		Value of outputs for resilience planning	+	+	•	?	?	?	+?	•	•?
		Consistency with PPD-21	+	+	•	+	+	•	•	•	-
3	Impacts assessed	Physical impacts and recovery times	+	+	•	•	•	•	•	•	•
		Economic impacts and recovery times	•	+?	•	•	•	•	+?	-	•
		Social impacts and recovery times	•	•	•	•	•	•	+?	•	•
4	Techniques used	Checklists	-	-	+	+	+	-	+	+	•
		Interviews, Surveys	-	-	-	•	+	-	+	•	•
		Ratings	+	+	+	•	+	-	+	•	+
		Existing national data sets	-	-	-	-	-	+	-	-	+
		Physical inspections	•	•	•	•	-	-	-	•	•
		Engineering analysis or expert opinion	+	+	•	•	-	-	-	•	+
		Statistical inference	•	•	-	•	-	-	-	-	+
		Simulations	•	•	-	•	-	-	-	-	+
5	Critical Assessment	Maturity	+	+	•	+	-	+	•	?	+
		Unique/innovative	+	•	•	+	+	+	•	-	+
		Objective/repeatable	•	•	•	•	•	+	+?	-	+
		Scientific merit	+?	+?	-	?	?	?	+?	?	+

Group	**Symbol**	**Description**
1	+	Addresses a broad range
	•	Focused subset, but not inherently limited
	-	Limitation
	?	Additional information required
2	+	High
	•	Moderate
	-	Low
	?	Additional information required
3	+	Explicitly assessed
	•	Partially or indirectly assessed
	-	Not assessed
	?	Additional information required
4	+	Yes
	•	Optional
	-	No
	?	Additional information required
5	+	Strength
	•	Neither a strength nor a weakness
	-	Weakness
	?	Additional information required

Figure 10-1. Preliminary Summary Assessment of Nine Existing Community Resilience Methodologies

10.5. Economic Evaluation of Community Resilience Investment Portfolio

This section presents a brief overview of existing economic concepts related to the evaluation of investments to improve community resilience. The focus is on the development of a portfolio of investments that maximize the social net benefits to the community, recognizing constraints, uncertainty, and interdependencies that affect the mix of investments.

10.5.1. Portfolio Considerations

10.5.1.1. Economic Efficiency

Economic efficiency refers to obtaining the maximum benefit from the resources available. Equivalently, it means not wasting resources.

10.5.1.1.1. Maximization of Net Benefits

Improved community resilience will also increase the level of service economically. Several alternatives may maximize the net benefits to the citizens of the local community.

This assessment takes into account the fact that improved levels of service are typically more costly. This type of analysis will identify the level of service where the net benefits (that is, the increased value of the improved level of service minus the cost of obtaining that level of service) are maximized.

10.5.1.1.2. Minimization of Cost + Loss

From an economic perspective, this is an equivalent formulation to maximizing net benefits. Since the "Level of Service" is defined in terms of minimizing costs and losses, it may be a more convenient format for analysis. Expressing the results of this analysis in terms of net benefits is straightforward.

10.5.1.1.3. First-Cost vs. Life-Cycle Cost

Any effort to identify the alternatives that produce a maximization of net benefits depends on accurate estimates of benefits and costs. With regard to the costs of attaining a desired level of service, all costs, covering the entire life-cycle of any mitigation measures, need to be accounted for. It is not sufficient to include first costs only. Operation costs, maintenance costs, replacement costs and end-of-life costs (among others) need to be included.

10.5.1.2. Multiple Objectives

There are several complementary (and overlapping) objectives that are likely to be considered, accounting for the types of losses that a community wishes to avoid. In any analysis of avoided losses, care needs to be taken to ensure that savings are not double-counted.

10.5.1.2.1. Minimize Economic Losses

The simplest consideration is that of minimizing economic losses. Treated in isolation, that simply means making sure that the difference between economic gain (in terms of losses avoided) and costs of the desired level of service are maximized. It is simpler than the other considerations because costs and benefits are both in dollar terms.

10.5.1.2.2. Minimize Loss of Life

The remaining objectives all relate to economic losses of one sort or another. The most important consideration is avoiding loss of life and other casualties.

10.5.1.2.3. Minimize Other Losses

Other losses a jurisdiction might wish to avoid include disruption of key government services, disruption of social networks, and damage to the environment. Including non-economic factors such as these in the optimization is difficult, as benefits and costs are measured in different terms. If loss of life is included in the optimization, the benefits are measured in terms of lives saved (or deaths avoided), while the costs are typically measured in dollars. The normal economic way of handling this issue is by assigning a value to the benefits. For lives saved, Value of a Statistical Life is a standard approach. For other benefits, a number of techniques are available to determine the value a community places on those benefits.

However, there is a strong reluctance to put a price on a life (which is nominally what Value of a Statistical Life does) and other non-economic amenities. As an alternative, some form of Lexicographic Preferences could be used. Here each objective is strictly ranked, and then optimized in order. For example, an assessment could optimize for loss of life and then for economic losses. This ranking approach would ensure the selection of an alternative that minimizes loss of life (irrespective of costs). Next, the minimum cost alternative that maintained the minimum loss of life would be found.

Why not choose zero loss of life? As a practical matter, tradeoffs between safety and costs cannot be avoided.

10.5.1.3. Constraints

To the extent a local community has a limited budget, that budget must be factored into the optimization. Other constraints can also be factored in, largely by screening out potential plans that do not meet the constraints.

10.5.1.4. Economic Interdependencies

The economy in general is affected by the resilience of the built environment. The reverse also holds – the resilience of the community depends on the health and resilience of the economy.

10.5.2. Economic Decision-Making Involving Risk and Uncertainty

10.5.2.1. Expected Utility Theory

Economists often approach decision-making with expected utility theory. The basic idea is that people will choose the alternative that has the best ‘utility’ or value for them, as indicated by the highest probability-weighted average value. The value is adjusted to account for both time preference and risk preference.

10.5.2.1.1. Time Preference

Most people prefer consumption now over consumption later. The typical way to address that is to discount future consumption.

10.5.2.1.2. Risk Preferences

Most people would prefer to avoid risk – that is, they are risk averse. For people who are risk averse, a large potential loss weighs more heavily than a large number of small losses, which together, add up to the same value as the big event. Someone who is risk neutral would weigh the two equally.

Risk aversion is handled in economic theory by weighting the large losses more heavily (or equivalently, by weighting large gains less heavily). The simplest approach, and the one used most often in net benefit analyses, is to assume that the community is risk neutral. Then you simply compute the present expected value. However, when it comes to disasters it seems unlikely that communities will be risk neutral.

To account for risk preferences, it will be necessary to measure those risk preferences. A number of widely-accepted methods for measuring risk preferences exist.

10.5.2.2. Behavioral Economics and Cognitive Bias

People are not Expected Utility maximizers; there is a very large body of literature regarding departures from Expected Utility maximization. Expected utility maximization is a difficult problem, and typically, there are not enough resources available to solve it. There are several approaches to thinking about these departures from economic theory, but the most widely accepted is the Heuristics and Biases school. They argue that people use standard shortcuts—heuristics—that work well most of the time. However, there will be cases where they do not work well, and in those situations they will be biased. The biases are generally used to try and identify the heuristics used.

There are a number of identified biases, some of which are relevant here. These include Uncertainty v. risk, overconfidence, and small probability events, among others.

10.5.2.3. Uncertainties

Uncertainties regarding estimates of expected damages and recovery times from disasters fall into two categories. First, there are factors that cannot be known with certainty in advance, such as the timing and magnitude of future hazard events. Second, there are things that are in principal knowable, but are not currently known with certainty. For example, while in principal the cost of a particular project can be estimated, the level of uncertainty associated with the estimate can vary and will likely increase with the scope of the project.

Mitigation costs, recovery costs, and losses will have uncertainties in their estimates. As community resilience plans are developed and refined, the level of uncertainty may reduce.

A particularly high level of uncertainty exists regarding business interruption losses. In cases where they have been estimated, such losses are often as large or larger than direct economic losses. However, they are difficult to estimate, due to the lack of data from past events to support estimates.

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