NIST Special Publication 1240

Data, Information, and Tools Needed for Community Resilience Planning and Decision-Making

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National Institute of Standards and Technology
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Justin Kates, City of Nashua, NH
Sean McGlynn, City of Santa Rosa, CA
Jay Wilson, Clackamas County, OR
Janet Zeis, Chester County, PA

The participants in the October 25-26, 2018 workshop brought a wealth of experience and information. Their knowledge and experience with data, information, and tools related to community resilience planning and decision-making is greatly appreciated. The workshop and this report benefited significantly from the diverse group of participants, whose affiliations are listed on the following page.

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October 25-26, 2018 Workshop Participant Affiliations

- 100 Resilient Cities
- AIR Worldwide
- American Institute of Architects
- American Planning Association
- Argonne National Laboratory
- Applied Research Associates, Inc.
- Cedar Rapids, IA
- AT&T
- Bonneville Power Administration
- Boulder, CO
- Center for NYC Neighborhoods
- Chester County, PA
- Clackamas County, OR
- Colorado State University, CO
- Delaware Air National Guard
- Delaware Valley Regional Planning Commission
- Dewberry
- Department of Homeland Security, National Risk Management Center
- Dubuque, IA
- Howard County, MD
- LEED for Cities & Communities
- Economic Development Agency, Economic Recovery and Resilience
- Energetics
- Ernst & Young
- Facility Engineering Associates, LLP
- Federal Emergency Management Agency
- Federal Emergency Management Agency, Community Capacity Building
- Fort Collins, CO
- Global Research Institute
- Hillsborough County, FL
- Idaho National Lab
- InsightFive
- Institute for Building Technology and Safety
- Institute for Defense Analysis, Science and Technology Policy Institute
- Insurance Institute for Business & Home Safety
- International City/County Management Association
- International Organization for Standardization
- Larimer County, CO
- LeadersLink
- Louisiana Office of Recovery
- Metropolitan Washington Council of Governments
- Miami, FL
- Michael Baker
- Mid-America Regional Council
- Milwaukee, WI
- Nashua, NH
- National Association of Counties
- National Academies
- National Association of Regional Councils
- National Institute of Building Sciences
- New York City Department of Information Technology and Telecommunications
- National Fire Protection Association
- National Institute of Standards and Technology
- National League of Cities
- National Oceanic and Atmospheric Administration, Office for Coastal Management
- Northeast States Emergency Consortium
- Oklahoma State University
- PCS Solutions
- Pew Charitable Trust
- PPC
- Resilient Virginia
- Santa Rosa, CA
- SEFT Consulting Group
- SGD Urban Solutions, LLC / RAND Corp.
- Stanford University
- State of Louisiana Office of Community Development
- Talus Analytics
- Texas A&M University
- Transportation Research Board
- University of Illinois Urbana-Champaign
- University of Florida
- Urban Sustainability Directors Network
- Walden University
- Washington, DC, Office of Planning
- Xylem Inc
- Zurich Services Corporation

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Executive Summary

Many communities across the United States are seeking the ability to prepare for, adapt to changing conditions, and withstand and recover rapidly from the effects of natural hazard events by actively developing plans to achieve their resilience goals. The term community refers to a place designated by geographical boundaries under the jurisdiction of a common governance structure, such as a town, city, or county. It is within these communities that people live, work, play, build their futures, and develop goals and plans.

Community resilience planning requires methods to assess and measure a community's current resilience level and the risks and benefits of plans for its social and economic institutions and physical systems. The prioritization and implementation of resilience improvement projects requires data and information to fully understand and effectively evaluate project alternatives, support investment decisions, and assess the outcomes of projects as they are implemented and completed. These activities also require resources to collaborate and communicate with stakeholders and to identify, process, and analyze data with tools from a variety of sources and disciplines.

Research at the National Institute of Standards and Technology (NIST) and the Center for Risk-Based Community Resilience Planning (Center) supports community resilience planning and risk-informed decision-support for mitigating the impacts of natural hazards. To this end, NIST and the Center organized a workshop on community resilience data, information, and tools for community resilience planning and decision-making. The October 2018 workshop aimed to: (1) gain an improved understanding of communities' resilience decision-making processes, (2) identify issues associated with obtaining data and information, (3) identify common data needs for the development and use of community-focused tools, (4) identify analysis tools currently used to support planning and decision-making by communities, and (5) develop potential actions to address the issues and needs. Based upon input from the community, practitioner, academic, and government stakeholders received in the workshop and research by NIST and the Center, this report summarizes the current approaches, issues, and gaps in resilience data, information and tools that help communities to plan and implement resilience strategies.

Key Findings

Key findings for potential next steps to advance data, information, and tools for community resilience are summarized below and in Figure E-1.

1. **Communities seek practical approaches and methods to develop resilience plans, communicate with stakeholders, and track progress.**

Efforts to develop community resilience plans are often led by community officials, who are responsible for considering the social, economic, physical, and natural systems within a community, understanding the effects of natural hazards on these systems, and obtaining input from and communicating with community members. Data for buildings, infrastructure systems, social and economic institutions, and community members for the periods before, during, and after a hazard event are essential for performing comprehensive community assessments and developing plans. Obtaining input from and communicating resilience goals and strategies to community stakeholders is a significant challenge given the range of interests and perspectives across a community.

Resilience leaders seek practical, scientifically-grounded methods and tools to ensure they are addressing community goals and recommending technically appropriate actions in the resilience plans. Essential elements for a standard approach include establishing resilience goals, identifying vulnerabilities, prioritizing projects, and tracking progress towards resilience goals. Another significant challenge is integrating the different geographic and time scales across data sources in models or tools. Measuring resilience progress requires a core set of indicators and metrics to assess the performance of community systems before and after a natural hazard event. Additionally, advances in resilience leadership training, as

well as visualizing and communicating risks and benefits to community leaders, residents, and businesses, are critical to community understanding and willingness to adopt and implement resilience strategies.

2. **Development of resilience data standards would improve the accessibility of data and tool development for communities, practitioners, and researchers.**

Data and information resources and community technical capabilities are the foundation of analyses and assessments informing resilience plan development. While the increasing set of data sources on the social, economic, and physical dimensions of communities is helpful, communities often must invest significant resources and time to integrate multiple external data sources with their own information technology and management systems for planning, analyses, and assessments. In addition to data sources, communities seek resilience tools that aid planning efforts in two general categories: (1) analytical tools to characterize hazard exposure and support vulnerability assessment, and (2) decision-support and visualization tools to evaluate trade-offs, support implementation decisions, and enhance community stakeholder engagement.

Efforts are needed to increase the discoverability and accessibility of resilience data, to help communities understand appropriate uses of data for resilience planning, to increase compatibility with community software platforms and tools, and to standardize data to facilitate the application for disaster assistance from federal agencies and other funding sources. The development of common community resilience data standards and best practices for curation and dissemination of validated data and tools would reduce the technical burden on communities. Community resilience tools will benefit from engagement and collaboration between end-users and tool developers to align the technical requirements of analytical tools to community decision-support needs, including visualization of results for communication.

3. **Advancing plan implementation requires identifying optimal funding opportunities and evaluating the economic benefits and costs of resilience projects.**

Once a resilience plan has been published, communities face the hurdles associated with plan implementation. Communities seek to articulate the business case and benefits before and after hazard events for their resilience plan. To achieve the resilience plan goals, communities must complete a series of technical and administrative tasks, including: identifying necessary public and private funding sources, understanding administrative requirements of funding options, and securing funding at the right time to achieve the goals of the plan. Further, communities seek methods that allow decision-makers to understand trade-offs between projects and justify investments. Demonstrating the value of resilience investments includes fully accounting for the direct, indirect, and co-benefits, in addition to the costs, of resilience projects and strategies.

Communities also seek a consolidated set of resources that allow them to identify potential funding sources. Additionally, standard methods to quantify the benefits of resilience investments and project evaluation methods need to be developed and recognized by the organizations funding resilience investments and applied in user-friendly economic decision-support tools.

Moving Forward

Advancing the science and practice of resilience planning currently is an active field which brings together researchers, practitioners, and communities. Collaboration across these diverse sectors with the common goal of increasing community resilience to natural hazards is an essential element of addressing the issues presented in this report. The potential next steps presented in this report are opportunities for collaboration between governments, organizations, and communities to work toward advancing the science and practice of community resilience planning.

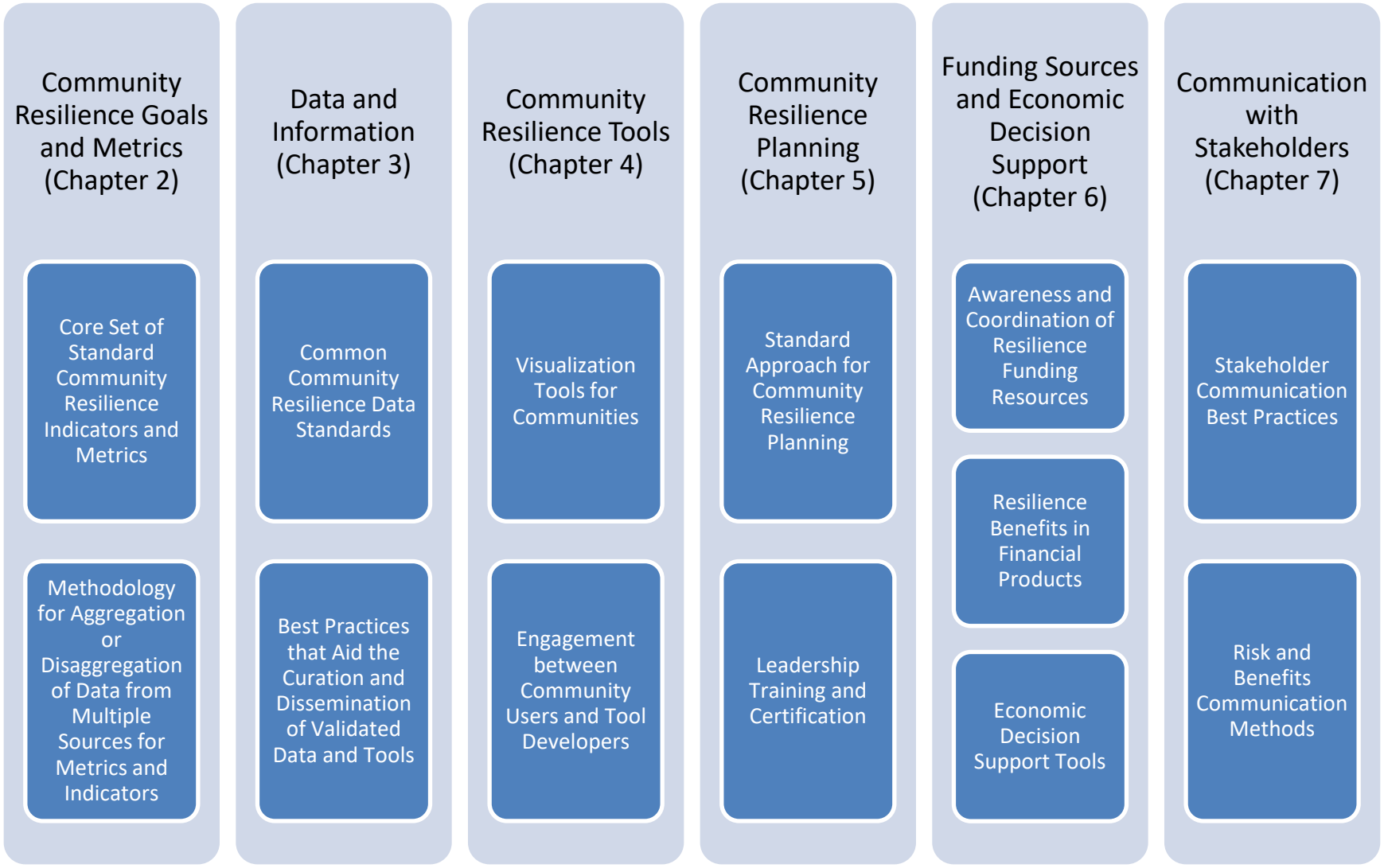

Figure E-1. Summary of Potential Next Steps Identified in the Report

1. Introduction

Community resilience is the ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions [PPD-21 2013]. Local decision-makers face many challenges as they plan and implement actions to increase the resilience of their communities to natural, technological, and human-caused hazards. The purpose of this report is to assess and improve the current state of the art with regard to the data, information and tools that are necessary for communities to plan and implement strategies to enhance the resilience of their communities.

While communities may face many types of disruptive events, this report focuses specifically on community resilience to natural hazards, considering how the performance of the built environment helps achieve community social, economic, and physical well-being. Challenges and opportunities to enhance the use of data, information and tools that are currently used or are urgently needed by communities to support their resilience planning and decision-making processes are identified in this report.

Communities planning for resilience require data, information, and science-based tools to measure the performance of social, economic, and physical dimensions of their community and their dependencies. Decision-support tools are also needed to support evaluation and selection of actions to improve resilience and meet other community priorities.

For the purposes of this report, the terms data, information, and tools are defined as follows:

- "Data" means quantitative and qualitative facts and figures that generally require further manipulation and/or interpretation to be used for decision-making. For example, the responses of residents to a survey to obtain household incomes are "data".
- "Information" refers to data that has been processed and/or organized into an understandable and usable format. For example, the average household income for a community is information derived from data.
- "Tools" are instruments, models, or analysis methods that are used to collect, process, and organize data into additional types of information. For example, geographic information systems (GIS) tools can be used to analyze spatial relationships between household income and other social, economic, or physical data and economic tools can be used to conduct benefit-cost analyses.

Additional terms and definitions are provided in Appendix 1.

1.1. Stakeholder Workshop

To better understand the resilience planning needs of communities, the National Institute of Standards and Technology (NIST) and the Center for Risk-Based Resilience Planning (Center) sponsored a workshop on *Data Needs for Resilience Planning and Decision-Making,* held in Rockville, Maryland, on October 25-26, 2018 [NIST 2018a]. The objectives of the workshop were to:

- Gain a more complete understanding of communities' decision-making processes associated with resilience planning at the community level,
- Identify issues associated with the data and information needed to support community resilience planning and decision-making,
- Identify common data needs of communities and researchers for the development and use of tools, and
- Identify actions to support the development of analysis tools that support planning and decision-making by communities.

One key challenge is finding, organizing, and processing data and information in a cost-effective manner to support planning, decision-making, and implementation most effectively.

There are five major decision points in the resilience planning process where data and information are required or could be of assistance:

1. Establish social and economic goals and priorities
2. Identify building clusters[1] and supporting infrastructure systems, including their geographic locations and dependencies
3. Determine performance goals and anticipated performance of building clusters and infrastructure systems based on the expected hazard exposure and future conditions
4. Identify and prioritize performance gaps for building clusters and infrastructure systems, and their impacts on social and economic functions and services
5. Determine and evaluate project options to address performance gaps and meet other community priorities

These decision points are based on input from communities and the *NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems [2016].* Using these five decision points, the workshop was organized around three topics:

- How communities characterize themselves, set goals, and make decisions (decision points 1 and 2)
- The gap between current and desired performance of the built environment (decision point 3)
- Community resilience priorities and solutions (decision points 4 and 5)

The workshop included speakers and participants who represented cities, counties, regional bodies, and states, as well as representatives from federal agencies, universities, non-profits, and the private sector. The speakers and participants were asked to identify specific needs based on their experiences. Participants were organized into categories based on their organization's affiliation: community representatives, researchers, federal employees, and practitioners/consultants. In addition, the participants took part in parallel breakout sessions that contained a balanced distribution of participants from these categories to ensure that all perspectives were considered in each discussion.

A steering committee, including representatives from community organizations, local government, federal agencies, and practitioners assisted NIST in planning the workshop. The steering committee members assisted NIST by identifying important topics based on their individual experience with communities, identifying workshop speakers, and engaging their stakeholders.

1.2. Report Development and Organization

1.2.1 Report Topic Development

This report was informed by the workshop and research conducted by NIST and the Center. Data, information, and tools needed to inform integrated planning processes for resilience on a community scale were identified. Each chapter has three sections to document and discuss current approaches, issues in practice, and gaps and needs to be addressed. The scope of data, tools, and information listed is not intended to be exhaustive, but rather representative of the types of sources available. Further, the topics discussed in the report do not represent a consensus perspective of the workshop participants or workshop steering committee members.

[1] Building clusters are sets of buildings, not necessarily geographically co-located, that serve a common function such as housing, healthcare, retail, etc.

1.2.2 Report Organization

Chapter 2 reviews the need for resilience goals and metrics that can be used to guide community plans and to monitor community performance before and after hazard events.

Chapter 3 highlights the extensive data, information, and tools that exist, and identifies steps that could be taken to better organize these resources to increase access and use for community resilience planning.

Chapter 4 emphasizes the need for easy-to-use and easy-to-understand tools and guidance for community resilience planning and decision-making.

Chapter 5 summarizes community resilience planning approaches, discusses steps for advancing education and training in resilience planning, and identifies community plans that provide examples of integrating resilience into a community.

Chapter 6 summarizes data and information needed by communities to obtain planning and recovery funding and emphasizes the need for increased engagement with the private sector to enhance resilience.

Chapter 7 highlights the need for improved methods and approaches to communicate the elements of resilience strategies, plans, and projects, and increase community awareness and understanding of hazard risk.

Chapter 8 concludes the report with a summary of implementation needs and recommendations.

2. Community Resilience Goals and Metrics

Communities establish resilience goals to guide plans and future development, prioritize actions that address hazard risks, and support resource allocation decisions. Indicators and metrics are often used to track progress toward meeting community resilience goals.

2.1. Current Approaches

2.1.1. Community Resilience Goals

Community resilience goals help decision-makers establish priorities and allocate resources. Many communities monitor economic development, population growth, utility services, etc., but often do so in a piecemeal fashion where each goal or program is evaluated separately. This piecemeal approach can lead to unintended conflicts between projects relative to broader community goals. For example, new developments may be planned for available property that is subject to flooding. Community resilience goals provide a comprehensive basis for integrating existing plans for physical (e.g., hazard mitigation, public works), social (e.g., education, healthcare), and economic (e.g., economic development) aspects of a community and help identify gaps and conflicts between plans.

Progress toward community goals is evaluated with quantitative metrics or indicators over time. Community metrics can help decision-makers evaluate the performance and functionality of individual community systems and services, spot emerging trends, and assess potential impacts of planned or expected changes relative to the resilience goals. However, given the uncertainty of when a hazard event will occur, resilience metrics need to be meaningful both before and after hazard events, so that they guide community resilience improvements prior to the next event.

2.1.2. Indicators and Metrics Development Methodology

NIST and the Center are developing assessment methodologies and analytical models to provide a rigorous approach for assessing community functions and services based on the performance of its physical, social, and economic systems and to evaluate the sensitivity of indicators and metrics [NIST 2019a; Center 2019]. The evaluation includes sensitivity to changes in input parameters, associated uncertainties, and dependencies on other factors or systems.

NIST tasked Lavelle et al. [2015] to conduct a critical assessment of existing methodologies that can be used to measure or assess community resilience for social and physical systems. Nine existing methodologies representing ranges of community systems and modeling approaches were reviewed. The selected methodologies were not necessarily developed specifically for the purpose of assessing community resilience, but they were considered relevant and potentially applicable to the problem of community resilience assessment, either in whole or in part. Three of the methods are noted here:

- *Rockefeller Foundation City Resilience Framework (CRF) [Rockefeller 2014] and City Resilience Index (CRI) [Rockefeller 2016]*: The framework forms the basis of a tool to enable those interested in city resilience to establish a common understanding of that idea and to assess the city's baseline. The framework and the index are intended to facilitate a process of engagement with and within cities. Ultimately, the process should lead to new ideas and opportunities to engage many stakeholders on what makes a city resilient. The City Resilience Framework provides a lens through which the complexity of cities and the numerous factors that contribute to a city's resilience can be understood. The framework is made up of 12 key indicators that describe the fundamental attributes of a resilient city.
- *Baseline resilience indicators for communities (BRIC) [Cutter et al. 2014]*: The purpose of BRIC is to measure overall pre-existing community resilience. Using U.S. counties as the study unit, the approach provides an empirically-based resilience metric for use in a policy context. It uses

data from public and freely available sources, drawing on a common set of 49 indicators associated with six different domains: social, economic, housing and infrastructure, institutional, community capital, environmental.

- *NOAA Coastal Resilience Index (CRI) [NOAA 2010]*: The National Oceanic and Atmospheric Administration's (NOAA) Coastal Resilience Index was developed to provide a simple self-assessment tool to help community leaders predict their community's level of functioning after a disaster. The tool is intended for use by experienced local planners, engineers, floodplain managers and administrators using readily available, existing sources of information, and a yes/no question format. The eight-page assessment addresses six broad areas: critical facilities and infrastructure transportation issues, community plans and agreements, mitigation measures, business plans, and 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.

To address the challenges associated with the measurement of resilience, NIST is developing a standardized methodology to guide identification, evaluation, selection, and development of composite indicators and metrics for community resilience [Dillard 2017]. The methodology will identify a more comprehensive, integrated suite of composite indicators and metrics across community systems that are meaningful before and after a disruptive event. This approach will seek to achieve consensus among existing resilience methodologies and frameworks and will conduct validation studies (e.g. evaluation of indicators against historical events) on resilience metrics and outcomes associated with a resilient system (e.g., shorter recovery time, better performance during hazard event).

The Federal Emergency Management Agency (FEMA) National Integration Center (NIC) Technical Assistance (TA) Branch tasked Argonne National Laboratory (Argonne) with providing a data-driven basis to prioritize locations for TA investment. The methodology is based upon a literature review of peer-reviewed community resilience assessment methodologies published within the past five years, evaluation of these methodologies in relation to a number of criteria, and the development of twenty indicators, eleven with a population focus and nine with a community focus [Edgemon et al. 2018]. Common statistical methods and data structuring were used to establish five categories of data for each indicator and produced choropleth maps of the U.S. showing county-level data for each indicator.

The Center and NIST researchers developed a set of preliminary community resilience goals and related indicators and metrics that were informed by community outreach and the NIST Community Resilience Planning Guide [NIST 2016], as shown in Table 2-1 [Ellingwood et al. 2019]. These resilience goals and indicators are being evaluated for their usefulness for decision-makers addressing community resilience, as well as the data that are available for their quantification.

2.1.3. Data Sources for Indicators and Metrics

Data to support community resilience assessment and planning are obtained from federal agencies (see Appendix 2) and from state or local sources. There is a desire for data that is typically held by private sources, such as electric power, communication, water systems, and insurance companies. However, there are challenges associated with obtaining this data which include proprietary data concerns, security, personally identifiable information, and competition among vendors or suppliers.

Some issues communities identified are that data are not available at the desired spatial or temporal scale at present. This includes data associated with emerging climate conditions, such as increasing variability and/or intensity associated with some natural hazards (e.g., rainfall or hurricanes), drought, wildfires, and the effects of sea level rise on community flooding. Data are also needed to better characterize vulnerable populations, the vulnerability of social/economic community systems, physical infrastructure performance, and physical/social system dependencies.

Table 2-1. Example of Community Resilience Goals and Indicators

Community performance goals	Examples of resilience metrics
Population stability	Number of households dislocated; percent population remaining in the community; percent population remaining in homes; change in housing vacancy rate
Economic stability	Household income; employment; earnings by sector; assessed value of property; change in taxes and revenue (resources); change in gross city product (GCP)
Social services stability	Hospital bed demand/supply ratio; school teacher/student ratio; availability of key retail and financial services
Physical services stability	Percent functionality of buildings and transportation systems; percent of population served by water, wastewater, electric power, gas, and telecommunication systems
Governance stability	Percent of population with access to police and fire protection and other essential public government services

2.2. Issues in Practice

2.2.1. Indicators and Metrics Selection and Validation

There are many indicators, composite indicators, and metrics used to characterize the performance and functionality of social, economic, physical, and natural systems. A review of community resilience actions and measurements identified several quantitative and qualitative indicators and metrics for social, economic, infrastructure systems and community preparedness [National Academies 2019]. Checklists were also reviewed, as some provide scores based on responses.

Validation of indicators and metrics remains an ongoing challenge. A report published by the National Academies [2019] found that none of the reviewed indicators and metrics had been validated for measuring changes in community resilience. The varying range of rigor applied to developing indicators and metrics presents a challenge in determining whether they can signal significant changes in a given community function or service and inform decision-makers. A core set of validated indicators and metrics would enable communities to better track progress towards resilience goals and would enable learning from resilience efforts in other communities. The lack of validated community resilience indicators and metrics raises questions about the usefulness of those that are currently in use, specifically for the purpose of resilience planning.

2.2.2. Data Sources for Indicators and Metrics

Data sources may include a combination of data from standardized national sources (e.g., American Community Survey) and community sources (e.g., taxes, business data, electric power, and water service). Primary data collection (e.g., surveys, interviews) may be used when the desired data is not available. However, for resilience planning and implementation, this requires a substantial commitment to continue collecting and analyzing the required data over time. Such a commitment may be made at a local, regional, or national scale.

Spatial and temporal scales vary across data types for community systems. For instance, building data is often available for a given location, demographic data may be obtained at a census block or tract scale, and economic data may be obtained at a community or regional scale. National data may be collected at an annual frequency whereas local data may be collected at a monthly or quarterly frequency. There are

significant technical challenges associated with aggregating and de-aggregating data from multiple sources for a set of indicators or metrics at the community scale [Ellingwood et al. 2019].

2.3. Gaps and Needs

The following steps are needed to advance the development of indicators and metrics for community resilience:

- Develop a core set of standard indicators and metrics that quantitatively evaluate the performance and functionality of social, economic, physical, and natural systems before and after natural hazard events.
- Identify data requirements and sources for key indicators and metrics, with spatial scale and temporal frequency.
- Develop methods to integrate and aggregate (or de-aggregate) multi-disciplinary data for indicator and metric computation.

3. Data and Information

A community's data and information comprise the foundation of resilience planning processes. Successful development, management and curation of these data resources would enable and improve the community decision process. Developing and maintaining data and information includes establishing and enforcing high quality data standards, accessing public sources of data, and maintaining local databases and data management systems. Examples of data sources used by communities are listed in Appendix 2, as well as other data that communities might need to support their resilience planning and implementation.

Communities acquire data to inform their resilience planning processes from several sources. Municipal governments develop their own databases and data management systems for planning and operations. Municipal data systems vary in scale and complexity based upon an individual community's planning needs, compliance with funding and other regulatory requirements, and available resources. All communities rely upon public data and information, which are essential to resilience planning. However, not all data that are useful to community resilience planning is available to communities, such as data for privately held infrastructure systems and facilities. Challenges persist in ensuring that communities can: (1) discover and access public data in a timely manner, (2) understand appropriate uses of the data for resilience planning, and (3) ensure that data are compatible with the platforms and analytical tools in use.

Opportunities exist to address these challenges by increasing the discoverability and accessibility of data supporting resilience planning and ensuring consistency in the curation, maintenance, and distribution of data for resilience planning across communities.

3.1. Current Approaches

3.1.1. Community Data Management and Acquisition

Many communities maintain data sources and management systems to manage their operations and support planning and assessment activities. The extent and sophistication of the data collection, management, and analytical capabilities varies with community resources. Generally, community data provide information about the community's built environment (e.g., buildings permits, infrastructure operations), local economy (e.g., tax revenues, business licensing), social institutions (school attendance), and demographics (e.g., population, race/ethnicity). For other types of data needed in resilience planning, communities rely upon public data sources. These data sources may be based on experience, sources that are shared by other communities, or sources referred by partner organizations (e.g., non-governmental organizations, research organizations, consultants).

3.1.2. Discipline-Specific Data Management, Practices, and Dissemination

Communities, their partners, and contractors currently are responsible for identifying, acquiring, and integrating public data sources with a community's internal data sources and analytical tools. Training and expertise are required to identify, acquire, integrate, and analyze data from multiple disciplines, such as those listed in Appendix 2. For example, data on infrastructure systems may be maintained by private owners and operators, hazard data are maintained by standards organizations and government agencies, and social, demographic, and economic data are largely maintained by government agencies.

Some data types require accessing multiple data sources, such as natural hazard data. Buildings and infrastructure have design values for wind, hurricane, flood, earthquake, rain, and snow events which can be obtained from the appropriate standards organizations. Other hazards, such as wildfire, tornadoes, hail, and landslides, have less well-developed design values for buildings, and hazard design values are often based on historical events and site-specific studies. Historical data may be useful for community planning purposes but may be less severe than design values from standards. For community resilience assessments,

hazard scenarios are used to test the integrated performance and response of the community and may be based on design standards or historical data. Data from past events can also be used to validate predictive models.

Some data can have multiple uses for resilience planning. For instance, if tax data shows limited sales tax generation in one area of a community, it may indicate an economically vulnerable population. Tax appraisal data is sometimes used to identify areas at risk for a hazard event, using building age as a proxy for building code provisions and estimating anticipated performance for a hazard event. However, this approach is a substitute for obtaining the data the design code at building construction.

The following are examples of the types of data that community representatives indicated as being generally available and particularly useful for integrated resilience planning efforts (see Appendix 2):

- Built environment:
  - Adopted building code at time of building construction
  - Structural plans and drawings (when required)
  - Number of dwelling units
  - Construction type
  - First floor elevation (FFE)
  - Location of heating, ventilation, and air conditioning (HVAC) systems
- Social and Demographic:
  - Population and household data [American Community Survey, Census Bureau 2019]
  - Population, household, and transportation data [US Census of Population and Housing, also aggregated in Social Vulnerability Index by CDC 2019]
  - Household information for rapid needs assessment from the Community Assessment for Public Health Emergency Response (CASPER) [CDC 2018]
  - Population vulnerabilities (e.g., location of Medicare beneficiaries with electrically powered medical equipment from emPOWER [HHS 2018]
- Economic:
  - Assessed value of structures
  - Employment and wages data [BLS 2019]
  - County or community tax data

3.2. Issues in Practice

3.2.1. Proliferation of Resilience-Related Data Resources

The types of data supporting resilience planning are broad, spanning multiple topics and scientific disciplines. Similarly, sources for acquiring these data are also numerous. This proliferation of resilience-related data, generated by government agencies, professional organizations, or communities themselves, has created a situation where data formats are variable and significant amounts of resources and labor can be expended to curate data for resilience planning activities. Several factors contribute to the pace of data creation and the use and uptake of resilience-related data sources:

- Resilience planning includes many elements of communities, such as buildings, transportation, energy, telecommunications, water, wastewater, human services, economics, health care, and education. Synthesizing these diverse types of data into usable and accessible formats for analysis and assessments from multiple disciplinary fields is a challenging task for both research and community planning purposes.
- Resilience data would benefit from guidance and standardization on data formats for analysis tools supporting community resilience planning and assessment.

- Community input on data that are not currently available for resilience planning, including the required format and scale (both spatial and temporal), will inform agencies, practitioners and researcher efforts.

3.2.2. Data and Information Discoverability and Accessibility Challenges

A related, but separate, challenge is the need to ensure that resources are easily accessible by the stakeholders and end-users. There are multiple challenges associated with data and information accessibility: development and maintenance of databases and repositories of information, public awareness and use of information resources in a manner consistent with its intended design, and interoperability with other resources and tools.

Generally, data producers want their resources to be discoverable and accessible (although exceptions exist for sensitive data sources) and used in a technically appropriate manner. However, communities find that identifying an appropriate data source from the large number of data sources available to be challenging. Issues include awareness of available data sources, understanding their differences and options, and how to select suitable sources of data.

3.2.3. Lack of Guidance and Standards for Data and Information

Communities require multiple sources of data and information that often are incompatible with the required format of a tool or for integrated evaluation. For example, resilience planning requires data on a community's built environment, demographics, economy, and hazards. Integrating multiple sources of data for resilience assessment and planning requires expertise across multiple disciplines. There is a lack of guidance and standards on data formatting and methods for combining multiple sources of data for community resilience analytical tasks. Often these data sources are collected for purposes other than resilience planning (e.g., permit data, tax and revenue data), which can lead to lack of uniformity when to attempting to integrate various sources. Additionally, data needed by communities for resilience planning may involve personally identifiable information that are collected directly or through surveys of community residents. Standards and guidance are needed to ensure these data are available to aid planning and that personal or security information remain protected.

At present, communities and practitioners face a technically challenging and time-intensive data selection effort. Additionally, the lack of data guidance and standards limits the comparability of analyses supporting resilience planning efforts and hinders community sharing of resilience data and information technology resources.

3.3. Gaps and Needs

3.3.1. Development of Data Standards, Data Management, and Best Practices

Advances in standards and best practices for data will help communities characterize the resilience of their built environment and social and economic systems to natural hazards. These advances have the potential to reduce the resources needed to conduct resilience planning and improve the quality of the results. To foster and support their use, maintenance, and dissemination, data standards and best practices need to be adopted and maintained by standards organizations, or similar organizations.

Data standards and best practices are needed to provide a common format, structure, and principles to ensure a set level of compatibility between data sources. Data standards and best practices would also improve tool development. Additionally, engagement opportunities for the producers, end-users (communities), and

intermediary organizations are needed to support multi-disciplinary collaboration for developing and maintaining common data standards and best practices.

Initial steps to develop data standards and best practices could include:

- Evaluate methods used by other efforts that have established data standards, with features such as community-level spatial scales and integration of interdisciplinary datasets.
- Develop technical requirements for ensuring data set quality control and accessibility.
- Establish standards that address classification of data and metadata.
- Develop open data management principles, that include federal government open data principles and policies [CIO 2019].
- Identify and engage the necessary standard development organizations that have standing and representation across disciplines involved in resilience planning.

3.3.2. Develop Processes that Aid the Curation and Dissemination of Validated Data

To reduce the burden on individual communities in locating data sources best suited for their needs and verifying technical credibility of those data, improved approaches and methods for resilience data curation and dissemination are needed.

Efforts to improve the curation of resilience data, information products, and tools could include:

- Identify existing successful curation and dissemination models to support end-user resilience planning data and information needs.
- Develop curation and dissemination models with multi-disciplinary collaboration of organizations and sectors involved in the development, dissemination, and use of data, information sources, and tools in resilience planning.
- Develop data management best practices for data curation and dissemination to ensure that resilience data portals are designed with user needs in mind. Specifically, compatibility with common data tools and platforms used by communities, such as GIS analysis tools, is needed.

4. Community Resilience Tools

Communities and practitioners require analytical and visualization tools to evaluate the integrated performance of the built environment and the social, and economic systems they support to aid resilience planning efforts. Hazus [FEMA 2018a] is one such tool that supports mitigation planning. More comprehensive tools are currently being developed by NIST [NIST 2019a] and the Center for Risk-Based Community Resilience Planning [Center 2019]. At present, most analyses tools focus on individual systems used for capital asset and infrastructure planning, operations, and evaluation. Individual system analyses often lack recognition of dependencies on other infrastructure systems, and do not address impacts of the performance of the built environment on social and economic systems.

Many of the data and information challenges discussed in Chapter 3 are similar to community resilience tool challenges. There is a need for best practices and guidance on analyses and decision-support information output and visualization of results. Tools that support community resilience planning and decision-making also should address resilience metrics and indicators, interdependencies between systems, multiple types of losses, short and long term benefits, and resilience impacts of future projects or policy changes.

4.1. Current Approaches

4.1.1. Community Resilience Analysis, Decision-Support, and Visualization Tools

Many communities maintain spatial analysis tools, often in a GIS format, and have in-house technical staff to perform analysis to support operational and policy making needs. GIS tools display information using layers for each type of data (e.g., population, tax revenue and other economic information, buildings, infrastructure systems) across the community. Communities seek additional GIS tools to better support resilience planning and to aid with visualizations and communication.

Tools that communities can update and maintain with local and public data, and that allow control over results are needed. While GIS resources have tremendous utility for communities, they have a training and resource requirement that not all communities can support.

In recent years, there have been efforts by organizations across multiple sectors to curate the best available tools and associated data for specific resilience planning applications and stakeholder needs. Collectively, these efforts provide valuable curation of resources that could inform the standardization and organization of high-quality tools and data sources. While tool resource collections help serve the diverse needs of communities, it can be challenging for communities to determine which tools and methodologies are most appropriate for their planning. Examples of tool resource collections are included in Appendix 3.

Community resilience tool selection is often motivated by resilience planning and external funding program requirements. Examples of external programs include FEMA hazard mitigation programs, Department of Housing and Urban Development (HUD) Community Development Block Grant (CDBG) and CDBG-Disaster Recovery (CDBG-DR) programs, and Department of Commerce Economic Development Agency (EDA) programs. Each of these programs offers financial support for various components of a community resilience plan to qualifying communities. Each of these programs have requirements for current and historical data, plans, matching funds, and other input that varies in format and content depending on the purpose of the program. Further examples of funding programs are discussed in Chapter 6 and provided in Appendix 4.

4.1.2. Examples of Currently Available Tools

Most community resilience tools are publicly available and developed by government agencies, non-profit organizations, or research organizations. These tools can be grouped into two classes: *analysis tools* and *decision-support and visualization tools*. Analysis tools provide methodologies and data to help communities characterize their hazard exposure, support assessments, and provide the analytical foundation for resilience planning. Decision-support and visualization tools support tradeoff analysis options, justify investment decisions, and engage and communicate with stakeholders.

Examples of analytical, decision-support, and visualization tools include Hazus [FEMA 2018a], Economic Decision Guide Software (EDGe$) [NIST 2018b], and Interconnected Networked Community Resilience Modeling Environment (IN-CORE) [van de Lindt et al. 2018; van de Lindt et al. 2018].

- Hazus [FEMA 2018a] estimates potential losses from earthquakes, tsunamis, floods, and hurricanes using GIS technology to estimate physical (e.g., buildings, some infrastructure systems), economic (e.g., job losses, business interruptions, repair and reconstruction costs), and social (e.g., shelter requirements, displaced households, exposed populations) impacts. It has three levels of analysis:
    - Level 1 – Default hazard, building and infrastructure inventory, and damage information
    - Level 2 – Combinations of user-input and default hazard, inventory, and damage data
    - Level 3 – User-input of detailed engineering data

  Level 1 analysis requires a limited amount of user input but the results also have reduced accuracy and confidence level. Levels 2 and 3 may provide more detailed or accurate results but require specialized knowledge for input preparation.
- The NIST Community Resilience Economic Decision Guide [NIST 2015] and EDGe$ tool [NIST 2018] provides a life-cycle cost analysis methodology to help communities prioritize and select cost-effective, community resilience projects that includes consideration of indirect benefits and co-benefits (e.g. reduction in air and water emissions, increased economic activity).
- The Center is developing the Interconnected Networked Community Resilience Modeling Environment (IN-CORE) [Center 2019; van de Lindt et al, 2018, van de Lindt et al, 2019], an analysis environment that will address the impacts of and recovery from hurricane, tornado, earthquake and flood events on the built environment and on community social and economic functions. It will also identify optimal solutions sets that meet community resilience goals to aid with resilience planning. The first release of IN-CORE, scheduled for December 2019, will facilitate community and user feedback to inform the development of the full version in 2022.

Other examples of available tools are included in Appendix 3.

4.2. Issues in Practice

4.2.1. Community Resilience Analysis Tools

Communities seek analytical tools that describe the impacts of hazards at spatial and temporal scales relevant to community decisions and investments for their built environment, social institutions, economy, and citizens.

Best practices are needed to guide the application of hazards and hazard scenarios in analysis tools for the built environment in communities. Analytical tools for assessing hazard impacts on individual facilities or infrastructure systems rely on either design criteria in standards or historical events for hazards less well-addressed by standards and codes, such as tornadoes, wildfires, or sea level rise. Methods and tools for assessing hazard impacts across a community's buildings or infrastructure systems often use hazard

scenarios to determine interdependencies between systems and direct and cascading impacts over a geographic area.

Analytical tools are needed to characterize the immediate damage and losses to physical, social, and economic systems, as well as their recovery. For example, some neighborhoods and populations are affected disproportionately by factors associated with the hazard: intrinsic vulnerabilities in the built environment, availability of resources, and challenges due to individual or family vulnerabilities. Existing tools for resilience planning primarily focus on mitigation planning, but do not include recovery models that reflect interdependencies and how they can vary with alternate mitigation options and/or recovery strategies. Further advances are needed for more complete assessments to support community resilience planning.

4.2.2. Decision-Support and Visualization Tools

As plans and solutions are identified to improve a community's resilience, tools are needed that can provide information to help decision-makers prioritize potential solutions. Information that quantifies the full range of benefits of resilience enhancement strategies, including non-monetizable benefits, is needed. Quantifying indirect benefits and co-benefits is needed to determine the value of resilience beyond the reduction in direct costs of repairing damage to the built environment.

In the process of developing resilience plans, communities face the challenge of understanding how their existing plans across multiple departments support or detract from their overall resilience goals. Tools are needed that can help decision-makers understand how proposed resilience projects and strategies impact existing plans and advance community resilience.

As alternative proposals are put forward and decisions are made, community leaders need tools to help them communicate effectively with their constituents and stakeholders and to obtain feedback. Geographic information systems (GIS) tools are used by many communities for data collection and to show current conditions and future impacts of plans graphically. However, additional tools are also needed for effective communication of resilience plans that convey risks, benefits, and changes over time for proposed resilience strategies.

4.3. Gaps and Needs

4.3.1. Analysis and Decision-Support Tools

Communities need analysis tools that can characterize their built, social, and economic systems and assess hazard impacts, determine expected damage and losses, and estimate rates of recovery across these systems. Tools for investment decision-support are also needed that address community risks and benefits of a particular project. Efforts to increase the utility of community resilience analysis and decision-support tools include:

- Develop best practices and standards for selecting hazard scenarios for community resilience analyses. Methods to characterize hazards not currently addressed by standards are needed to inform their inclusion in analysis tools.
- Develop and validate tools that characterize immediate damage and losses for hazard events as well as subsequent recovery of community system functions.
- Develop analysis tools to assess the effects of proposed resilience improvement projects or actions, their impacts on the population, businesses, organizations, and built environment, and the risks and benefits for community resilience.

4.3.2. Visualization Tools for Communication

GIS visually communicates information across geographic areas and can depict complex interactions or dependencies over space and time. Thus, GIS is often used to convey current or proposed future conditions across physical, social and economic systems. A complex issue, such as the spatial interactions of household income, infrastructure functionality, and land use on post-event recovery rates, can be conveyed relatively simply with overlays of each element, as indicated in Figure 4-1 [NIST 2016]. Similarly, GIS overlays at various points in time can also be used to identify cascading effects between systems.

Figure 4-1. GIS can be used to Communicate Co-Located System Interactions Graphically at the Community Level

Other visual methods may be required to help communicate the vulnerabilities, risks, and benefits of a plan or project to a community. For example, community values that are not easily characterized or quantified often play a large role in decision-making and may be represented with qualitative indicators. Examples include quality of life issues, such as maintaining historic districts or having more greenspace, such as parks, accessible to the public.

Visualization tools to support decision-making are often summarized by a suite or 'dashboard' of indicators or metrics that are aligned with community goals. Quantifying and presenting a range of indicators and metrics across physical, social, and economic systems can be challenging. Issues include relative weighting of each indicator relative to community priorities, consistent quantification methods, and meaningful indicators and metrics that are broadly understood.

Next steps to improve visualization tools for resilience include:

- Develop methods to graphically depict dependencies, vulnerabilities, risks, and benefits over space and time.
- Develop methods to help communicate qualitative indicators or values.
- Develop methods to effectively communicate a range of indicators and metrics across physical, social, and economic systems.

4.3.3. Opportunities for Engagement between Community Users and Tool Developers

Opportunities for engagement are needed to facilitate information exchange on tool development and use challenges between community users, including practitioners that support communities, and tool developers.

Two potential approaches are:

- Provide opportunities for community users to regularly interact with, support, and test the development of resilience tools with the goal of providing user community and feedback to developers. Existing analysis tool forums may provide useful examples of formats, support needs, and other experiences to support this need.

- Develop platforms and other opportunities to increase community-to-community sharing and learning to help both communities and developers of data and tools identify and promote best practices for resilience planning. Some of the most valuable learning opportunities come from community-to-community interactions. Communities share information about what tools are most useful, how to overcome challenges associated with incorporating new tools and information that they may not be familiar with and seeking support in resilience planning.

5. Community Resilience Planning

Community resilience planning has evolved over the last few decades, with more recent focus on comprehensive community planning for resilience before and recovery after hazard events. At present there is a wide range of approaches, tools, and supporting data for addressing natural hazards and future climate impacts, but a standard approach for community resilience planning is lacking. Additionally, those responsible for leading resilience efforts have a variety of backgrounds, including political science, business administration, emergency management, sustainability (including climate adaptation planning), and urban planning. While these skills, education, and experience are important, community resilience planning requires a multi-disciplinary skill set. This section explores how communities and their representatives currently undertake comprehensive community resilience planning and potential steps to advance the practice and field of community resilience planning.

5.1. Current Approaches

5.1.1. Community Resilience Planning Guidance

Resilience planning in communities has emerged as an important practice in recent years, prompted primarily by the damage and losses sustained in a number of wind, flood, and wildfire events. These events have demonstrated that reliance on federal aid, while important and valuable, is often insufficient to address long-term community resilience. Communities can do much more to reduce the severity of damage and plan for recovery when damage does occur. The following reports and activities are examples of efforts that helped develop that awareness.

- Starting in 2002, FEMA required communities to prepare hazard mitigation plans to qualify for their Hazard Mitigation Grant Program for assistance after disaster events [FEMA 2002]. Many communities have emergency management officials to manage this requirement and community planning for hazards,
- The BRIC index considers six categories of community resilience: social, economic, community capital, institutional, infrastructural, and environmental at the county level [Cutter 2010]. Used as a baseline for monitoring resilience to natural hazards (see Section 2.1.2), BRIC can be used to determine the specific drivers of resilience for counties and to monitor improvements in resilience over time.
- In 2011, Department of Homeland Security (DHS) FEMA released the National Preparedness Goal (NPG) [FEMA 2018c] which identified core capabilities across five mission areas—prevention, protection, mitigation, response and recovery. Each of these mission areas has guidance to help communities establish roles and responsibilities between local, tribal, territorial, state, and federal agencies for all types of disasters and emergencies [DHS 2015]. The risks include events such as natural disasters, disease pandemics, chemical spills and other manmade hazards, terrorist attacks and cyber attacks.
- The National Research Council report on Disaster Resilience [NRC 2012] examined the resilience of individuals, households, communities, and nation following the 2011 series of 14 weather related disasters. The current status of resilience planning was evaluated, with a call to develop a culture of resilience, which included transparent information on risks and vulnerabilities, resilience strategies at all levels of government, proactive investments and policy decisions, community coalitions to provide essential services before and after events, and rapid recovery with decreasing need for federal aid.
- The Rockefeller Foundation established the 100 Resilient Cities (100RC) global program, which was launched in 2013 [Rockefeller 2019a]. The program included shocks (e.g., natural hazards) as

well as stresses (e.g., unemployment, food shortages, inadequate public transportation) as part of resilience planning. Interested cities submitted applications to the 100RC program to receive support for a Chief Resilience Officer, expert support, access to service providers, and a global network of member cities. In April 2019, the Rockefeller Foundation announced the 100RC program was concluded, but that resources were committed to continue the resilience initiatives underway [Rockefeller 2019b].

- NIST conducted a series of national workshops on community resilience in 2014, which supported the development of the Community Resilience Planning Guide [NIST 2016]. The workshops addressed the resilience of physical, social, economic community systems and services, with input from a broad range of public and private stakeholders.
- As part of the recovery mission area, the Community Planning and Capacity Building Recovery Support Function developed the Pre-Disaster Recovery Planning Guide for Local Governments [FEMA 2017].

See Appendix 4 for other federal programs that provide support for community resilience planning and/or funding.

5.1.2. Community Resilience Planning in Communities

Communities may undertake resilience planning after being impacted by a disaster or proactively plan for future hazard events. While the specifics of scope and purpose varies, the following common activities occur when conducting community resilience planning, as outlined by the Guide [NIST 2016]:

Guide Step 1: Collaborative Planning Team

- Identify resilience leadership and engage key stakeholder representatives

Guide Step 2: Understand the Situation

- Characterize anticipated performance and vulnerabilities of existing physical, social, and economic systems

Guide Step 3: Determine Goals and Objectives

- Articulate resilience goals and methods to measure progress

Guide Step 4: Plan Development

- Develop a resilience plan that identifies solutions for vulnerabilities and community needs before and after disruptive events that aligns other community plans with resilience goals

Guide Step 5: Plan Preparation, Review, and Approval

- Ensure community involvement, support, and approval of resilience plans

Guide Step 6: Plan Maintenance

- Follow-up with implementation and monitoring of solutions to improve resilience

These activities are taking place in many communities, although the approach and scale of the efforts vary depending on the community's resources, motivations, and the availability of appropriate data and tools.

Community resilience planning approaches by four communities, which were presented at the October 2018 workshop [NIST 2018a], highlight similarities and differences in current practice.

- **Cedar Rapids, IA.** Cedar Rapids began resilience planning following the 2008 flood that displaced 10,000 residents, damaged 5,900 residential properties, and 1,133 commercial properties, caused

1,360 job losses, and damaged or destroyed 310 city-owned facilities. Recovery priorities were set for people and housing, business recovery, and public building recovery. Immediately after the flood, the City Council led recovery efforts with its residents to develop plans that would restore its pre-flood state and improve its resilience going forward. Within five months, the local government approved a River Corridor Reinvestment Plan that established a flood control system for the river corridor and guidance for rebuilding that included acquiring residential and commercial properties in floodplains, elevating new buildings to one foot over the 100-year flood elevation, maintaining the building codes and permit process to balance rebuilding quality with rapid restoration [Cedar Rapid 2012].

The residents contributed input on a vision and goals for Cedar Rapids, as well as plans for 10 neighborhood and transportation and infrastructure needs. Additional neighborhood plans have been developed over the past decade. Prior to the flood, the city developed a Downtown Revitalization Plan for the economy, which was adjusted after the flood. All these activities included a significant community engagement component.

- **Joplin, MO.** On May 22, 2011, an EF-5 tornado destroyed 4,000 structures in Joplin and damaged another 3,500 structures. A total of 158 people died as a direct result of the tornado; another three deaths were indirectly related to the event. Following the tornado, the City Manager and City Planner recognized the value of including the residents in the long-term recovery planning, which led to the formation of the Citizens Advisory Recovery Team (CART). A community-wide goal was to maintain Joplin's population. The first public meeting of the CART brainstormed and collected ideas for rebuilding. The second public meeting voted on the rebuilding ideas to support prioritization. The third meeting focused on making decisions to move forward which led to a CART Plan [CART 2013] that provided the city with a prioritized list of projects and programs. The city government still refers to the CART report when funding opportunities arise to identify projects for implementation.

  These meetings reflected two key tenets identified for communication and decision-making, noted in the workshop presentation: "Communication is not the dissemination of a decision, but the effort and inclusion of the appropriate people and organizations to make the right decision" and "If your partners and resources are affected by a decision yet don't have some ownership of it, the likelihood of successful completion diminishes greatly".

  During the recovery process, GIS mapping capabilities were used to monitor where people were located (with FEMA input) and properties for sale (realtor input) and under construction or demolition (permitting input). A notable gap was the need for expertise about housing assessments, financing, and solutions [CART 2013].

- **Nashua, NH.** Nashua is using the NIST Community Resilience Planning Guide [NIST 2016a] to develop a resilience plan that incorporates a Hazard Mitigation Plan (HMP) under the leadership of the Director of Emergency Management. The impetus to develop a resilience plan was prompted by the need to update their HMP. Nashua formed a Collaborative Planning Team (CPT) that included key stakeholders, such as residents, city staff, businesses, and nonprofits. The CPT identified the social functions that were important to the community and 500 buildings and infrastructure that support those functions. Data were collected on the 500 buildings to evaluate the anticipated performance of the buildings and infrastructure for hurricanes, earthquakes, and floods using Hazus [FEMA 2018a] and to identify vulnerabilities. Challenges included selecting hazard scenarios for evaluation and communicating community vulnerabilities and risks. Community goals of desired performance were established with input from community stakeholders.

- **Oregon Resilience Plan (ORP).** The ORP was published in 2013 by the Oregon Seismic Safety Policy Advisory Committee [OSSPAC 2013]. This statewide plan was developed using a scenario magnitude 9.0 earthquake on the Cascadia Subduction Zone Fault to estimate damage to buildings

and infrastructure. The expert judgement and consensus of 169 volunteers was used to set goals for and determine the anticipated recovery time of buildings and infrastructure in four zones of the state. Resilience goals were based on business and community needs for each zone. The resilience goals included acceptable target timeframes to recovery essential functions in communities (e.g., electricity, police and fire services, water and sewer, highways, and healthcare). The target timeframes account for the fact that businesses can only tolerate two to four weeks of disruption of essential services. The planning process identified large gaps between the desired and anticipated performance across the built environment and provided recommendations for statewide policies and actions to achieve the desired performance targets. Projects at the local level are underway.

5.1.3. Community Resilience Guidance

Guidance methods or processes help communities develop technically credible planning documents.

Examples of community resilience guidance include the Plan Integration Scorecard (Scorecard) [Masterson et al. 2017], the NIST Community Resilience Planning Guide (Guide) [NIST 2016a and 2016b], and ASTM E3130-18 Standard Guide for Developing Cost-Effective Community Resilience Strategies [2018].

- The Scorecard compares community plans to improve their coordination and identify gaps and inconsistencies. Additional tools are being developed at the state and local level, such as guidance for land use planning, zoning, and climate planning [CO-DOLA 2019].
- The Guide provides a 6-step planning process to help communities engage all their stakeholders, characterize and evaluate their existing community social, economic, and physical systems for hazard events, determine community resilience goals, and develop and maintain community plans that incorporate the resilience goals.
- ASTM E3130-18 provides an economic framework to evaluate investment strategies to help communities with a standardized approach for their resilience planning.

5.2. Issues in Practice

The concept of community resilience emerged over the past two decades following the series of disaster events experienced across the country that included the human-caused disasters on September 11, 2001, and other natural disasters (e.g., earthquakes, wind, flood, wildfire). Significant risk continues to exist across the nation for substantial damage from hazard events due to urban development, population growth, and aging infrastructure [McAllister 2013].

While federal assistance is available to help communities and states that are overwhelmed by a disaster event, there was an observed disconnect between community planning for growth and preparations for hazard events. For example, community planning for hazard mitigation, response, and recovery is being addressed by many more communities, but it is often not incorporated into other community plans, potentially leading to conflicting goals between plans in communities.

Even today, communities have many plans, such as comprehensive or general plans, economic development plans, public works plans, and hazard mitigation plans. However, these plans often do not address the same community goals, consider vulnerable populations or recovery plans. To improve community resilience, communities need tools and metrics to proactively identify their resilience goals, characterize their current community conditions, identify gaps in performance, integrate all community plans around resilience goals, and develop prioritized solutions that advance their resilience.

To enable community resilience planning, leaders with broad multi-disciplinary training are needed. However, curricula for community resilience education and professional certificate programs have yet to be developed.

5.3. Gaps and Needs

Community resilience planning is underway across the United States. As planning efforts evolve and mature, gaps in standard approaches and supporting methods are being identified. However, many community resilience leaders' expertise and training are based on prior professional experience and backgrounds in disciplines such as emergency management, sustainability, urban planning, or city management. The following steps will help advance community resilience leadership and planning:

- A standard approach to community resilience planning will improve the basis for developing a core set of indicators, metrics, and associated data, facilitate community collaboration, and develop risk-consistent measures for evaluating investment strategies that enhance community resilience.
- Resilience education should be formalized to help leaders and technically skilled workers address the range of disciplines, stakeholders, and issues required for community resilience planning, including planning, mitigation, adaptation, and recovery of physical, social, and economic systems and services; this could be achieved through accredited academic curriculum or professional certification programs.

6. Funding Sources and Economic Decision-Support

Success for any resilience planning effort will be measured by a community's ability to implement the actions recommended and realize the outcomes described in the plan. Plan implementation requires a community to identify funding sources, raise revenue, and provide operational support to (possibly new) administrative roles supporting recovery.

Communities may seek options, approaches, and tools that allow them to transition their resilience plans into tangible capital projects and administrative programs. To accomplish this, economic decision-support tools are needed to help establish project funding priorities and demonstrate the economic benefits of projects.

6.1. Current Approaches

6.1.1. Federal Programs

The role that federal agencies play in administering pre- and post-event mitigation and recovery programs is essential to improving community resilience. Their engagement and outreach efforts to communities are a primary method for raising awareness of available funding. Community input indicated that federal program requirements drive many project implementation decisions and help communities prioritize actions before and after an event. Appendix 4 lists examples of federal funding assistance resources.

The National Mitigation Investment Strategy (NMIS) [MitFLG 2019] was published recently and includes several priority actions that aim to serve community stakeholders by conducting outreach to raise awareness of funding opportunities. The NMIS identifies the need to simplify the process for acquiring funding and reporting requirements.

The HUD Office of Community Planning and Development (CPD) [HUD 2019a] promotes integrated approaches for housing, living environments, and economic opportunities for low and moderate income persons through development of partnerships between public and private entities. These approaches are encouraged for application to HUD grant programs.

The U.S. Economic Development Administration (EDA) is partnering with HUD to facilitate the ability of communities, regions and states to access and co-invest agency resources for comprehensive, high-impact economic and community development projects [EDA 2019]. Under EDA's Economic Development Integration Team and the HUD CPD, a series of voluntary guidance tools are being developed to conduct comprehensive streamlined planning processes that satisfy the criteria for both an EDA Comprehensive Economic Development Strategy (CEDS) and a HUD Consolidated Plan.

6.1.2. Internal and Outsourced Knowledge and Experience

Communities may have internal staff resources dedicated to resilience funding management or they may outsource these responsibilities by hiring a contractor. Many communities use both approaches to varying degrees.

Additionally, communities rely on their neighboring communities for mutual aid and to gain knowledge about preparation for hazard events. Communities that have faced significant recovery processes can guide their counterparts facing similar circumstances. Communities also plan on technical support from volunteer community organizations, such as faith-based organizations and the American Red Cross [NVOAD 2019].

6.1.3. Business Case for Resilience

To realize large community resilience projects, such as improvements to at-risk properties or replacement of infrastructure, funding is often required from public and private sources. Such projects often have large initial costs but can accrue much greater benefits before and after hazard events to the properties and community over time. Accounting for "co-benefits" of resilience projects, such as business growth and property value appreciation, builds a business case for private sources of funding for resilience projects [Helgeson et al. 2018]. Current practice focuses on short-term direct returns for the investments. The challenge of 'monetizing' the resilience dividend over longer periods of time is not well-addressed and needs accepted methods, tools, and financial instruments for such applications [Fung and Helgeson 2017, RMS et al. 2018].

Tools are being developed to identify measures to promote more resilient designs that are cost effective. The EDGe$ tool [NIST 2018] and the associated Economic Decision Guide [NIST 2015] help identify and compare the relevant present and future resilience costs and benefits associated with new capital investment alternatives versus maintaining a community's status-quo.

The RAND Corporation and the Rockefeller Foundation formed a partnership to develop a framework to estimate the net benefits of a resilience project [Bond et al. 2017], the Resilience Dividend Valuation Model (RDVM). The framework defines the resilience dividend to include the net benefits associated with the absorption of shocks and stressors, the recovery path following a shock, and co-benefits that accrue from a project, even in the absence of a shock.

The National Institute of Building Sciences recently published a report of an interim study that examined two sets of mitigation strategies and found that society saves $6 for every $1 spent through mitigation grants funded through select federal agencies [NIBS 2017]. There was a corresponding benefit-cost ratio (BCR) of 4:1 for investments that exceeded select provisions of the 2015 model building codes.

6.2. Issues in Practice

6.2.1. Identifying Funding Sources for Community Resilience Planning and Project Implementation

Communities may interact with a number of funding programs to help them prepare for and recover from hazard events. Funding sources may include the federal and state governments, nonprofit organizations, insurance, in-kind support from volunteers, and their own resources.

Prior to a hazard event, communities often find that the requirements for funding mitigation and preparedness projects are complex or challenging. After a disruptive hazard event, community leaders are faced with responding to the near-term needs of their citizens, including the protection of life and property, while also navigating the requirements of recovery funding programs and long-term alignment of community growth with resilience plans.

6.2.2. Economic Decision-Support Tools

The benefits of resilience projects may include cost savings and avoided damages because enhancing resilience on a community-scale can create value and benefits, even if a hazard event does not occur. For example, two solutions to the same resilience issue may have different associated co-benefits (i.e., benefits that accrue on a day-to-day basis even if a disruptive event has not yet occurred), which are also referred to as the resilience dividend [Rodin 2014]. Inclusion of co-benefits in the evaluation of community resilience projects avoids underestimating the total value of a resilience project. To date, quantification of the net co-

benefits of resilience planning is not often addressed, as it is not a straight-forward task [Fung and Helgeson 2017]. Additionally, federal programs may not permit accounting for co-benefits.

When evaluating potential solutions to achieve resilience goals, communities need tools that help evaluate projects on their relative contribution to resilience goals, community benefits, and their financial merit. There are several factors associated with this challenge: communities may not be aware of existing economic decision-support tools that could meet their needs, current tools may not be compatible with community management systems or meet a grant program's requirements, or current tools may lack features needed for full evaluation of resilience considerations.

6.2.3. Financial Instruments to Finance and Monetize Benefits of Resilience Projects

Implementing resilience projects often requires new sources of financing, which may involve a combination of public and private sources. Financial instruments that fund a wider range of community resilience projects are needed. Communities indicate that both public and private financial instruments do not currently account for broader resilience benefits (i.e. indirect benefits and co-benefits), which can help demonstrate a positive financial return for investors. The current financial instruments limit the ability of communities to raise the necessary capital for these projects.

6.3. Gaps and Needs

6.3.1. Increase Awareness and Coordination of Resilience Funding Resources

Most communities have limited resources for identifying potential funding sources. Websites and other support mechanisms that identify sources of funding and assist with the application process would be valuable to communities. Consolidated guidance for resource opportunities that increase awareness of funding opportunities would benefit communities. One approach could be to:

- Develop websites that maintain consolidated up-to-date listings of funding programs and sources, and associated requirements, to inform and educate communities about funding opportunities.

6.3.2. Recognition of Resilience Benefits in Financial Products

Communities find it challenging to obtain private sector financing for funding resilience projects. The benefits of resilience need to be characterized in ways that 'make the business case' for resilience investments and that are recognized by the financial sector, including:

- Engage with the financial sector to identify economic data and information needed to assess the value of resilience planning and implementation. This could include representatives of municipal bond markets, insurance markets, and capital markets.

6.3.3. Economic Decision-Support Tools

Economic decision-support tools beyond direct costs and benefits will help communities to fully characterize and prioritize resilience investments. The following steps will advance the quality of existing tools:

- Identify the benefits of resilience planning and project implementation, including indirect benefits as well as co-benefits (i.e., the resilience dividend), and develop standard methods for their evaluation. A comprehensive list of the types of benefits associated with resilience, and how they should be evaluated, will improve support provided for community decision-making.

- Ensure compatibility with existing tools and benefit-cost analysis methods that are required by many public and private funding programs.
- Develop economic decision-support tools that are recognized by funding programs and finance institutions for use by communities. Economic decision-support tools should consider community decision-support information needs before, immediately and after hazard events, be compatible with common community project evaluation requirements, and be recognized by external funding programs.
- Incorporate all net benefits of resilience planning into economic decision-support tools for community resilience. Tools are needed that can characterize the full range of potential benefits that may accrue to a community during and after resilience projects are implemented with quantification of benefits and externalities beyond traditional avoided loss quantification, including potential co-benefits accrued in the absence of a hazard event.

7. Communication with Stakeholders

Community resilience includes multiple social, economic, and physical systems across the geographic bounds of a community. There are also a range of interests, values, and perspectives across communities. Effectively communicating the risks and benefits associated with the likely outcomes of resilience plans, strategies, and decisions to community leaders, residents, and businesses is critical to community understanding and willingness to adopt and implement resilience strategies.

A community resilience plan is more likely to be implemented if it is embraced by the residents and stakeholders, endorsed by policy officials, and actionable for those who must implement the plan. Through engagement and outreach, the resilience plan will evolve and take form, generate support among community leaders, and be understood by the general public.

7.1. Current Approaches

Formation of a representative community resilience planning team and frequent communication with stakeholders during resilience strategy development is key to building trust and incorporating community input. A variety of communication methods should be used, including meetings, news and social media, and websites. Visualization tools, from GIS maps to storyboards, can help provide compelling and effective communication support, as described in Chapter 4. Best practices to aid community officials with stakeholder communication are discussed in NIST Guide Brief 14 [2019b].

According to best practices identified by practitioners and researchers [Bergstrom et al. 2012; Herefordshire Council 2015], the benefits of community engagement—including engagement associated with project planning, infrastructure development, and resilience planning—are:

- Increased legitimacy and support
- Increased ownership and buy-in
- More effective implementation of projects and plans resulting from local knowledge and input
- Increased networks, communication, and trust among planners and community members
- Reduced long-term costs

A review of best practices and research findings for risk communication and behavior by NOAA [2019a] focuses on natural hazard events (i.e., tornado, severe wind, flood, tropical cyclone, tsunami, volcano and wildfire). A set of recommended practices are outlined: have an informed plan, speak to their interests not yours, explain the risk, offer options for reducing risk, work with trusted sources and the public, test messages or products, and use multiple ways to communicate. These recommended practices are the foundation for a NOAA guideline [2019b] for natural hazard risk communication, which outlines a process for developing a strategy to communicate risk and uncertainty to stakeholders.

7.1.1. Community Resilience Risks and Benefits

Communicating risks requires the ability to convey the key findings, and unknowns or uncertainties associated with its components: hazard, vulnerability, and consequences.

For instance, when communicating hazard information, many stakeholders do not understand the probabilistic terminology used by researchers and professionals. For example, mean recurrence intervals (MRI) describe the average rate of occurrence for hazards, where a 100-year MRI refers to a flood event that occurs once every 100 years on average over a longer time period (e.g., approximately ten times over a thousand years). A 100-year MRI can also be described as having a one percent chance of occurring each year. Both of these measures convey the same event, but they may be interpreted differently.

Examples of communication challenges for probabilistic hazard occurrence descriptions include:

- The average person does not understand what a 100-year flood event is or why it can occur more frequently than once every 100 years.
- When people hear about 500 or 1,000-year events, they tend to dismiss them because these are so much greater than their own realm of experience or life span.
- For certain natural hazards, the annual probabilities that are sufficiently small (or MRIs are sufficiently large) that the risk may be considered negligible or acceptable.

Some hazards cannot be represented accurately with MRIs as there are insufficient data for mean recurrence interval estimates or probability analysis. Additionally, hazard characterizations based solely upon statistical analysis of historical hazard event data do not address or account for future changes in hazard intensity or frequency due to climate change effects (e.g. sea level rise, temperature, precipitation, severe storms, coastal flooding).

Analysis of vulnerabilities and consequences focuses on the damage to buildings and infrastructure systems, and the loss of functionality for social and economic systems. Impacts to infrastructure may be assessed through a combination of engineering analyses, historical records of damage and insurance payouts, and expert judgement. Loss of functionality may be assessed through a combination of infrastructure impacts, analysis of population dislocation and economic losses, historical records, and expert judgement. Where information is not available, assumptions are made to complete the assessments.

Once the failures, losses, and injuries are estimated, the consequences to community functionality and recovery may be estimated in terms of time, monetary impacts, and opportunity costs. Consequences may be assessed through a combination of economic analysis, expert judgement, and historical records of consequences and recovery.

The ‘do nothing’ option provides a baseline to compare proposed resilience strategies or individual projects for consequences. Communities and stakeholders may use different goals and metrics to guide the comparison. Consistent benefit evaluation between alternative strategies is essential for comparison and presentation purposes.

7.2. Issues in Practice

7.2.1. Community Resilience Strategies and Decisions

Community resilience strategies, which include goals, plans, and solutions for implementation, take time to develop and require input from a range of stakeholders during the development process. There are several issues that can impede acceptance and adoption of resilience strategies: community resilience strategies, which include goals, plans, and solutions for implementation, take time to develop and require input from a range of stakeholders during the development process. There are several issues that can impede acceptance and adoption of resilience strategies:

- Lack of engagement of all stakeholders can lead to significant gaps in the plans, and loss of support.
- Broad geographic distribution of interdependent community systems can make resilience strategies and how they affect various systems and stakeholders challenging to convey.
- Difficulty in communicating risks and benefits in terms of various stakeholder interests.
- Insufficient support for the actions described in the resilience strategy when lack of stakeholder engagement leads to missing issues the community wants to address.

7.2.2. Community Resilience Risks and Benefits

Effectively communicating risks and benefits to a range of community stakeholders requires presentation of complex information in a context that is meaningful and relevant to all stakeholders. Stakeholders include residents, vulnerable populations, public and private businesses, institutions, nonprofits, and government agencies.

Risk is often described with three components: probability of a hazard event (*hazard*), probability of a negative outcome (failure, loss, injury) for a given the hazard (*vulnerability*), and the consequences of the hazard and outcome (*consequences*). These components are often summarized as follows:

Risk = Hazard x Vulnerability x Consequences

While this conceptual description of risk is more easily understood by the public, the computation of risk by professionals can be complex, with each component of risk requiring separate analyses with estimated or incomplete information. Interpreting and conveying risks from analyses of a single system can be challenging. The challenge is amplified for community resilience when multiple physical, social, and economic systems are included.

Similar issues exist for communication of benefits related to a proposed strategy or individual project. Resilience benefits can provide short- and long-term benefits. A more complete measure of benefits includes direct, indirect, and co-benefits (see Appendix 1). However, methods and approaches to monetize indirect and co-benefits are difficult to assess and can be a significant source of variability between analyses.

7.3. Gaps and Needs

7.3.1. Community Resilience Strategies and Decisions

The methods for community communication identified in Section 7.2.1 provide examples of current practices, but a comprehensive evaluation of these methods is lacking. The following action would advance the knowledge in this area:

- Collect and disseminate best practices for communicating the elements of resilience strategies. Best practices and methods for community communication need to be applied, evaluated, and refined with a focus on effective communication with a broad range of stakeholders and community sizes.

7.3.2. Community Resilience Risks and Benefits

Presenting risk and its components in terms that can be better understood for a range of stakeholder contexts is needed. As an example, the probability of hazard occurrence could be expressed in terms of a 30-year mortgage, as shown in Table 7-1. Rather than presenting hazard information in terms of MRIs or an annual probability of occurrence, the probability of hazard occurrence over a period of time may be more meaningful to people. For instance, the risk of an event with an MRI of 30 years is 64% over that time period, which may be more meaningful to home and business owners and financial institutions.

Similarly, methods to convey vulnerabilities and consequences of hazard events that convey the impacts to individuals, businesses, and the community are needed.

Table 7-1. Example of Ways to Communicate the Probability of Hazard Occurrence

MRI (years)	Annual Probability of Occurrence	Probability of Occurrence over 30-Years
30	3.3%	64%
50	2%	45%
100	1%	26%
500	0.2%	5.8%
700	0.14%	4.2%
1,000	0.1%	3.0%
1,700	0.059%	1.7%
2,500	0.040%	1.2%

The following actions can improve communication of risks and benefits for community resilience planning and support:

- Identify approaches to present risks and benefits in terms that can be understood by all stakeholders.
- Improve methods for communicating hazard exposure, vulnerability, and consequences. Tested approaches are needed for presenting vulnerabilities, risks, and losses associated with hazard events, the anticipated recovery of community functions, and short- and long-term benefits for proposed resilience strategies.
- Develop methods to incorporate future projections of changes in hazard profile (e.g. intensity, frequency) due to estimated impacts of climate change on sea level rise, temperature, precipitation, severe storms, and coastal flooding.

8. Summary and Potential Next Steps

Community officials responsible for resilience planning are charged with a significant technical, organizational, and administrative undertaking. Their efforts require collaboration across multiple government departments and offices, and community stakeholders. They also need to lead technically complex data collection, modeling, and analysis. Lack of guidance on how to identify and integrate the data, information, and tools from a variety of disciplines remains a challenge to effective resilience planning efforts.

The organizations that support resilience planning span a wide range of research organizations, government agencies, private sector firms, non-governmental organizations, and communities. The October 2018 workshop on *Data Needs for Resilience Planning and Decision-Making*, hosted by NIST and the Center, brought together many of these stakeholders. The issues, challenges, and next steps identified by this diverse set of stakeholders provide insights into the status of the growing field and practice of resilience planning and informs future efforts.

Summary of Potential Next Steps for Collaboration Among Communities, Practitioners, and Researchers

1. Developing Community Resilience Indicators and Metrics: Communities establish resilience goals to prioritize actions to address hazard risk and support resource allocation decisions. This would ideally be accomplished through a rigorous assessment that uses validated indicators and metrics to track progress toward meeting community resilience goals. Steps to advance the development of resilience goals and metrics include:
    - Development of a core set of indicators and metrics to assess the performance and functionality of social, economic, physical, and natural systems before and after hazard events.
    - Establishment of data requirements and sources for core indicators and metrics, including spatial scales and temporal frequencies.
    - Development of methods to integrate and aggregate (or de-aggregate) multi-disciplinary data for indicators and metrics.
2. Improving the Accessibility and Use of Community Resilience Data and Information: Analysis for community resilience planning often starts with a community's internal information resources and expands to external information resources that need to be processed and adapted to a specific community's needs and circumstances. There are opportunities across sectors and organizations to work together to aid communities in these data and information efforts through:
    - Development of data standards, that include open data principles and policies, with the engagement of standard development organizations involved in resilience planning.
    - Establishment of data standards that address classification and metadata and technical requirements for data quality control and accessibility, based on the evaluation of established data standards for community-level spatial scales and integration of interdisciplinary datasets.
    - Establishment of data management best practices that address user needs and compatibility with common data tools and platforms used by communities, such as GIS analysis tools.
    - Development of data curation and dissemination models through collaboration of organizations and sectors involved in the development, dissemination, and use of data and information sources.

3. Increasing the Utility and Dissemination of Community Resilience Tools: Planning tools allow communities to analyze potential hazard exposure, characterize built environment vulnerabilities, translate these vulnerabilities to associated social functions, and effectively communicate risks and associated resilience goals with constituents and stakeholders. While there are a number of analysis and visualization tools publicly available, steps to increase the utility of existing and future community resilience tools include:

    - Development of best practices and standards for selecting hazard scenarios for community resilience analyses, including hazards not currently addressed by standards.
    - Validation of tools that address immediate damage and losses for hazard events, the subsequent recovery of community systems, and the ability to compare alternative resilience project impacts.
    - Development of methods to communicate and visually depict analysis results, such as dependencies, vulnerabilities, risks and benefits, and indicators and metrics over space and time for community systems.
    - Development of platforms and opportunities to increase community-to-community sharing and learning to help both communities and developers of data and tools regularly interact and test the development of tools and provide feedback to developers.

4. Advancing the Practice of Community Resilience Planning: While the value of community resilience planning continues to grow in terms of awareness and recognition, it remains a relatively new concept that involves multiple disciplines and government departments. Planning approaches often vary from community-to-community and there is a lack of standardization across these approaches and methods. The following steps will advance the practice of community resilience planning:

    - Development of a standard approach to community resilience planning, including the use of a core set of indicators and metrics and risk-consistent measures for evaluating investment strategies that enhance community resilience.
    - Formalization of resilience planning education opportunities to help professionals from various disciplines to work with the range of disciplines, stakeholders, and issues required for community resilience planning.

5. Advancing Economic Decision-Support Tools: Implementation of resilience plans requires communities to identify, organize, and acquire public and private sector funding. Identification of these funding resources and understanding the respective application and requirements of each is a resource- and time-intensive administrative undertaking. Further, in support of plan implementation, communities seek economic decision-support tools that allow them to fully account for the cost and the full range of potential benefits that may accrue to a community during and after resilience projects are implemented. These needs could be addressed through efforts such as:

    - Development of a publicly available compendium of funding programs and sources, and associated requirements, to inform and educate communities about funding opportunities.
    - Determination of the benefits of resilience planning and project implementation, including indirect benefits as well as co-benefits (i.e., the resilience dividend) that result in the development of standard methods for their evaluation.
    - Development of economic decision support tools that are recognized by funding programs and finance institutions for use by communities that incorporate all net benefits of resilience planning.

6. Supporting Community Stakeholder Communication and Engagement: Community resilience planning involves engagement and input from community members and developing a representative planning team for these various stakeholder groups. The involvement and input of community members through the process of developing a resilience plan needs to be representative of community values and objectives. To aid community officials, needed advancements in communication methods include:

    - Identification of best practices for communicating resilience strategies and anticipated outcomes that address the broad range of stakeholders for a range of community sizes.
    - Development of approaches to present risks and benefits in terms that can be understood by all stakeholders. This would include improving methods for communicating hazard exposure (including future projections in changes of hazard profile due to impacts of climate change), vulnerability, and consequences.
    - Develop methods to incorporate future projections of changes in hazard profile (e.g. intensity, frequency) due to estimated impacts of climate change on sea level rise, temperature, precipitation, severe storms, and coastal flooding.

Conclusion

As communities across the nation conduct resilience planning efforts and implement projects that reduce their vulnerabilities to hazard events, their needs for data, information and tools are becoming clearer. The following principles continue to apply to all the topics addressed in this report:

- Collaborate broadly across sectors and disciplines. Successful implementation of resilience planning lies within no single sector or discipline. All sectors have a role and various responsibilities for supporting the planning and subsequent projects within community resilience plans. Addressing many of the issues identified in this report and the success of future community resilience efforts is enhanced when many sectors collaborate to achieve common objectives and goals.
- Focus on community end-users. As new data, information, and tool resources are developed, the perspective of the various end-users should continually be considered through community engagement practices. Various end-user goals, resources, and skill sets can inform the ultimate curation, dissemination, and future successful use of these important uses. Further, end-user needs serve as inspiration for future technical and research efforts to enhance community research.

Glossary of Acronyms

100RC	100 Resilient Cities
ACS	American Community Survey
APA	American Planning Association
BCR	Benefit-cost ratio
BLS	Bureau of Labor Statistics
BRIC	Baseline Resilience Indicators for Communities
BRIC	Building Resilient Infrastructure and Communities (BRIC) Program
CART	Citizens Advisory Recovery Team
CASPER	Community Assessment for Public Health Emergency Response
CDBG	Community Development Block Grant
CDBG-DR	Community Development Block Grant Disaster Recovery
CDC	Centers for Disease Control and Prevention
CPT	Collaborative Planning Team
CRAFT	Community Resilience Assessment Framework and Tools
DHS	Department of Homeland Security
DRRA	Disaster Recovery Reform Act
EDA	Economic Development Administration
EDGe$	Economic Decision Guide Software
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FFE	First floor elevation

FIMA	Federal Insurance and Mitigation Administration
FIRMs	Flood Insurance Rate Maps
GIS	Geographic Information Systems
HGMP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HUD	Department of Housing and Urban Development
HVA	Health Vulnerability Analysis
HVAC	Heating, ventilation, and air conditioning
ICMA	International City/County Management Association
IN-CORE	Interconnected Networked Community Resilience Modeling Environment
MRI	Mean recurrence interval
NACo	National Association of Counties
NADO	National Association of Development Organizations
NARC	National Association of Regional Councils
NDRF	National Disaster Recovery Framework
NETS	National Establishment Time Series database
NFIRS	National Fire Incident Reporting System
NIST	National Institute of Standards and Technology
NLC	National League of Cities
NMIS	National Mitigation Investment Strategy
NOAA	National Oceanic and Atmospheric Administration
NPG	National Preparedness Goal

ORP	Oregon Resilience Plan
PDM	Pre-Disaster Mitigation
RDVM	Resilience Dividend Valuation Model
RRAP	Regional Resilience Assessment Program
SHELDUS	Spatial Hazard Events and Losses Database for the United States
STAPLEE	Social, Technical, Administrative, Political, Legal, Economic, Environmental
THIRA	Threat and Hazard Identification and Risk Assessment
TRI	Toxic Release Inventory
USACE	US Army Corps of Engineers
USGS	US Geological Survey

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Appendix 1. Definitions

Term	Definition
Baseline	A value that represents normal levels of functionality or services, established at a discrete point in time with historical data, against which changes in performance can be evaluated [Cutter and Derakhshan 2019].
Benefits	Positive returns realized from resilience planning. Benefits include direct, indirect, and co-benefits. Benefits encompasses economic and non-economic (i.e., no market price) positive effects from resilience planning. • Direct benefits account for positive returns that are intended outcomes of a resilience project or strategy. • Indirect benefits account for additional positive returns that are not a direct outcome but are nonetheless realized due to a resilience project or strategy. • Co-benefits account for the positive returns from a resilience project or strategy that improve community function and value even when a hazard event has not occurred.
Buildings	Individual structures with a roof and walls, including equipment and contents, that house people and support social institutions.
Built Environment	All buildings and infrastructure systems that are designed and constructed to support services and functions.
Clusters	A set of buildings and supporting infrastructure systems that serve a common community function, such as housing, healthcare, retail, etc. Clusters may be geographically distributed across a community,
Community	In the National Preparedness Goal (NPG), the term "community" refers to groups with common goals, values, or purposes (e.g., local businesses, neighborhood groups). In the NIST Community Resilience Planning Guide, the term "community" refers to a place designated by geographical boundaries that functions under the jurisdiction of a governance structure, such as a town, city, or county. It is within these places that people live, work, play, build their futures, and develop goals and plans.
Community Resilience	The ability of a community to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions [PPD-21, 2013].

Term	Definition
Composite indicator	A mathematical aggregation of multiple indicators to assess a multi-dimensional concept (e.g., community healthcare) that cannot be captured by a single indicator (https://stats.oecd.org/glossary/detail.asp?ID=6278) (Sasiana and Tarantola 2002).
Critical Facilities	Buildings that support functions and services related to life safety and are intended to remain operational during and immediately after hazard events. These facilities are sometimes referred to as essential buildings.
Critical Infrastructure	"Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters" [PPD-21, 2013].
Data	Objective, quantitative facts (e.g., length, time, quantity) and subjective, qualitative non-numerical observations (e.g., interviews). Note that qualitative data can be quantified (e.g., ratings on a scale of 1 to 10).
Dependency	The reliance of physical and/or social systems on other physical and/or social systems to function or provide services.
Disaster	A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources [National Science and Technology Council, 2005].
Hazard	A potential threat or an incident, natural or human-caused, that warrants action to protect life, property, the environment, and public health or safety, and to minimize disruptions of government, social, or economic activities [PPD-21 2013].
Indicator	Parameter based on one or more quantitative or qualitative measures that when measured over time can point out the direction of change (Freudenberg 2003: 7).
Information	Data that has been processed and/or organized into an understandable and usable format.
Infrastructure System	Physical networks, systems, and structures that make up transportation, energy, communications, water and wastewater, and other systems that provide services for people and social institutions.
Measure	Observed, quantitative data at a single point in time.
Metric	A standard of measurement for performance or progress (Black et al. 2009). A *metric* may be based on a *composite indicator* that has demonstrated sensitivity to support decision-making for its intended application.

Term	Definition
Mitigation	Activities and actions taken to reduce loss of life and property by lessening the impact of hazard events.
Resilience	"The ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies" [PPD-8, 2011]. "The ability to prepare for and adapt to changing conditions and to withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents" [PPD-21, 2013].
Risk	Possibility of loss or injury due to the impact of a hazard event on a system, given its condition or vulnerability.
Shelter-in-place	Safely remaining in a building, e.g., a residence, during or after a hazard event.
Social Institutions	Formalized delivery of services for the welfare of society, including healthcare, education, governance, banking, business, etc.
Target	A value for future levels of functionality or services, which specify changes to baseline values, against which changes in performance can be evaluated.
Tools	Instruments, models, or analysis methods that are used to collect, process, and organize data into useful information, or to analyze relationships between data sets.
Vulnerable populations	Groups of individuals within a community whose needs may go unmet before or after a disaster event, including the elderly, people living in poverty, racial and ethnic minority groups, people with disabilities, and those suffering from chronic illness. Additional social vulnerabilities can include renters, students, single-parent families, small business owners, culturally diverse groups, and historic neighborhoods.

Appendix 2. Examples of Data Sources Discussed in Workshop

National Data Sources

- Center for Disease Control (CDC) Community Assessment for Public Health Emergency Response (CASPER, https://www.cdc.gov/nceh/hsb/disaster/casper/default.htm): household information for rapid needs assessment
- CDC Social Vulnerability Index (SVI, https://svi.cdc.gov/): population, household, transportation data
- Census Bureau, Decennial Census (https://www.census.gov/programs-surveys/decennial-census/data.html) and American Community Survey (ACS, https://www.census.gov/programs-surveys/acs): population and household data
- Department of Health and Human Services (HHS) empower (https://empowermap.hhs.gov/): location of Medicare beneficiaries with electrically powered medical equipment
- Environmental Protection Agency (EPA) Toxic Release Inventory (TRI, https://www.epa.gov/toxics-release-inventory-tri-program): toxic chemical releases and pollution prevention activities reported by industrial and federal facilities
- Federal Emergency Management Agency (FEMA) Flood Map Service Center (https://msc.fema.gov/portal/home): official public source for flood hazard information produced in support of the National Flood Insurance Program (NFIP)
- FEMA NFIP insured properties (https://www.fema.gov/policy-claim-statistics-flood-insurance): current and historical NFIP policy and claims statistics, including information about significant historical NFIP flooding events
- FEMA NFIP Community Rating System (CRS, https://www.fema.gov/national-flood-insurance-program-community-rating-system): fact sheets, contact information, a national map of participating communities, details about how community discounts are calculated, and other information about the Community Rating System
- National Fire Incident Reporting System (NFIRS, https://www.nfirs.fema.gov/): reports by US fire departments on fires and other incidents
- National Land Cover Database (NLCD, https://www.mrlc.gov/): land cover, impervious surface, and shrubland data
- National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP, https://coast.noaa.gov/digitalcoast/tools/lca.html): coastal land cover and land cover change information
- Spatial Hazard Events and Losses Database for the United States (SHELDUS™, https://cemhs.asu.edu/sheldus): county level hazard data set for the US for historic events and associated losses from 1960 to present [Arizona State University 2018].

Other Data Sources

Local data:

- Building age as proxy for building code and expected performance
- Status of building retrofits
- Tax assessor information

- Number of dwelling units
- Construction type
- Age of construction
- First floor elevation (FFE)
- Building code governing construction
- Location of heating, ventilation, and air conditioning (HVAC) systems and other mechanical, electrical, and plumbing systems
- Assessed value of structure
- Major modifications
- Sales tax data as a proxy for social equity

Desired Data

- Business continuity and supply chain
- FEMA National Risk Index (available 2020)
- Financial health and resource access (insurance, bonds, etc.)
- Hazard risks and impacts for local use by communication
- Housing damage impacts on demographics
- Infrastructure dependencies
- Infrastructure performance – public and private systems
- Insurance coverage
- Insurance loss data
- Physical asset condition and performance assessment
- Public health event impacts
- Shelter capacity
- Spatial assessment of physical infrastructure
- Storm surge and land loss over time
- Vegetation data for wildfire
- Vulnerable populations
- Vulnerability of social/economic community systems

Appendix 3. Examples of Current Publicly Available Community Resilience Tools

There are many tools and guidance documents that are publicly available for use in resilience planning. A sampling of tools and guidance documents includes:

- Guidance documents
  - FEMA Social, Technical, Administrative, Political, Legal, Economic, Environmental (STAPLEE) criteria worksheet – mitigation plan implementation [FEMA 2013b]
  - FEMA Pre-Disaster Recovery Planning Guide for Local Governments [FEMA 2017]
  - FEMA Plan Integration: Linking Local Planning Efforts [FEMA 2015] (https://www.fema.gov/media-library-data/1440522008134-ddb097cc285bf741986b48fdcef31c6e/R3_Plan_Integration_0812_508.pdf)
  - EPA Flood Resilience Checklist [EPA 2014] (https://www.epa.gov/sites/production/files/2014-07/documents/flood-resilience-checklist.pdf)
  - EPA Regional Resilience Toolkit [EPA 2019] (https://www.epa.gov/smartgrowth/regional-resilience-toolkit)
  - National Disaster Recovery Framework (NDRF) [FEMA 2011]
  - NIST Community Resilience Planning Guide [NIST 2016a and b]
  - NIST Economic Decision Guide [NIST 2015]
  - New York City Climate Resilience Design Guidelines [NYC 2019]
  - Rockefeller 100 Resilient Cities Framework and city Index [Rockefeller 2014; Rockefeller 2016]
  - Threat and Hazard Identification and Risk Assessment (THIRA) [FEMA 2013a]
- Analysis tools
  - Communities Advancing Resilience Toolkit (CART) [TDC 2012]
  - Community Resilience Assessment Framework and Tools (CRAFT) [IBTS 2017]
  - FEMA's Hazus [FEMA 2018a]
  - Hazard Maps
    - FEMA Flood Insurance Rate Maps (FIRMs) [FEMA 2018d]
    - US Geological Survey (USGS) earthquake probability maps [USGS 2018]
    - Urban-Wildfire interface zones or maps [Martinuzzi et al. 2015]
    - National Oceanic and Atmospheric Administration (NOAA) hurricane storm surge map [NOAA NHC 2018]
  - Kaiser Permanente Health Vulnerability Analysis (HVA) [California Hospital Association 2018]
  - MAEViz, Mid-America Earthquake Center Seismic Loss Assessment System [MAE Center 2013]
  - NIST Economic Decision Guide Software (EDGe$) [NIST 2018b]
  - NOAA Sea Level Rise Viewer [NOAA Office of Coastal Management 2017]
  - Spatial Hazard Events & Losses database for US (SHELDUS) [Arizona State University 2018]
  - Texas A&M/DHS Coastal Resilience Center of Excellence Plan Integration Scorecard [Texas A&M University 2017]
  - US Army Corps of Engineers (USACE) sea-level change curve calculator [USACE 2017]
- Tool resource collection examples
  - 100 Resilient Cities Tools [Rockefeller 2019c] (http://www.100resilientcities.org/tools/)
  - Resilience Shift Toolbox [RS 2019] (https://www.resilienceshift.org/tools)
  - Naturally Resilient Communities [NRC 2019] (http://nrcsolutions.org/strategies/#solutions)

- Department of Housing and Urban Development Community Resilience Planning Resources [HUD 2019b] (https://www.hudexchange.info/programs/community-resilience/community-resilience-planning-resources/#tools-and-assessments)
- State of California Governor's Office of Planning and Research Adaptation Clearinghouse [CAOPR 2019] (https://resilientca.org/search/?types=11#resources)
- Climate Adaptation Knowledge Exchange [Ecoadapt 2019] (https://www.cakex.org/resources/type/tool)
- Partnership for Preparedness and Resilience [PREP 2019] (https://www.prepdata.org/resources)
- U.S. Climate Resilience Toolkit [USGCRP 2019] (https://toolkit.climate.gov/)

Appendix 4. Examples of Funding Programs

The following resources for funding programs and support were noted by workshop participants, NIST, and the CoE. Additional disaster recovery funding resources are listed at https://www.fema.gov/media-library-data/1474548130660-db3c22abcc037416428fe7db69d45926/FundingResources.pdf

- **Department of Homeland Security (DHS)**
  - Regional Resilience Assessment Program (RRAP) https://www.dhs.gov/cisa/regional-resiliency-assessment-program
- **Department of Transportation (DOT)**
  - Federal Highway Administration – Federal Aid Highway Emergency Relief Program https://www.fhwa.dot.gov/programadmin/erelief.cfm
  - Federal Transit Administration – Public Transportation Emergency Relief Program https://www.transit.dot.gov/funding/grant-programs/emergency-relief-program
- **Economic Development Agency (EDA)**
  - Comprehensive Economic Strategy Development (CEDS) (also eligible for post-event) https://eda.gov/ceds/
  - Economic Adjustment Assistance Grant (also eligible for post-event) https://www.eda.gov/pdf/about/Economic-Adjustment-Assistance-Program-1-Pager.pdf
  - Public Works Program (also eligible for post-event) https://www.eda.gov/pdf/about/Public-Works-Program-1-Pager.pdf
- **Environmental Protection Agency (EPA)**
  - Clean Water State Revolving Funds (also eligible for post-event) https://www.epa.gov/cwsrf
  - Water Infrastructure Finance and Innovation Act Programs https://www.epa.gov/wifia
- **Federal Emergency Management Agency (FEMA)**
  - Pre-Disaster Mitigation Grant Program https://www.fema.gov/pre-disaster-mitigation-grant-program
  - Fire Management Assistance Grants https://www.fema.gov/fire-management-assistance-grant-program
  - Flood Mitigation Assistance Grants https://www.fema.gov/flood-mitigation-assistance-grant-program
  - Individual Assistance. (https://www.fema.gov/individual-disaster-assistance)
  - Public Assistance. (https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit)
  - Hazard Mitigation Grant Program (HGMP). https://www.fema.gov/hazard-mitigation-grant-program
  - Disaster Unemployment Assistance https://www.fema.gov/media-library/assets/documents/24418

- Community Disaster Loan Program https://www.fema.gov/media-library/assets/documents/176527
- Cora Brown Fund https://www.fema.gov/media-library/assets/documents/24409

- **National Oceanic and Atmospheric Administration (NOAA)**
  - Coastal Zone Management Program (also eligible for post-event, not tied to specific disaster) https://coast.noaa.gov/czm/about/
  - National Coastal Resilience Fund (also eligible for post-event, not tied to specific disaster) https://www.nfwf.org/coastalresilience/Pages/home.aspx
- **Small Business Administration (SBA)**
  - Disaster Assistance Loans (https://www.sba.gov/funding-programs/disaster-assistance)
  - Economic Injury Disaster Loans for Business https://disasterloan.sba.gov/ela/Information/EIDLLoans
  - Physical Disaster Loans for Business https://disasterloan.sba.gov/ela/Information/BusinessPhysicalLoans
  - Home and personal Property Disaster Loans https://disasterloan.sba.gov/ela/Information/HomePersonalPropertyLoans
- **US Department of Agriculture (USDA)**
  - Forest Service – Volunteer Fire Assistance https://www.fs.usda.gov/naspf/topics/fire/volunteer-fire-assistance
  - Forest Service - Wildland Fire Management Assistance https://www.fs.usda.gov/naspf/featured-projects/2017/wildland-fire-management-volunteer-fire-assistance-grants-help-rural
  - Farm Service Agency - Emergency Conservation Program https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index
  - Farm Service Agency - Emergency Forest Restoration Program https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/emergency-forest-restoration/
  - Farm Service Agency - Emergency Farm Loans https://www.fsa.usda.gov/programs-and-services/farm-loan-programs/emergency-farm-loans/index
  - Natural Resources Conservation Service - Emergency Watershed Protection Program https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/
- **US Department of Housing and Urban Development (HUD)**
  - Community Development Block Grant https://www.hud.gov/program_offices/comm_planning/communitydevelopment/programs
  - Community Development Block Grant - Disaster Recovery (CDBG-DR). https://files.hudexchange.info/resources/documents/DR-H-Funding-Guide-Recovery-Resources.pdf