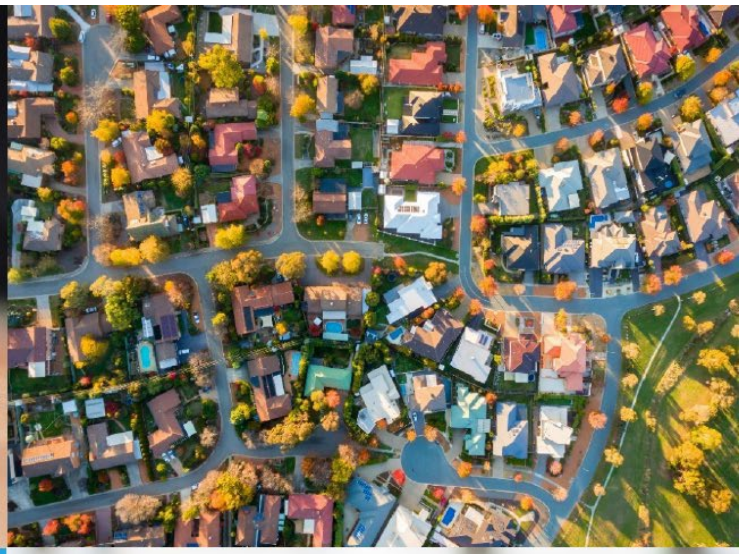

Community Resilience Challenges Index

Methodology for Identifying Commonly Used Indicators from Peer-Reviewed Research Published 2003-2021

August 2024

FEMA

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1. Introduction

In 2017, FEMA identified the need to establish a data-driven basis for prioritizing locations for technical assistance investment to support local emergency management planning and operations. To achieve this goal, FEMA tasked Argonne National Laboratory (Argonne) with reviewing the landscape of published peer-reviewed research on community resilience and social vulnerability to identify commonly used indicators across methodologies.

These indicators and the composite Community Resilience Challenges Index (CRCI) provide emergency managers with insights for targeted outreach strategies, planning, mitigation investments and response and recovery operations. Communities, regional governments and others can use this data to better understand potential challenges to resilience. As the social science field of examining and validating indicators of resilience evolves, FEMA will update RAPT to provide emergency managers and community partners with additional data and tools to inform planning, mitigation, response and recovery.

It is important to understand that the role of the emergency manager is not to change or to "improve" the data, but to plan appropriately for the community characteristics reflected in the data. These datasets are community characteristics that researchers have identified as important considerations for resilience. For example, people with disabilities may have greater challenges to be resilient to disasters. If a community has a high population of people with disabilities, the emergency manager(s) may need to create tailored preparedness outreach programs and strategies to ensure those residents have support if evacuation is necessary.

Rather than label the CRCI and the underlying indicators as an absolute measure of resilience, FEMA considers this data as "potential challenges to resilience." Everyone is vulnerable to disasters. While scholars theorize that certain characteristics may make an individual or a household less resilient (or more socially vulnerable), the data does not reflect measures that individuals and/or communities have taken to address potential challenges, such as emergency management planning and outreach or household preparedness measures. To aid emergency managers in understanding how to use these indicators, calling them potential challenges to resilience supports a more positive and strategic application of the data in all phases of emergency management.

2. Methodology Overview

The analysis process begins with a literature review of published peer-reviewed assessment methodologies on social vulnerability and community resilience, including methodologies from developed countries other than the United States.

The literature review findings are then filtered by inclusion criteria established by the research team to ensure the methodologies include:

Community Resilience Challenges Index Methodology

1. Conduct literature review of published peer-reviewed research.
2. Identify methodologies that meet inclusion criteria.
3. Catalogue indicators and identify those that are used in at least one third of the methodologies.
4. Identify best data source for each indicator.
5. Bin the data for each indicator, format for GIS display, and conduct a correlation analysis.
6. Create the composite FEMA Community Resilience Challenges Index from the commonly used indicators.

- **Quantitative measures:** To ensure that indicators could be easily compared across methodologies, the team only included methodologies that used exclusively quantitative measures.
- **Publicly available methodology:** For the analysis and findings to be transparent, the team only included methodologies that were publicly available.
- **Public data source:** To ensure transparency, replicability and updates over time, indicator data had to be from publicly available secondary sources, such as the U.S. Census and the Bureau of Labor Statistics.
- **At least county-level unit of analysis:** The team only included studies where the unit of analysis was, or could be easily adapted to, a U.S. County. Although more granularity offers greater clarity, many studies do not include data below the county level.
- **Generalized risk:** Because FEMA provides technical assistance relative to a wide range of hazards, the inclusion criteria retained methodologies that applied to multiple hazards. Methodologies that focused on one specific risk (such as earthquakes, food security, poverty or public health) were included in the CRIA analysis. Although these studies offer insights for these topic areas, studies with an all-hazards perspective were more appropriate for comparative purposes.
- **Pre-disaster conditions:** To support communities with building resilience prior to a disaster, the research team focused on community characteristics present before an incident occurred.

After identifying the set of methodologies that meet these criteria, the research team identifies the commonly used indicators across these methodologies, an indicator used in approximately at least one third all methodologies. Next, the research team selects the best data source for each indicator, primarily from the U.S. Census American Community Survey (ACS) five-year estimates. The research used the five-year estimates because it provides greater statistical reliability of population and community characteristics than one-year data, especially for smaller geographic areas.

The next step is to bin the indicator datasets, format for visual geographic information systems (GIS) display and conduct a correlation analysis. Finally, the research team creates a composite index, the FEMA Community Resilience Challenges Index (FEMA CRCI), bins the FEMA CRCI value by percentile and identifies the top three drivers of the CRCI value for each county.

To make the CRCI data more accessible and more actionable, each individual indicator and the FEMA CRCI is binned and included in FEMA's Resilience Analysis and Planning Tool (RAPT).[1] RAPT enables emergency managers and community partners to quickly visualize relative differences in potential resilience by census tract, county, and Tribal Nation. The data for CRCI and the underlying indicators are updated every year in RAPT.

FEMA and Argonne completed the first analysis of commonly used indicators in 2018 and repeated the process in 2022.

[1] RAPT is a free, online, geographic information system (GIS) tool with data layers on population characteristics, infrastructure and hazards. RAPT is designed to support all phases of emergency management. Access RAPT here: www.fema.gov/rapt.

3. Literature Review and Selected Methodologies

The literature review is conducted via a Web of Science library search using the search terms: "resilience" and "index, methodology(ies), or indicator(s)" and "community or disaster." The 2018 literature review examined research published from 2013-2017. The 2022 literature search drew from publications from 2018-2021. Appendix A includes the comprehensive list of over 90 methodologies identified from the 2018 and 2021 literature reviews. The table includes the methodologies names, dates of publication, a link to the methodology reports or developers and a determination for each inclusion criterion.

Combining the findings from both literature reviews, 14 methodologies met all of the inclusion criteria. Full citations for these methodologies are included in Appendix B.

Methodologies that met the inclusion criteria from the 2021 literature review:

- Fraser: Japanese Social Capital and Social Vulnerability Indices
- Nursey-Bray: Indicators for Adaptive Capacity
- Regional Climate Resilience Index (RCRI)
- Composite Community Disaster Resilience Index (CCDRI)
- Comprehensive Disaster Resilience Index (CDRI2)
- Social Vulnerability Index (SoVI)

Methodologies that met the inclusion criteria from the 2018 literature review:

- Australian National Disaster Resilience Index (ANDRI)
- Baseline Resilience Indicators for Communities (BRIC)
- Community Disaster Resilience Index (CDRI)
- Community Resilience Index (CRI2)
- Disaster Resilience of Place (DROP)
- Resilient Capacity Index (RCI)
- Social Vulnerability Index (SVI)
- The Composite Resilience Index (TCRI)

4. Commonly Used Indicators and Data Sources

To identify the commonly used indicators across the analysis set of 14 methodologies, the team first documented all the indicators used in each of the six newly identified methodologies published between 2018-2022, (157 in total) and added them to the list of the indicators from the 2018 methodologies, published between 2013-2017. The research team then established the threshold of commonly used indicators as those used in five or more of the 14 methodologies (those use in at least 35% of the methodologies). This analysis resulted in identifying 22 commonly used indicators. The research team also documented citations from the methodologies' authors that explained their reasoning for using each indicator.

The following table lists the 22 indicators and references how many of the 14 methodologies used that indicator.

Table 1: 22 CRCI Indicators

Commonly Used Indicators	Number of Methodologies Using this Indicator (of 14)
Unemployed labor force	13
Population without a high school diploma	11
Percent of inactive voters*	10
Households without a vehicle	9
Number of hospitals	9
Population age 65 and older	9
Medical professional capacity	8
Population with a disability	7
Households with limited English	7
Single-parent households	7
Population without health insurance	7
Unemployed women labor force*	7
Presence of civic and social organizations	6
Median household income	6
Income inequality	6
Population change	6
Population without religious affiliation	6
Mobile homes as percentage of housing	6
Owner-occupied housing	6
Workforce in predominant sector*	5
Households without a smartphone*	5
Population below poverty level*	5
Public school capacity	*4*
Rental property capacity	*4*
Hotel/motel capacity	*3*

The five indicators added in 2022 are marked with an *asterisk* "*"

The three indicators that were included in the 2018 analysis have been retired because they are not used in at least five of the 2022 methodologies. These are noted in *blue italics.*

After identifying the 22 commonly used indicators, the research team selected the most authoritative data source for each indicator. Most of the indicators related to population and community characteristics are available from the U.S. Census Bureau. RAPT includes data for these indicators in multiple geographic areas when available from Census, i.e., census tracts, counties, and Tribal Nations.

The 22 CRCI indicators can be grouped into the following six categories:

Population Characteristics

- Population without a High School Education
- Population 65 and Older
- Population with a Disability

Household Characteristics

- Households without a Vehicle
- Households with Limited English
- Single-Parent Households
- Households without a Smartphone

Housing

- Mobile Homes as Percentage of Housing
- Owner-Occupied Housing

Healthcare

- Number of Hospitals*
- Medical Professional Capacity*
- Population without Health Insurance

Economic

- Population Below Poverty Level
- Median Household Income
- Unemployed Labor Force
- Unemployed Women Labor Force
- Income Inequality+
- Workforce in Predominant Sector

Connection to Community

- Presence of Civic and Social Organizations*
- Population with Religious Affiliation*
- Percent of Inactive Voters*
- Population Change*

Census data for the CRCI indicators is available for census tracts, counties, and Tribal Nations, except as noted:

** Indicates County level data only,*

+ Indicates County and Tribal level data only

5. Data Binning

With such large datasets, binning the data and assigning consistent color ramps for the bins provides a visual cue to quickly grasp a data range. While the specific datapoint for the geography (county, census tract or tribe) is also available, the bins provide a more immediate high-level understanding of a geographic area's characteristics.

To bin each dataset for mapping, Argonne used the Python Spatial Analysis Library, PySAL, and its Exploratory Spatial Data Analysis sub-package. Python is an open-source, high-level programming language that is used in social science research. The package includes nine binning methods. Rather than make arbitrary "breaks" in the data, these binning methods allowed the research team to use the best binning method that would group data that are close in value to each other and maximize the variance between bins.

The team evaluated which of the nine binning methods 1) best fit the relationships of the breaks to each dataset's means and medians and 2) could be consistently replicated. This analysis identified four binning methods as the best fit for most datasets. For the county-level datasets, the research team binned the dataset into five bins. For the indicators with census tract data, the research team binned the dataset into seven bins, allowing greater differentiation with these substantially larger datasets. The binning methods for the 22 CRCI indicators are:

- **Fisher–Jenks Breaks:** This method aims to return class breaks such that classes are internally homogenous while assuring heterogeneity among classes. The Python toolkit calculates squared deviations against class means.

- **Jenks–Caspall Breaks:** This method aims to minimize the absolute deviation from within-class medians. Python's calculation focuses on within-class absolute deviations from the median.

- **Head/Tail Breaks:** Algorithmically optimal breaks and the number of classes are based on the dataset itself. The Head/Tails Breaks method works well with heavily tailed datasets, iterating through the data to minimize around the mean.[2]

- **Other:** In specific cases, the team used alternative criteria to select binning methodologies.

  - Income: A convention for displaying income data already exists: $0–20,000, $20,001–$40,000, etc. (an intuitive methodology similar to equal intervals).

  - Population Change: The population change dataset is provided by the U.S. Census as "net migration," which provides a positive (increase in population) or negative (decrease in population) number.[3] Large population changes in either direction could cause challenges to resilience. The team chose to represent the population change data as standard deviations from zero, where less change is preferred to more change (regardless of whether the change is positive or negative).

[2] Jiang, B., 2013, Head/tail Breaks: A New Classification Scheme for Data with a Heavy-tailed Distribution. The Professional Geographer, 65, 482-494.

[3] U.S. Census Bureau. https://www.census.gov/glossary/#term_Netmigration, accessed March 28, 2022.

FEMA updates tables for the CRCI indicators each year, FEMA Community Resilience Challenges Index: Annual Update of Indicator Table and Correlation Analysis available on the RAPT Resource Center. For each indicator, these tables include:

- Indicator metric
- Data source
- National average
- Binning methods
- Data geography (county, census tract, Tribal Nation, Puerto Rico, and other)
- Author rationale for including this indicator
- Methodologies that use the indicator

6. Correlation Analysis

The research team conducted a correlation analysis to measure and describe the strength and direction of the relationships among the 22 CRCI indicators. The correlation analysis shows how individual indicators may be related to each other. Understanding these correlations helps communities design resilience strategies that take these relationships into account.

The Pearson Correlation Coefficient is a numerical measure of linear correlation from −1 to 1.

- A coefficient closer to 1 indicates a positive correlation (variable A increases as variable B increases).
- A coefficient of 0 indicates no correlation.
- A coefficient closer to −1 indicates a negative correlation (variable A increases as variable B decreases).

As jurisdictions consider strategies to address indicator metrics that reveal challenges to resilience, the correlation analysis helps identify populations that may face multiple challenges concurrently. For example, there is a high correlation between individuals that are unemployed and those that are more likely to speak a language other than English and be without access to a vehicle. Outreach to these populations should consider all three of these characteristics.

The chart of Pearson Correlation Coefficients is included in the FEMA Community Resilience Challenges Index: Annual Update of Indicator Table and Correlation Analysis available on the RAPT Resource Center.

7. FEMA Community Resilience Challenges Index (CRCI)

The research team developed a process to create a composite index comprised of the 22 commonly used indicators, the FEMA CRCI. This index provides a relative composite value by county and by census tract, measured as an average of counts of standard deviations from the national mean for each indicator. The FEMA CRCI is updated annually with the latest data from the U.S. Census American Community Survey five -year estimates.

To produce the CRCI, the team first orients all the datasets in the same direction (higher numbers or percentages represent higher resilience challenges) and then converts each county and census tract's data point to a standardized score value based on standard deviations above or below the

indicator's national mean (except for population change calculated as standard deviations from zero). The team then averages the 22 standardized score values for each county and census tract to create the FEMA CRCI value. Because there is no validated method for weighting resilience indicators, the research team did not weight individual indicators in developing the FEMA CRCI.

- County CRCI: When data for an indicator is not available for a given county, the team uses the national mean for that indicator; this approach does not artificially push an aggregate indicator more positive or more negative. Though the team examined linear and non-linear models, they determined that using the national mean for missing county data, the simplest solution, was the best solution.

- Census Tract CRCI: When data for an indicator is not available at the census tract level, the research team imputes the county data for the census tract calculation.

The FEMA CRCI process produces a numerical standard deviation data point for each county and each census tract. As with the indicator datasets, the FEMA CRCI is binned into five bins for the county and seven bins for the census tract by percentile and are included in RAPT. Including the CRCI data in RAPT allows users to view both the composite index and datapoints for each indicator comprising the index to better understand the drivers behind the composite index values. For the county CRCI, RAPT also includes the top three drivers for the CRCI value. Driver analysis quantifies the importance of a series of predictor variables in predicting an outcome variable. The top three drivers are the three indicators that deviate the most from the national average of the 22 indicators in the CRCI.

8. Limitations and Benefits of Analysis

To provide appropriate context for this research, it is important to acknowledge the limitations and the benefits to the process and the available data.

Limitations

Incomplete national datasets. The U.S. Census's primary datasets do not include information for many of the U.S. territories, including Guam, the U.S. Virgin Islands, American Samoa, and the Commonwealth of the Northern Mariana Islands. Territories other than Puerto Rico may face some of the highest challenges to resilience in the U.S. but have not been assessed in this report because the data are not included in national datasets.

Some data unavailable at census tract level. Some CRCI indicators have data available at the county level but not at the census tract level (Presence of Civic and Social Organizations, Inactive Voters, Number of Hospitals, Religious Affiliation and Population Change). When developing the census tract CRCI, the research team imputed the county data for the census tract CRCI calculation.

Universal application of indicators. With the exception of not including the Households with Limited English indicator for CRCI in Puerto Rico, the CRCI for all other jurisdictions includes all 22 indicators. The CRCI does not factor in potential differences for challenges to resilience based on rural, sub-urban, or urban locations.

No assessment of hazard risk or community capacity. This analysis identifies potential challenges to community resilience to help communities plan, prepare, and build resilience. This analysis does not

capture specific hazard risk nor ways that a community may have developed the capacity to address these challenges. For example, communities with relatively lower levels of hospitals or medical professions per capita may have developed surge capacity support for medical services by training the public, supporting volunteer programs, or investing in mobile clinics.

Lack of validation. While the methodologies reviewed have been peer-reviewed, it is important to note that these methodologies have not been validated in the field. This means that these methodologies are academically sound, based on examination of disaster outcomes and pre-disaster community characteristics, but the indicators have not been systematically validated for predictive value. There is also insufficient research in weighting certain factors or indicators more than others. Field research on indicators of social vulnerability and community resilience is an emerging field of study.

Benefits

Peer-reviewed research. The analysis in this paper draws exclusively from the current body of peer-reviewed research on community resilience and social vulnerability in disasters. The peer review process helps to ensure that the research methodologies have been subjected to the scrutiny of experts in related academic fields.

Commonly used indicators suggest research agreement. This analysis identifies specific, individual indicators used in multiple methodologies (at least five methodologies out of 14 methodologies meeting the inclusion criteria). This approach captures multiple research perspectives to identify important resilience indicators rather than choosing one methodology among many.

Both an index and data for individual indicators. In addition to producing a composite index, this analysis also provides county and census tract datapoints for each indicator. Many research methodologies produce an index to support high-level relative values and, in some cases, sub-indices, without providing the underlaying data for each indicator. By providing data for each indicator, FEMA's approach may help pinpoint specific areas to develop community capacity.

Open-source data. The research team used only publicly available data to ensure that this analysis was fully transparent and could be replicated at no cost. The appendix outlines the source data for each indicator.

Broad application of findings. In addition to helping to prioritize locations for FEMA technical assistance, this analysis is useful for all phases of emergency management and can be used by many FEMA program areas and State, Local, Tribal and Territorial partners.

9. Future Research

As the social science of community resilience continues to evolve, additional analysis could evaluate the usefulness of weighting the indicators, validating the indicators, examining specific indicators by risk and adding or retiring indicators. Principal component analysis, factor analysis, regression analysis, or structured sensitivity analysis could provide findings on the relative importance and weight of an indicator's contribution to overall resilience. It may also be of interest to examine how these indicators may have different impacts in rural versus urban areas or differences by region.

The researchers involved in developing the CRCI process, and RAPT continue to look for opportunities to evaluate the validity and usefulness of this set of indicators with the goal of ensuring

that the data is easily accessible and a useful focusing tool for initial situational awareness for preparedness, mitigation, response and recovery efforts.

Appendix A: Methodologies from the Literature Review

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
Hazus	Frequent Version Updates	Federal Emergency Management Agency (FEMA)	*Hazus Methodology*	Community	United States	Earthquake, Flood, Hurricane, Tsunami	Post	Yes	Yes	Yes
Open Resilience Index (ORI)	2021	Feldmeyer, D; et. al.	*An open resilience index: Crowdsourced indicators empirically developed from natural hazard and climatic event data*	National	Global	All-hazards	Pre	Yes	Yes	Yes
Japanese Social Capital and Social Vulnerability Indices	2021	Fraser, T	*Japanese Social Capital and Social Vulnerability Indices: Measuring Drivers of Community*	Local	Japan	All-hazards	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
			Resilience 2000-2017							
Conceptual Framework for Social Vulnerability	2021	Mason, K; et. al.	*Social Vulnerability Indicators for Flooding in Aotearoa New Zealand*	Local	New Zealand	Flood	Pre	Yes	Yes	Yes
	2021	Nursey-Bray, et. al.	*Developing indicators for adaptive capacity for multiple use coastal regions: Insights from the Spencer Gulf, South Australia*	Local	Australia	All-hazards	Pre	Yes	Yes	Yes
Australian Disaster Resilience Index (ADRI)	2021	Parsons, M; et. al.	*Disaster resilience in Australia: A geographic assessment using an index of coping and adaptive capacity*	National	Australia	All-hazards	Pre	Yes	Yes	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
	2021	Zarghami, SA; Dumrak, J	*A system dynamics model for social vulnerability to natural disasters: Disaster risk assessment of an Australian city*	Local	Australia	All-hazards	Pre	Yes	No	Yes
Composite Community Disaster Resilience Index (CCDRI)	2020	Al Rifat, SA; Liu, WB	*Measuring Community Disaster Resilience in the Conterminous Coastal United States*	County	United States	All-hazards	Pre	Yes	Yes	Yes
Regional Climate Resilience Index (RCRI)	2020	Feldmeyer, D; et. al.	*Regional Climate Resilience Index: A Novel multimethod Comparative Approach for Indicator Development, Empirical Validation and Implementation*	County	Germany	All-hazards	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
	2020	Yang, YF; et. al.	*A Federated Pre-Event Community Resilience Approach for Assessing Physical and Social Sub-Systems: an Extreme Rainfall Case In Hong Kong*	Urban	Hong Kong	All-hazards	Pre and Post	Yes	Yes	No
	2020	Zobel, CW; Baghersad, M	*Analytically comparing disaster resilience across multiple dimensions*	Local	United States	All-hazards	Post	Yes	Yes	No
	2019	Gillespie-Marthaler, L; et. al.	*Selecting Indicators for Assessing Community Sustainable Resilience*	Local	United States	All-hazards	Pre	Mixed	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
DRIFT	2019	Manyena, B; Machingura, F; O'Keefe, P	*Disaster Resilience Integrated Framework for Transformation (DRIFT): A new approach to theorizing and operationalizing resilience*	Local	Global	All-hazards	Pre	Yes	Yes	No
Comprehensive Disaster Resilience Index (CDRI2)	2019	Marzi, S; et. al.	*Constructing a Comprehensive Disaster Resilience Index: The case of Italy*	Local	Italy	All-hazards	Pre	Yes	Yes	Yes
	2019	Nicholson, D; Vanli, OA; Jung, S; Ozguven, EE	*A spatial regression and clustering method for developing place-specific social vulnerability indices using census and social media data*	Local	United States	All-hazards	Post	Yes	Yes	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
	2018	Rohith, VR; et. al.	*Disaster Preparedness Index: A Valid and Reliable Tool to Comprehend Disaster Preparedness in India*	Local	India	All-hazards	Pre	No	Yes	No
5S Social Resilience Framework	2018	Saja, AMA; et. al.	*An inclusive and adaptive framework for measuring social resilience to disasters*	Local	Global	All-hazards	Pre	No	Yes	No
NaHRSI	2018	Summers, JK; et. al.	*Measuring Community Resilience to Natural Hazards: The Natural Hazard Resilience Screening Index (NaHRSI) - Development and Application to the United States*	County	United States	All-hazards	Pre	Yes	No	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
ANDRI2	2017	P. Morley et. al.	The *Australian Natural Disaster Resilience Index (ANDRI2): A System for Assessing the Resilience of Australian Communities to Natural Hazards*	Community	Australia	Natural	Pre	Mixed	Yes	Yes
GRI	2017	FM Global	*2018 FM Global Resilience Index (GRI)*	Country	Global	Multiple	Pre	Yes	Yes	No
CREAT	2016	U.S. Environmental Protection Agency	*Climate Resilience Evaluation and Awareness Tool (CREAT)*	Water Utilities	United States	Climate Risk	Pre	Mixed	No	No
	2016	National Institute of Standards and Technology (NIST)	*Community Resilience Planning Guide for Building and Infrastructure Systems* (Volumes 1 and 2)	Community	Kenya/ Uganda	Infrastructure	Pre	No	Yes	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
RIM	2016	N.S. Lam et al.	*Resilience Inference Measurement (RIM): Measuring Community Resilience to Coastal Hazards along the Northern Gulf of Mexico*	County	United States	Coastal Hazards	Post	Yes	Yes	Yes
WRI	2016	Institute for Environment and Human Security of the United Nations	*World Risk Index (WRI)*	Country	Global	Multiple	Pre	Yes	Yes	Yes
AGIR	2015	European Commission	*Measuring and Monitoring Progress on Resilience Building for Food and Nutrition Security*	Country	West Africa	Food Security	Pre	Mixed	No	Yes
CDR	2015	D. Keun et al.	*A Measurement of Community Disaster Resilience (CDR) in Korea*	Community	South Korea	Natural	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
CDRST	2015	Torrens Resilience Institute	*Developing a Model and Tool to Measure Community Disaster Resilience*	Community	Australia	Multiple	Pre	Mix	Yes	Mixed
CRDSA	2015	S.A. Alshehri et al.	*Disaster Community Resilience Assessment Method: A Consensus based Delphi and AHP Approach*	Community	Saudi Arabia	Multiple	Pre	Mix	No	No
CR-E	2015	Nasrullah et al.	*Status of Community Resilience in Disaster Prone Districts of Pakistan*	District	Pakistan	Earthquake	Pre	Yes	Yes	No
CRF	2015	The Rockefeller Foundation, Arup	*City Resilience Framework (CRF) and City Resilience Index*	City	Global	Multiple	Pre	No	Yes	No
FSRI	2015	New Economics Foundation	*Financial System Resilience Index (FSRI)*	Country	Global	Financial System	Pre	Yes	No	No
RELi	2015	Capital Markets Partnership	*RELi Resilience Action Checklist*	Community	United States	Infrastructure	Pre	No	Yes	No
TCRI	2015	T. Perfrement and T. Lloyd	*The Composite Resilience Index (TCRI)*	Community	Australia	Natural	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
TNC Coastal Resilience	2015	The Nature Conservancy (TNC)	*Coastal Resilience Mapping Tool*	Community	Global	Coastal Hazards	Pre	Yes	No	Yes
UDRI	2015	Earthquakes and Megacities Initiative	*A Guide to Measuring Urban Risk Resilience – the Urban Disaster Risk Index (UDRI)*	City	Global	Natural	Post	Mixed	Yes	No
Spatially Explicit Resilience Vulnerability Model (SERV)	2014	Tim G. Frazier, et. al.	A framework for the development of the SERV model: A Spatially Explicit Resilience-Vulnerability model	Local	United States	Flood	Pre	Yes	No	No
ASPIRE	2014	The World Bank	*The Atlas of Social Protection Indicators of Resilience and Equity (ASPIRE)*	Country	Global	Poverty	Pre	Yes	Yes	Yes
BRIC	2014	Susan Cutter et al.	Baseline Resilience Indicators for Communities (BRIC), *The Geographies of Community Disaster Resilience*	County	United States	Multiple	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
CoBRA	2014	United Nations Development Programme (UNDP)/Drylands Development Centre	*Community Based Resilience Analysis (CoBRA)*	Community	Kenya, Uganda	Drought	Pre	No	Yes	No
CRS	2014	Community and Regional Resilience Institute, Meridien	*A Practical Approach to Building Resilience: Community Resilience System (CRS)*	Community	United States	Multiple	Pre	Yes	No	No
FCR	2014	International Federation of Red Cross (IFRC)	*IFRC Framework for Community Resilience* (FCR)	Community	Global	Multiple	Pre	Mixed	Yes	No
Grosvenor	2014	Grosvenor	*Resilient Cities Research Report*	City	Global	Multiple	Pre	Mixed	No	N/A
RCI	2014	Foster, K.A.	*Resilience Capacity Index (RCI)*	Metro-politan Statistical Area	United States	Multiple	Pre	Yes	Yes	Yes
RRI – Rural	2014	Rural Disaster Resilience Project	*Rural Resilience Index (RRI)*	Community – Rural	Global	Multiple	Pre	No	No	N/A

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
UCR	2014	Rockefeller Foundation	*Urban Climate Resilience (UCR): A Review of Methodologies Adopted under the ACCCRN Initiative in Indian Cities*	City	India	Natural	Pre	No	No	No
United Nations International Strategy for Disaster Reduction (UNISDR)	2014	UNISDR	*Disaster Resilience Scorecard for Cities*	City	Global	Multiple	Pre	No	Yes	No
WISC	2014	Well-being, Identity, Services and Capitals (WISC)	*Theorizing Community Resilience to Improve Computational Modeling*	Community	United States	Multiple	Pre	Yes	No	Yes
CCRAM	2013	D. Leykin et al.	*Conjoint Community Resilience Assessment Measure (CCRAM)*	Community	Global	Multiple	Pre and post	Mixed	No	No
CRR	2013	World Economic Forum	*Global Risks 2013*	Country	Global	Multiple	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
CV	2013	Texas A&M University, Hazard Reduction and Recovery Center	*Status and Trends of Coastal Vulnerability (CV) to Natural Hazards Project*	County	United States	Coastal Hazards	Pre	Yes	Yes	Yes
IDRI	2013	United Nations Development Programme	*Indonesia Disaster Recovery Index (IDRI)*	Community	Indonesia	Volcano/ Flood	Post	Mixed	No	Yes
IDS	2013	Institute of Development Studies (IDS)	*Towards a Quantifiable Measure of Resilience*	Multi-level	Global	Food Security	Pre	Yes	Yes	N/A
LDRI	2013	P.M. Orencio and M. Fujii	Localized Disaster-Resilience Index (LDRI)	Community	Philippines	Coastal Hazards	Pre	Mixed	No	No
ODI	2013	NIST	Overseas Development Institute (ODI), *Disaster Risk Management Potential Targets and Indicators*	Community	Global	Multiple	Pre and Post	Yes	No	N/A

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
ORP	2013	Oregon Seismic Safety Policy Advisory Commission	*The Oregon Resilience Plan (ORP) Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami*	Regional	Oregon	Infrastructure	Post	Mixed	Yes	No
OXFAM	2013	OXFAM	*A Multidimensional Approach to Measuring Resilience*	Community	Global	Humanitarian	Pre	Mixed	No	No
RMI	2013	Argonne National Laboratory	*Resilience Measurement Index (RMI): Indicator of Critical Infrastructure Resilience*	Facility	United States	Infrastructure	Pre	Mixed	No	Mixed
RRI2	2013	DARA	*Risk Reduction Index (RRI2)*	Territorial Units	West Africa	Multiple	Pre	No	Yes	No
SERI	2013	Verisk Maplecroft	Socio-economic Risk Index (SERI)	Country	Global	Multiple	Pre	Yes	No	N/A
Surging Seas	2013	Climate Central	Surging Seas Risk Finder	Community	U.S. Coast	Storm Surge/Flood	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
US Agency for International Development (USAID)	2013	Feed the Future	*Community Resilience: Conceptual Framework and Measurement – Feed the Future Learning Agenda*	Community	Global	Poverty	Pre	Yes	No	No
CART	2012	R.L. Pfefferbaum et al.	*Communities Advancing Resilience Toolkit (CART)*	Community	United States	Multiple	Pre	No	Yes	No
DRLA	2012	Disaster Resilience Leadership Academy (DRLA), Tulane University	*Haiti Humanitarian Assistance Evaluation: Resilience Perspective*	Household	Haiti	Natural	Pre	Mixed	Yes	No
GFM	2012	UN Office for the Coordination of Humanitarian Affairs (OCHA) and Maplecroft	*Global Focus Model (GFM)*	Country	Global	Multiple	Pre	Yes	No	Mixed
ICBRR	2012	Canadian Red Cross	*Measuring Disaster-Resilient Communities: Integrated Community Based Risk Reduction (ICBRR)*	Coastal Community	Indonesia	Coastal Hazards	Pre	Mixed	No	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
LCOT	2012	Tufts University	*Livelihoods Change Over Time (LCOT)*	Household	Sudan, Ethiopia, Haiti	Multiple	Post	Yes	Yes	Yes
BCRD	2011	RAND	*Building Community Resilience to Disasters (BCRD)– A Way Forward to Enhance National Health Security*	Community	United States	Health	Pre	Mixed	No	Mixed
PVI	2011	Inter-American Development Bank	*Indicators of Disaster Risk and Risk Management; Prevalent Vulnerability Index (PVI)*	Country and Sub-national	Latin America	Multiple	Pre	Yes	No	Yes
ResilUS	2011	U.S. Resilience Institute, Western Washington University	U.S. Resilience Institute (*ResilUS*)	Community	United States	Earthquake	Post	Yes	No	Yes
SVI	2011	Agency for Toxic Substances & Disease Registry	*Social Vulnerability Index (SVI)*	County	United States	Multiple	Pre	Yes	Yes	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
Community Disaster Resilience Index (CDRI)	2010	W. G. Peacock, et. al.	*Advancing Resilience of Coastal Localities: Developing, Implementing and Sustaining the Use of Coastal Resilience Indicators*	Coastal	U.S. Coastal	Multiple	Pre	Mixed	Yes	Yes
CDRI3	2010	Kyoto University, UNISDR	*Climate and Disaster Resilience Initiative (CDRI3): Capacity Building Program*	City	Southeast Asia	Multiple	Pre	Mixed	Yes	No
CERI	2010	Advantage West Midlands	*Community Economic Resilience Index (CERI)*	Community	U.K.	Recession	Pre	Yes	Yes	Yes
CRI	2010	Mississippi-Alabama Sea Grant Consortium	*Coastal Resilience Index (CRI): A Community Self-Assessment*	Community	United States – Coastal	Coastal Hazards	Post	No	Yes	No
CRI2	2010	K. Sherrieb et al.	*Measuring Capacities for Community Resilience,* Community Resilience Index (CRI2)	County	United States	Multiple	Pre	Yes	No	Yes

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
DROP	2010	S. Cutter et al.	Disaster Resilience of Place (DROP), *Disaster Resilience Indicators for Benchmarking Baseline Conditions*	County	United States – Southeast	None	Pre	Yes	Yes	Yes
FAO	2010	Food and Agriculture Organization (FAO) of the United Nations (UN)	*FAO Resilience Tool*	Community	Global	Food Security	Pre	Yes	Yes	Yes
FAO-Livelihoods	2010	L. Alinovi et al., European Report on Development	*Livelihoods Strategy and Household Resilience to Food Insecurity*	Country	Kenya	Food Security	Pre	Yes	Yes	No
PEOPLES	2010	NIST, MCEER: University of Buffalo	*PEOPLES Resilience Framework*	Community	United States	Multiple	Pre	Mixed	No	Yes
CRT	2009	Bay Localize	*Community Resilience Toolkit (CRT): Workshop Guide*	City or County	United States	Climate Change	Pre	No	Yes	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
DFID	2009	DFID Disaster Risk Reduction Interagency Coordination Group	*Characteristics of a Disaster-Resilient Community*	Community	Global	Multiple	Pre	Mixed	Yes	No
SPUR	2009	San Francisco Planning + Urban Research Association (SPUR)	*The Resilient City: Defining What San Francisco Needs from its Seismic Mitigation Policies*	Community	United States	Earthquake/ Infrastructure	Post	Yes	No	No
CARRI	2008	Oak Ridge National Laboratory	*Community and Regional Resilience Initiative (CARRI)*	Community	United States	Multiple	Pre	Yes	Yes	Not Identifie d
Hyogo	2008	International Strategy for Disaster Reduction	*Indicators of Progress: Guidance on Measuring the Reduction of Disaster Risks and the Implementation of the Hyogo Framework for Action*	City	Global	Natural	Pre and Post	Mixed	Yes	No

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
RASA	2008	B. Maguire and S. Cartwright	*Assessing a Community's Capacity to Manage Change: A Resilience Approach to Social Assessment (RASA)*	Community	Australia (rural)	Water Scarcity	Pre	No	Yes	No
Resilient Capacity Index (RCI2) – Regions	2008	Berkeley Institute of Urban and Regional Development	*Resilience and Regions: Building Understanding of the Metaphor*	Metro Regions	Global	Multiple	Pre	N/A	Yes	N/A
CCR/ IOTWS	2007	USAID-Asia Community Coastal Resilience (CCR)	*A Guide for Evaluating Coastal Community Resilience to Tsunami/Other Hazards*	Community	Southeast Asia	Tsunami	Pre	No	Yes	No
MCEER R4	2007	Multidisciplinary Center for Earthquake Engineering Research (MCEER), University of Buffalo	*Conceptualizing and Measuring Resilience*	Community	Global	Infrastructure	Pre	N/A	Yes	N/A

Name	Date Published	Author/ Developer	Title	Unit of Analysis	Area of Focus	Risk Focus	Pre or Post Disaster	Quant-itative?	Public Domain?	Public Data Source?
TRIAMS	2006	World Health Organization	*Tsunami Recovery Impact Assessment and Monitoring System Risk Reduction Indicators (TRIAMS)*	Community	Indian Ocean	Tsunami	Post	Mixed	Yes	No
THRIVE	2004	Prevention Institute	*Tool for Health & Resilience in Vulnerable Environments (THRIVE)*	Community	United States	Health Disparity	Pre	Mixed	Yes	No
Social Vulnerability Index (SoVI)	2003	Cutter, SL; Boruff, BJ; Shirley, WL	*Social Vulnerability to Environmental Hazards*	County	United States	All-hazards	Pre	Yes	Yes	Yes

Appendix B: Methodologies Meeting CRCI Inclusion Criteria

* Indicates a methodology identified in the 2018 analysis.
^ Indicates an international methodology

Australian Natural Disaster Resilience Index (ANDRI)*^
Phil Morley, Melissa Parsons and Sarb Johal, 2017, "The Australian Natural Disaster Resilience Index: A System for Assessing the Resilience of Australian Communities to Natural Hazards," Bushfire & Natural Hazards CRC. Available at https://www.bnhcrc.com.au/research/hazard-resilience/251, accessed March 20, 2023.

Baseline Resilience Indicators for Communities (BRIC)*
Susan L. Cutter, Kevin D. Ash and Christopher T. Emrich, 2014, "Baseline Resilience Indicators for Communities, the Geographies of Community Disaster Resilience," *Global Environmental Change* 29, 65–77. Available at https://www.sciencedirect.com/science/article/pii/S0959378014001459?casa_token=30407z10Qm0AAAAA:Y5uIORVy-s9vrNcwASxOb28AD15MgS35Urfa1VCQ1n7Hae3Mt3oR6y-Kjes9Y7K_f1HQiOYB, accessed March 30, 2023.

Composite Community Disaster Resilience Index (CCDRI)
Rifat, S. A. A., & Liu, W., 2020, "Measuring Community Disaster Resilience in the Conterminous Coastal United States." *ISPRS International Journal of Geo-Information*. Available at https://www.mdpi.com/2220-9964/9/8/469/pdf accessed March 30, 2023.

Community Disaster Resilience Index (CDRI)*
Walter Gillis Peacock, et al., 2010, "Advancing Resilience of Coastal Localities: Developing, Implementing, and Sustaining the Use of Coastal Resilience Indicators: A Final Report," *Hazard Reduction and Recovery Center*, December. Available at https://www.researchgate.net/profile/Walter_Peacock/publication/254862206_Final_Report_Advancing_the_Resilience_of_Coastal_Localities_10-02R/links/00b7d51feb3e3d0d4a000000.pdf, accessed March 30, 2023.

Comprehensive Disaster Resilience Index (CDRI2)^
Marzi, S., Mysiak, J., Essenfelder, A. H., Amadio, M., Giove, S., & Fekete, A., 2019, "Constructing a Comprehensive Disaster Resilience Index: The Case of Italy." *PloS one.* Available at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0221585, accessed March 30, 2023.

Community Resilience Index (CRI2)*
Kathleen Sherrieb, Fran H. Norris and Sandro Galea, 2010, "Measuring Capacities for Community Resilience," *Social Indicators Research* 99: 227–247. Available at https://link.springer.com/article/10.1007/s11205-010-9576-9, accessed March 30, 2023.

Disaster Resilience of Place (DROP)*

Susan L. Cutter, Christopher G. Burton and Christopher T. Emrich, 2010, "Disaster Resilience of Place, Disaster Resilience Indicators for Benchmarking Baseline Conditions," *Journal of Homeland Security and Emergency Management* 7. Available at https://www.degruyter.com/abstract/j/jhsem.2010.7.1/jhsem.2010.7.1.1732/jhsem.2010.7.1.1732.xml, accessed March 30, 2023.

Fraser^
Fraser, T., 2021, "Japanese Social Capital and Social Vulnerability Indices: Measuring Drivers of Community Resilience 2000–2017." *International Journal of Disaster Risk Reduction*. Available at https://www.sciencedirect.com/science/article/pii/S2212420920314679?casa_token=oaC86lYRuwgAAAAA:ChyrqLcLG-4TT_ZqxEMMDP9oFyRMJODxQ6To9x5yfaLmZxYOMUb4qc3Ulx1UdteBCftuEd7d, accessed March 30, 2023.

Nursey-Bray^
Nursey-Bray, M., Gillanders, B., & Maher, J. A., 2021, "Developing Indicators for Adaptive Capacity for Multiple Use Coastal Regions: Insights from the Spencer Gulf, South Australia." *Ocean & Coastal Management*. Available at https://www.sciencedirect.com/science/article/pii/S0964569121002118?casa_token=ofxgFiTUUE0AAAAA:qsHc0N1BtTDGNR4w5Phl6g9B_QGfpCj1y-GaF1CottH2i3eLEsQzPKLGC40C39LABoed8qmK, accessed March 30, 2023.

Resilience Capacity Index (RCI)*
Kathryn A. Foster, 2014, "Resilience Capacity Index: Disaster Resilience Measurements: Stocktaking of Ongoing Efforts in Developing Systems for Measuring Resilience*, United Nations Development Programme*, February, p. 38. Available at https://www.preventionweb.net/files/37916_disasterresiliencemeasurementsundpt.pdf, accessed March 30, 2023.

Regional Climate Resilience Index (RCRI)^
Feldmeyer, D., Wilden, D., Jamshed, A., & Birkmann, J., 2020, "Regional Climate Resilience Index: A Novel Multimethod Comparative Approach for Indicator Development, Empirical Validation and Implementation." *Ecological indicators*. Available at https://www.sciencedirect.com/science/article/pii/S1470160X20307998?casa_token=_VRVTAEajgUAAAAA:pTCr0FbuAU7Y7mjURGNV44_JYPRbhjy2cqxNXdiDcGhwt6SE-lUfzKFQQopJ0pKyZ2wwwTYB, accessed March 30, 2023.

Social Vulnerability Index (SoVI)
Cutter, Susan L., Bryan J. Boruff and W. Lynn Shirley, 2003, "Social Vulnerability to Environmental Hazards." *Social Science Quarterly 84.2*. Available at https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/1540-6237.8402002?casa_token=lUAXvoqNhUUAAAAA:SAFjsqpLIMmcdZHyB0n4s6DyUlw65VVv0u9XKwX4nRakED59dUqGHEW5FKDXDDRjiSTKIvmNzhM1Iw, accessed March 30, 2023.

Social Vulnerability Index (SVI)*[4]

[4] The CRCI literature review was conducted in 2021. The SVI has since been updated as of December 2022.

Barry E. Flanagan, et al., 2011, "A Social Vulnerability Index for Disaster Management," *Journal of Homeland Security and Emergency Management* 8. Available at https://svi.cdc.gov/Documents/Data/A%20Social%20Vulnerability%20Index%20for%20Disaster%20Management.pdf, March 30, 2023.

The Composite Resilience Index (TCRI)*
T. Perfrement and T. Lloyd, 2015, "The Composite Resilience Index: The Modelling Tool to Measure and Improve Community Resilience to Natural Hazards," *The Resilience Index*. Available at https://theresilienceindex.weebly.com/our-solution.html, accessed March 30, 2023.