Review

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A Systematic Literary Review on Community Resilience Indicators: Adaptation and Application of the BRIC Method for Measuring Disasters Resilience

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Abstract: Community resilience represents an important concept in the comprehensive approach to disaster management. It is assumed that optimal community resilience can mitigate negative impacts and enable adaptation, thereby reducing the negative consequences of future disasters. The measurement of community resilience to disasters has advanced over the past two decades, primarily through the use of indicators that measure community resilience indices. The Baseline Resilience Indicators for Communities (BRIC) represent an increasingly popular and frequently used quantitative method for measuring community resilience indices to disasters. This literature review was conducted to examine and assess the use and adaptation of the BRIC method in measuring community resilience. The review comprehensively analyzes relevant scientific papers, extracting and synthesizing the most important findings from the studies, which provided the necessary data to meet the objectives of the literature review. A total of 37 relevant studies were identified for analysis in the review. The indicators used were examined, including their selection, grouping, and evaluation procedures, as well as the calculation of the appropriate index. The review also covered the method of data collection needed to measure the impact of indicators on resilience, as well as the shortcomings of this process. The measurement of community resilience to disasters is a contemporary issue, with several detected shortcomings in the process itself. The need to adapt the BRIC method to the local context has been established. Improving the process of determining indicators and measuring indices would lead to broader use of the method in efforts to reduce disaster risk and enhance resilience to disasters.

Keywords: community resilience; disaster resilience indicators; natural disasters; resilience index; BRIC; DROP

1. Introduction

Community resilience is conceptually defined as the ability to resist the impact of hazards and reduce the likelihood of disaster occurrence (Aleksandrina et al., 2019; Goyal, 2019; Jaiye & Benjamine, 2021; Kabir et al., 2022; Olawuni et al., 2020). The first definition was used to describe the resilience of a system to absorb changes and disruptions while maintaining the same relationships between population and the state of variables (Holling, 1973, p. 14). The Sendai Framework for the period from 2015 to 2030 set an ambitious goal for preventing and reducing disaster risk by reducing exposure to risks and hazards, increasing preparedness, and strengthening resilience (*Sendai Framework for Disaster Risk Reduction 2015-2030*, 2015). Multidimensionality as one of the main

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characteristics of resilience encompasses the ability to withstand the circumstances that cause disasters, the ability to recover from them and, in the best case, to grow from the experience. Thus, resilience consists of the ability of society to adapt to the circumstances created by a disaster and minimize its impact (Alexander, 2013).

According to the United Nations and their International Strategy for Disaster Risk Reduction, resilience is defined as the ability of a system, community, or society exposed to hazards to resist, absorb, timely and effectively respond to, and recover from the consequences of hazards, including the preservation and restoration of essential basic structures and functions (*Terminology on Disaster Risk Reduction*, 2009). Considering that, according to UN data, 55% of the world's population today lives in urban areas, often densely populated (74% in Europe), and that by 2050, 68% of the global population will live in these areas, the multidisciplinary consideration of community resilience takes on special significance ("Department of Economic and Social Affairs," 2024). Special attention must be paid to the data on climate change caused by global warming and the fact that it will significantly accelerate the occurrence of more extreme events that will cause disasters (IPCC, 2023, p. 5). Exceeding a warming of two degrees would lead to irreversible processes with severe consequences for human life, caused by disaster impacts (Masson-Delmotte et al., 2018).

Traditional approaches to disaster management focus on damage prevention, effective response, and recovery, rather than mitigating consequences and building capacity. As a result, many studies related to disaster resilience are oriented toward outcomes, focusing on the ability and speed of recovery or minimizing the damage caused (Cimellaro, Reinhorn, & Bruneau, 2010). However, in contrast to this technical approach, a growing body of literature focuses on the human side of disaster resilience, on the individual and collective capacities that are essential for coping and adapting in times of crisis (Siambabala 2006).

Numerous studies support the idea that during periods of hardship, i.e., when facing immediate danger and physical injury, resilience is first manifested at the local level (Cvetković & Šišović, 2024; Cvetković & Šišović, 2024). Specifically, the affected people, their functioning, connectivity, and capacities, both individually and as a group, determine the level of resilience of local communities (Aldrich, 2012). Although the concept of resilience is considered a new foundation in disaster management, it has remained flexible without a specific set of indicators. The term resilience is not only multidimensional but also a multi-level construct that could refer to individuals, groups and communities (Cvetković et al., 2024; Cvetković, Rikanović, Knežević, 2022; Cvetković & Ivković, 2022; Cvetković, Grozdanić et al., 2024; Cvetković, 2023; 2024; Grozdanić & Cvetković, 2024). Consequently, for each specific case or community, there must be a clear definition of the entity (individuals, city, municipality, etc.), what they should be resilient to, the intensity they can endure, and the degree or speed of recovery after a disaster.

Disaster resilience indicators have evolved over time, progressing through phases in which the indicators were more precisely defined (Cai et al., 2018; Jülich, 2017). In addition to theoretical formulation, they have been concretized in terms of quantitative indicators that allow for more precise measurement and assessment of community resilience (Asadzadeh, Kötter, Salehi, & Birkmann, 2017; Chang & Shinozuka, 2004).

Baseline Resilience Indicators for Communities (BRIC) were developed by grouping various dimensions of indicators that measure community resilience. Initially, over 50 indicators were considered, and 36 were ultimately used for final analysis, divided into five groups deemed relevant, as shown in Table 1 (Cutter, Burton, & Emrich, 2010). Unlike the initial studies, there are now a total of 49 indicators grouped into six dimensions or groups ("Baseline Resilience Indicators for Communities," 2024). These indicators, as conceptual proof of measuring basic community resilience, apply so-called "preconditions" using the theoretical framework of Disaster Resilience of Place (DROP), which describes the most critical conditions for the resilience of a place before a catastrophic event occurs (Cutter et al., 2010).

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Table 1. Groups of Indicators for Measuring Resilience (Cutter et al., 2010).

Group of Indicators	Indicators
Social	Educational uniformity; 2) Age distribution; 3) Access to transportation; 4) Communication capacity; 5) Language proficiency; 6) Social needs; 7) Health insurance
Economic	Property ownership; 2) Employment; 3) Income distribution; 4) Sectoral employment; 5) Women's employment; 6) Business size; 7) Access to healthcare
Institutional	Disaster response plans; 2) Flood protection; 3) Local services; 4) Population capacity to cope with disasters; 5) Political fragmentation; 6) Previous experiences; 7) Civil protection; 8) Storm protection capacity
Infrastructure	Types of living spaces; 2) Shelter capacity; 3) Medical capacities; 4) Road infrastructure; 5) Age of living spaces; 6) Service accommodation capacity; 7) Public educational institutions
Social Capital	Population residency; 2) Immigrants; 3) Voter turnout; 4) Number of religious people; 5) Number of civil organizations; 6) Number of social organizations; 7) Share of employment in the innovative sector

The initial study that developed the BRIC model included an analysis of indicators in 736 counties across eight southeastern U.S. states. The area considered for analysis was historically prone to disasters but also characterized by intensive urbanization that brought numerous inequalities affecting disaster resilience (racial, health, and similar inequalities such as education, income, etc). Due to the high potential for deviation, ecology was not considered. The indicators were grouped into five categories: social, economic, institutional, infrastructure, and social capital.

The results of the first research, which served as the foundation for subsequent studies and method adaptations, were presented as a spatial assessment of the analyzed territories. Statistically, counties were analyzed, and results were provided based on the lowest and highest resilience indicators (results). The general conclusion of the research was that resilience was highest in urban areas, with the highest parameters found in the social, economic, and institutional groups. The "culprits" for the detected low resilience in rural regions were the groups of institutional and infrastructure indicators. The BRIC method is conducted through a recursive process in which complex sets of results are summarized and simplified, ultimately yielding average values. In the initial research and method development, all indicators had equal value or "weight"; they were not weighted, and values were normalized to a range from zero to one using an equation. These values were later summed to obtain a numerical resilience score (Cutter et al., 2010).

1.1. Theoretical Basis of the BRIC Method

The theoretical framework on which the BRIC method is developed is the DROP model (Disaster Resilience of Place). This theoretical model was developed in 2008 by the same researchers from the University of South Carolina who created the BRIC model. The aim was to design a theoretical model that would enhance comparative analysis and assessment of community resilience to disasters. This model combines elements of disaster prevention, adaptation to global changes, and responses to natural hazards. It incorporates an ecological and nature-based approach alongside comprehensive planning, offering a holistic framework for enhancing disaster resilience. The model clearly distinguishes resilience from vulnerability, stating that resilience is "the ability of a social system to respond and recover from disasters, including the primary conditions that allow the social system to absorb impacts, cope with the disaster, and adapt to post-disaster processes that facilitate the organization of society to function, change, and learn how to respond to threats" (Cutter et al., 2008, p. 599).

In the DROP model, communities are defined as "all interactions of the social system within a defined geographic space such as a neighborhood, census unit, city, or county" (Cutter et al., 2008, p. 599). The model was developed to assess resilience to natural hazards but can also be applied to other "rapid onset" shocks or long-term hazards such as droughts or pandemics. The model indicates how

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pre-existing conditions in a given place, combined with a disaster, produce a new impact on the community. A more resilient community will be able to implement better response mechanisms to mitigate the impact of the event. The impact of a hazard is a function of pre-existing conditions, the nature of the event, and response mechanisms. A disaster occurs when the absorptive capacity in that place is exceeded. Resilience, as a process, comes to the fore again at this stage, influencing the degree of recovery and preparedness for future events.

The key assumption of the model is that the social resilience of a place depends on the interconnection of natural systems, social systems, and the built environment. The model has six dimensions of resilience with a total of 29 indicators, which are shown in Table 2. "The model presents resilience as a dynamic process that depends on pre-existing conditions, the severity of the disaster, the time between hazard events, and the influence of external factors. Although conceptually dynamic, immediately before the disaster, the recovery process leads to a static representation of pre-existing conditions"(Cutter et al., 2008, p. 604).

Table 2. Dimensions of Resilience with Their Indicators (Cutter et al., 2008).

Dimensions of Resilience	Indicators
Environmental	Wetland areas; 2) Erosion rate; 3) Percentage of impermeable surfaces; 4) Biodiversity; 5) Coastal defence structures.
Social	Demographic factors (gender, age, ethnicity, and occupation); 2) Social networks and organizations; 3) Social cohesion; 4) Religious organizations.
Economic	Employment; 2) Property value; 3) Wealth distribution; 4) Local government funding.
Institutional	Participation in risk reduction programs; 2) Hazard mitigation plans; 3) Emergency services; 4) Zoning and building regulations; 5) Emergency response plans; 6) Communication interoperability; 7) Continuity of operations plans.
Infrastructure	Critical infrastructure; 2) Transportation network; 3) Structure and character of residential buildings; 4) Commercial and industrial buildings.
Community Competence	Local risk understanding; 2) Advisory services; 3) Absence of deviant behavior; 4) Health and sports; 5) Quality of life.

Based on all of the above, the aim is to conduct an integrative literature review to collect, critically assess, and synthesize the results of a larger number of studies on the subject, contributing to a deeper understanding of the research question. To gather and systematize the literature, the following steps were applied: identifying the topic and defining the guiding questions; data selection; defining the search; searching and saving results; selecting articles based on abstracts, according to inclusion and exclusion criteria; extracting data from selected articles; evaluating data; and synthesizing and interpreting data.

The primary reason for conducting the literature review is to identify and analyze studies that cover the following: a) indicators of community resilience to natural disasters or approaches for measuring community resilience to natural disasters; b) the use and modification of the BRIC method for measuring community resilience to natural disasters.

The focus of the critical literature review is on the BRIC method, aiming to evaluate the methodological quality of resilience index development, the range of indicators used, and the geographic locations where community resilience was measured using this method. The basis for the development and improvement of the BRIC method is the OECD "checklist" for composite indicators, which defines 10 steps for constructing a composite index (*Handbook on constructing composite indicators: Methodology and user guide*, 2008). This framework was referenced in the original BRIC study (Cutter et al., 2010). This is particularly important because there are significant possibilities for variations in how the BRIC model is applied in different contexts (index development, use for different geographic locations, differently defined communities, and the types of disasters or consequences they cause).

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2. Methods

An adequate research framework is a key element for conducting a systematic literature review, enabling a thorough study of extensive and diverse literature on community resilience indicators to natural disasters. In this process, the primary methodological approach is based on the methodology of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a widely accepted and standardized method for conducting literature reviews.

The PRISMA methodology (Page et al., 2021) involves several key stages: identifying relevant literature, assessing its eligibility, and selecting and including studies that will undergo detailed analysis. This systematic approach ensures that the literature review is comprehensive and representative, covering the most significant and relevant sources that contribute to a better understanding of community resilience to natural disasters.

With the proper application of the PRISMA methodology, the research gains scientific rigour, as this approach minimizes bias and ensures transparency in the selection and analysis process of the literature. Furthermore, PRISMA allows for clear tracking of the research process, from the initial identification of relevant sources to the final analysis and synthesis of results, ultimately providing reliable and valid conclusions that can serve as a foundation for further research and decision-making in the field of natural disaster risk management.

With such a structured and well-defined framework, the systematic literature review not only identifies trends and gaps in existing research but also contributes to building theoretical and practical knowledge about the factors that affect community resilience. In this way, it provides valuable insights that can directly impact the improvement of strategies for risk mitigation and strengthening resilience to natural disasters.

2.1. Search Criteria

The literature review on the subject of community resilience indicators to natural disasters, with a focus on the BRIC method based on the theoretical foundation of the DROP model, was conducted as follows:

- The search period spans from 2010 (when the BRIC model was initially developed) to 2024.
- The search was conducted using the free and accessible tool scholar.google.com (Google Scholar).
- Only research (scientific) articles focusing on the social aspect of community resilience to disasters, specifically on indicators, approaches to the use of indicators (models), and the BRIC method of resilience index measurement, were included.

The primary characteristic of the search is that it was limited to works published from 2010 onwards. The reason for this is that the BRIC method was first formulated at that time, and the goal was to include modern, relevant scientific articles published in English.

The initial search excluded materials such as books, book chapters, reports, systematic reviews, and articles whose titles, keywords, and abstracts do not reference community resilience indicators to natural disasters or the BRIC method, which is the focus.

During the analysis of the texts of the articles that initially met the criteria, in the next phase of the selection, the following articles were excluded:

- Those that did not use a quantitative methodological approach, as the BRIC model itself represents a quantitative model for measuring community resilience to natural disasters;
- Those that were not focused on natural disasters, were related to health, researched the resilience of organizations, businesses, or institutions, or focused on food, resources, etc. Additionally, articles that did not retain or modify the BRIC model but instead developed entirely new models based on it were excluded.

The keywords used during the search were: community resilience indicators, baseline resilience indicators, community resilience assessment tool, and community resilience assessment framework.

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2.2. Sources of Information and Search

The literature search was conducted in July 2024 and included articles from 2010 onward, searched through the Google Scholar search engine, following the predefined search criteria mentioned earlier. In addition to this search technique, relevant websites (organizations, institutions, etc.) and citations from relevant papers were also explored, which indicated the potential for finding appropriate academic works.

After an initial analysis of the academic articles, including reviewing titles, their topics, and their relevance to the objectives of this critical literature review, and considering the purpose, timeframe, resources, and the fact that the review is being conducted by a single researcher, titles containing specific English phrases, such as "community resilience indicators," "baseline resilience indicators," "community resilience assessment tool," and "community resilience assessment framework" were searched. The main goal was to optimize the process and exclude a large number of papers that were not aligned with the objectives of the critical literature review, arriving at a relevant number of articles for further analysis.

After selecting the papers, an additional search of the available texts was carried out. These texts were reviewed starting with the abstracts, and after confirming their relevance and validity, the full content of the papers was analyzed. The data from these articles were selected and stored in an appropriate Excel database. The database was designed to enable the collection and analysis of data under the objectives of the critical literature review.

2.3. Data Research Process

To ensure the highest quality of data systematization and result interpretation, two types of analyses were conducted. The first is a quantitative analysis, aimed at evaluating precise data, primarily concerning the following aspects: year of publication, country of origin of the first author, the nature of the study (empirical or theoretical), the approach to analysis, and the research design (qualitative, quantitative, or multimethod). It also focused on the instruments used for data collection, the indicators employed, how they were categorized, and the tools or frameworks used to measure community resilience. Special attention was given to the BRIC method and observed modifications.

The second analysis is qualitative, focusing on critically assessing the papers concerning their stated objectives, approaches to achieving those objectives, and conclusions concerning the use of the BRIC method for measuring community resilience.

2.3. Synthesis (Sublimation) of Results

By utilizing Google Scholar along with additional databases such as Web of Science, Scopus, and JSTOR and applying the specified criteria and search terms, a total of 87 papers were identified for consideration. The search returned 53 articles for the term "community resilience indicators," 11 for "baseline resilience indicators," five for "communities resilience assessment tool," and 18 for "communities resilience assessment framework." Among them, nine (n = 9) duplicates were registered, eight (n = 8) were not scientific articles, four did not contain the required search terms (n = 4), eight texts could not be retrieved (n = 8), two were not in English (n = 2), and 11 did not address the relevant subject matter according to their titles (n = 11). From the initial number of articles, 45 remained for further analysis. After reading the abstracts and, where necessary, the full articles, it was determined that a total of 28 articles were suitable for further analysis. A total of 17 articles were excluded because their content and nature did not align with the goals of the critical literature review. Out of the 28 articles, eight pertained to the BRIC method and its adaptation, while 20 focused on community resilience indicators and their application and adaptation for measuring disaster resilience. Of the eight articles related to the BRIC method, four pertained to entire countries, while the remaining four focused on specific regions.

Using the internet and searching appropriate platforms (Academia.edu, ResearchGate), as well as searching citations and analyzing them, where the same keywords as in the initial search were not used, a total of 89 papers were initially considered. Among them, 21 duplicates were registered

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(including the initial Google Scholar search) (n = 21), 17 were not scientific articles (n = 17), 19 texts were not available (n = 19), three were not in English (n = 3), and 11 did not address the relevant subject matter according to their titles (n = 11). From the initial number of papers, 18 remained for further analysis. After reading the abstracts and, where necessary, the full articles, a total of nine articles were deemed suitable for further processing. Nine articles were excluded because their content and nature did not align with the goals of the critical literature review. Of these, four articles pertained to the BRIC model and its adaptation, while five articles focused on community resilience indicators and their application and adaptation for measuring resilience to natural disasters. Of the four articles related to the BRIC model, two pertained to entire countries, while the remaining two generally related to its adaptation.

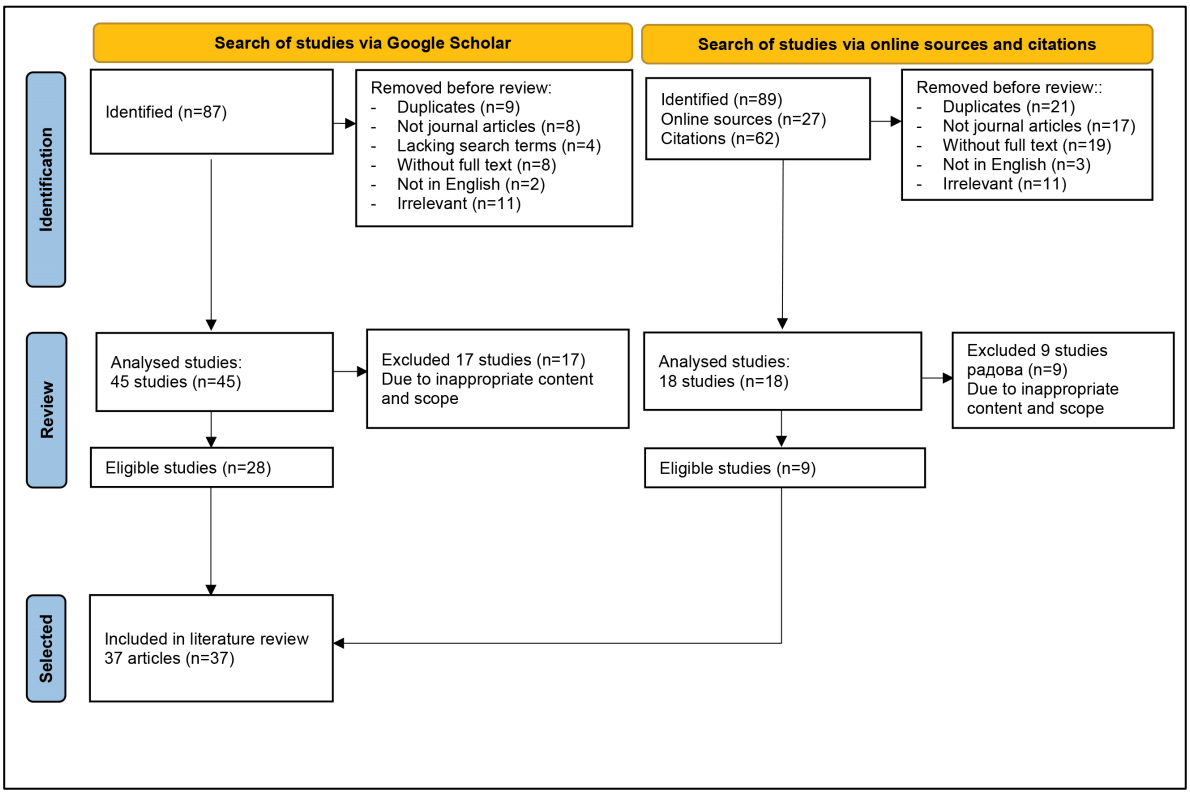

Figure 1. The article selection process is based on inclusion and exclusion criteria.

3. Results

3.1. Quantitative Characterization

A total of 37 articles were analyzed, all of which were in English. When examining the articles that specifically focus on the BRIC method and the DROP model as the theoretical foundation and operationalization of indicators, 12 articles were deemed sufficiently relevant for analysis. For the period starting from 2010, there is no dominant country from which the first authors of the articles originated. It is noteworthy that five papers deal with a specific region and the application or adaptation of the BRIC model, while seven papers either cover an entire country or address the topic in a general sense without a specific territorial application of the model. Regarding Europe, four papers are from that continent (another paper, which does not explicitly reference the BRIC method but pertains to a European country, was found but excluded from consideration).

Considering the timeline of publication and the fact that the model was created in 2010, it is evident that the number of papers has significantly increased since 2019, with a total of nine papers published since then. In terms of the type of disaster addressed in the articles, half of the papers (six) focus exclusively on natural disasters, while the other half takes a multidimensional approach, addressing all types of disasters.

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When the type of research is considered, three papers are purely theoretical, while the other nine are based on practical, empirical research. Regarding research design, of the 12 articles, one uses a qualitative approach, one uses a quantitative approach, and ten apply a multimethod research design. This is due to the complexity and diversity of the data that must be collected and analyzed in the process of evaluating numerous indicators, which require an appropriate multimethod approach to provide an integrated analytical process.

Another characteristic of the papers examining the BRIC method is that publicly available data, gathered by relevant government institutions, were predominantly used, with secondary data analysis being conducted. Due to this, many of the research papers highlighted the issue of missing data in certain segments and proposed ways to address such gaps to ensure the relevance of the results.

In summary, eight of the papers used publicly available data with a segmented content analysis of existing studies in the field. Four papers employed interviews, focusing on the Delphi technique and the involvement of experts in the research. Table 3 provides an overview of the results obtained from the analysis of papers related to the BRIC method, which also includes the consideration of the DROP theoretical model.

Table 3. Overview of Search Results and Analysis for Papers Related to the BRIC Method.

Quantitative Categories	Sample
Country of the first author	USA, Australia, Thailand, Norway, Taiwan, Brazil, Sweden, Nepal, Bangladesh, Iran, Hungary (x2).
Territory	Five papers — specific region. Seven papers — country or general territory.
Type of disaster	Six papers exclusively on natural disasters, six papers — multidimensional approach.
Year of publication	2010 — 1; 2014 — 1; 2015 — 1; 2019 — 1; 2020 — 3; 2021 — 2; 2022 — 1; 2023 — 2.
Type of Research	Theoretical — 3; Empirical— 9.
Research design	Qualitative — 1; Quantitative — 1; Multimethod — 10.
Data Collection	Access to publicly available data — 8; Interview (Delphi) — 4.

When examining articles related to resilience indicators in general, specifically their analysis, evaluation, adaptation, and overall successful application, 25 papers were analyzed. Of this number, it is noteworthy that the first author in 10 papers was from the USA during the observation period starting from 2010. Additionally, when considering the publication dates, the distribution is fairly even across the years, with two to three papers published in each observed year. Eight papers focus on specific geographic regions, while 17 papers address entire countries or the topic in a general sense without specific territorial application of the resilience index. Regarding Europe, six papers originate from that continent.

In terms of research type, it is characteristic that the majority—18 papers—take a theoretical approach, while seven papers focus on empirical research.

Regarding research design, of the 25 papers, nearly half (12) employ a qualitative approach, four use a quantitative approach, and nine apply a multimethod research design. A key characteristic of this group of papers is that the dominant approach to data collection is content analysis, which correlates with the qualitative research design and the subject matter of the papers. A total of 11 papers dealt with content analysis.

The next data collection method is the processing of publicly available data from relevant state institutions, which was used in eight papers. Four papers employed interviews and questionnaires as part of their research process. Among these, the Delphi method was used three times (in one paper, it was combined with the analysis of publicly available data). In two papers, the methodology was based on questionnaires and field research. Table 4 provides an overview of the results obtained from the analysis of papers related to resilience indicators and their application and adaptation.

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Table 4. Overview of Search Results and Analysis for Papers Related to Indicators.

Quantitative Categories	Sample
Country of the first author	The USA — 10; UK — 3; Malaysia — 2; Israel — 1; Sri Lanka — 1; Germany — 1; Japan — 1; Italy — 1; Taiwan — 1; China — 1; South Korea — 1; New Zealand — 1; Mauritius — 1.
Territory	Eight papers — specific region. Seventeen papers — country or general territory.
Year of publication	2012 — 1; 2013 — 3; 2015 — 2; 2016 — 2; 2017 — 2; 2018 — 3; 2019 — 2; 2021 — 3; 2022 — 3; 2023 — 2; 2024 — 2.
Type of Research	Theoretical — 18; Empirical — 7.
Research design	Qualitative — 12; Quantitative — 4; Multimethod — 9.
Data collection	Access of publicly available data — 8; Interview (Delphi) — 3; Questionnaire — 1.

Summarizing the quantitative characterization of the analyzed papers, within the context of the literature review, the predominant use of the Delphi technique stands out as the most significant finding. Additionally, in papers focused on practical research, data sources primarily came from secondary analysis of public institution data, supplemented in part by questionnaires and fieldwork. This is particularly evident in papers dealing with the application and adaptation of both the BRIC method and other methods or indices used to measure resilience to natural disasters.

3.2. Qualitative Characterization of Resilience Indicators

Summarizing the challenges related to the indicators used to measure community resilience to natural disasters, their application, adaptation across various models, and the implementation and adaptation of the BRIC method derived from the theoretical DROP approach, several conclusions can be drawn.

The indicators discussed in the papers can be categorized into eight groups. Using a generalized translation from English, these are socio-demographic, community well-being, economic status, institutions, infrastructure, geographic and spatial characteristics, cooperation, and risk analysis. These groups of indicators may vary slightly in names across different studies, but essentially, they refer to the same or similar indicators within the group that are related to the context of the indicator group's name.

As the basis for the consideration, selection, and use of indicators, in most cases, the Handbook on Constructing Composite Indicators: Methodology and User Guide by the Organisation for Economic Co-operation and Development (OECD) was used (*Handbook on constructing composite indicators: Methodology and user guide*, 2008).

Among the socio-demographic indicators, those that help determine the resilience of modern urban communities are the most numerous. Together with economic characteristics, social indicators assist in assessing the long-term capabilities of a local community (Ji, Wei, Shohet, & Xiong, 2021). These indicators describe the demographic characteristics that point to the ability of the local population to cope with unwanted events and occurrences (Scherzer, Lujala, & Rød, 2019).

The most important indicators in this group include age (percentage share of a defined age range), gender, vulnerable segments of the population (those particularly at risk in the event of a disaster), the share of women in the available workforce, population density in urban communities, the average number of people per household, the demographic dependency ratio, and educational status. These indicators can be generalized and measured for each household. It is assumed that communities with a majority of employed individuals can help themselves during disasters and even assist others, compared to minors and the elderly. The awareness of the employed segment of the community regarding the resilience of the local community can significantly positively affect their behaviour and preparedness for any type of disaster (Scherzer et al., 2019).

Furthermore, as an example, acquiring knowledge mostly occurs through formal education, where skills, knowledge, and competencies are gained, influencing the population's adaptive capacity to respond adequately to disasters. Local communities with a higher percentage of individuals with limited education increase the vulnerability of such communities due to their

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unwillingness to take timely actions, measures, and steps. Better-educated individuals return to normal life faster after disasters because they respond adequately and have access to better social and economic resources after disasters (Muttarak & Lutz, 2014). In summary, the most important and widely used indicators and their variables for this group include: age; gender; the degree and characteristics of the so-called vulnerable population; workforce and the share of women in it; population density; the number of people per household; the percentage of the non-working population; and educational status.

Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, the difference is that indicators related to social cohesion have not been developed, religious organizations are placed in another group of indicators, while social and value indicators have developed. Concerning the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as access to transportation, language competencies, and communication capacities. Community well-being, as the next group of indicators with its variables, significantly impacts overall community resilience because it subsequently affects all other groups of indicators when it comes to disaster resilience. According to research, it has been established that local communities with adequate resources can establish and implement strategies to mitigate the effects of disasters, while impoverished communities evidently lack the resources and the ability to equip themselves before any disaster (Bergstrand, Mayer, Brumback, & Zhang, 2015).

The development of local communities contributes to a higher degree of communication among its members through existing organizations and activities. This connection facilitates easier and better management before and during disasters, which increases community resilience (Mohamad, Jusoh, & Kassim, 2019). In this segment, the religious component is of certain importance due to its connection to the obligation to help others and to be prepared for something inevitable, such as natural disasters. The influence of religious organizations affects the preparedness of urban communities, where those with a high percentage of individuals with rooted belief systems maintain a high level of disaster resilience and promote ways to protect against destabilizing events (Kim & Marcouiller, 2018).

The most important and widely used indicators with their variables for this group include: community awareness of natural disasters; communication systems and information transmission; the ability to use previous experiences; the capacity to monitor potential risks; associations, communities, and groups formed by local authorities; religious beliefs; and prevention plans. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that, compared to the DROP model published in 2008, the difference is that no indicators related to the absence of psychopathological states were developed. Compared to the BRIC model published in 2010, it is concluded that it includes indicators not addressed in the relevant scientific papers, specifically indicators such as migration or population fluctuation and the percentage of the population engaged in creative and innovative activities. The economic condition, as the next group of indicators with its variables, is used to assess the resilience of individuals, families, and the community as a whole (Mohamad et al., 2019).

These indicators can be measured at the household level to provide a cumulative overview of the overall level of economic resilience. Indicators reflect the functioning of the economy during disasters, particularly for large and small firms. The general vitality of urban economies is reflected in employment rates, income, retail turnover, supply chains, and other aspects (Scherzer et al., 2019). The category of economic resilience encompasses both the static assessment of the current economy of the community (economic activity) and the dynamic assessment of the community's ability to continuously maintain economic growth (economic development) (Irwin, Schardong, Simonovic, & Nirupama, 2016).

The most important and widely used indicators with their variables for this group include: financial resources for disaster response, employment rates, household income levels, the percentage of the poor, and the characteristics and level of insurance coverage (from health insurance to all other types). Correlating these indicators with those listed in the works that established the BRIC and

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DROP models, it can be concluded that compared to the DROP model published in 2008, all indicators in this group have been developed. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as the GINI coefficient, the percentage of the population employed in the food industry, and the distribution and share of companies by size. The share of women in the total employed population, unlike the BRIC model, is treated as a socio-demographic indicator. Institutions - The indicators of urban community resilience with their variables within this category reflect community and crisis management. It is widely accepted that resilience is not an isolated characteristic or feature of institutions but a product or function of comprehensive institutional performance. It arises from institutional efficiency (or the ability to achieve and improve outcomes over time). This, in turn, creates trust, legitimacy, and credibility, which themselves represent sources of resilience that further strengthen institutional capabilities. It is believed that people who work in public institutions and hold higher positions of power influence the disaster response. They attract political support and economic resources for recovery (Scherzer et al., 2019).

Furthermore, the studies show that communities located near the centres of political and economic power often benefit from resources intended for disaster mitigation (Cutter, Ash, & Emrich, 2014). The most important and widely used indicators with their variables for this group include the availability of public and emergency services; civil protection programs; cooperation between the public and private sectors; regulations and guidelines for disasters; the existence of organized disaster response units; continuous public disaster preparedness; disaster response plans; evacuation plans; community crisis operation plans; adequate spatial planning; and the percentage of the employed population in local institutions. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, all indicators in this group have been developed, and new indicators and variables have been introduced. This significantly increased the quality of institutional resilience within local communities. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as flood risk in the community, emergency services funding, and political micro-community fragmentation. It is noticeable that more precise indicators with their variables have been developed, allowing for a more comprehensive understanding of institutional resilience in local communities than in the original BRIC model. Infrastructure, as a group of indicators with its variables, focuses on the resilience of residential units and the local infrastructure used by community members. The quality of materials used in the construction of housing and other communal infrastructure determines the community's recovery process (Scherzer et al., 2019).

Individuals with high incomes can afford quality housing units compared to those with low incomes, confirming the correlation between groups of indicators and the impact on overall resilience, according to research (Muttarak & Lutz, 2014). There is a direct correlation between the materials and construction processes adopted to make infrastructure and housing units disaster-resistant, which is necessary to achieve community resilience in infrastructure terms (Karanci, Ikize, Doğulu, & Özceylan-Aubrecht, 2016).

The most important and widely used indicators with their variables for this group include the share of areas covered by alert systems, building resilience assessments, building age, materials and construction quality, and maintenance of existing infrastructure. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, the indicators are more developed and refined, and transportation infrastructure is included under the overall infrastructure without specific segmentation. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as the share of mobile homes in the total number of units, the share of vacant properties, the number of hospital beds per 10,000 people, road network density, precise building age, the number of accommodation establishments per square mile, and the number of educational institutions (for shelter) per square mile. Geographical and spatial characteristics determine the resilience of local

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communities to natural disasters. Geographical diversity presents an additional challenge in assessing resilience. For example, coastal communities face risks that inland communities do not, such as hurricane storm surges and tsunamis, while only communities in seismic hazard zones need to improve earthquake resilience. Preparing for a flood or hurricane requires a different approach than preparing for an earthquake or tsunami. This reveals a limitation in the scalability of resilience metrics with different hazards and communities of varying sizes, locations, and characteristics (Johansen, Horney, & Tien, 2017). Resilience considerations require accounting for the interaction between the spatial and temporal scales of a community, including how people integrate with space and how those spaces shape behaviors, thoughts, and feelings within communities, thus building their resilience over time as they inhabit a particular area (Quigley, Blair, & Davison, 2018).

The most important and widely used indicators with their variables for this group include: the geographical location of the community, the spatial composition of the community, and the use of parts of the community's location. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is dispersed and not included as such. It is partially distributed across the environmental and institutional index groups. It is also important to note that it is not as clearly defined as it is in current studies.

Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There are some indices with specific variations in infrastructure resilience and community resilience that may be similar to this group of indicators, particularly in terms of the distribution of public institutions. Collaboration involves a broad spectrum of connections between individuals, organizations, institutions, and government authorities into a unified network that allows for continuous two-way communication and mutual influence in decision-making crucial to community resilience in the event of a disaster. "Communities have the authority to make decisions that allow for planning, financing, and implementing resilience measures, and they can act as logical intermediaries for collaboration with private property owners and utility services. Communities provide a range of services to meet social needs, supported by the built environment. The performance of these systems is integrated, though they are often designed and constructed independently of each other.

The resilience of individual buildings, facilities, and infrastructure systems should be defined in terms of the roles and functions they perform within the community. The resilience of the built environment should be evaluated as a system of systems with dependencies that can affect other systems and the entire community" (McAllister, 2015, p. 4). The most important and widely used indicators with their variables for this group include collaboration between local communities and higher authorities in decision-making and procedure implementation, comprehensive collaboration and networking at the local level, and community involvement in disaster management. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is more developed. In that model, social networking and its rootedness in the community are mentioned under the group of social indicators.

Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There is a communication capacity index in the group of social resilience indices, which only considers the proportion of the population with a telephone, a much narrower approach compared to the examined indices and their variations, which consider a much broader spectrum of communication establishment and maintenance methods. Risk analysis represents a proactive group of indicators aimed at identifying potentially vulnerable points within a community, where, in the event of a disaster, the least resilience would be mapped. The indicators of urban community resilience in this category include the availability of risk and vulnerability databases for communities, historical records of previous hazardous events, a database of the current number of people exposed to risks, a community risk assessment, the presence of disaster risk mapping associated with natural threats, and early warning response programs. Archiving data on previous disruptive events improves the learning experience for community resilience. Archived data on disruptive events

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represent a resilience indicator where historical data on disasters that have occurred in communities can be accumulated. This indicator represents the ability of communities to predict based on archived disaster data. Geographic Information Systems (GIS) are useful tools for governments, insurance companies, and other institutions to formulate disaster prevention strategies and implement early warning mechanisms (Macharia et al., 2020).

Advanced simulation techniques for scenario analysis can be used to identify and assess the impact of disasters. The goal of scenario analysis is to enable the generation of "surprising" threats or disruptive events that can provide valuable insights into how to make critical infrastructure resilient (Zio, 2016). The most important and widely used indicators with their variables for this group include: disaster risk databases; hazard assessments for the community; risk mapping; a database of the number of people potentially exposed to risks. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is also more developed. In the mentioned model, in the group of institutional indicators, segments can be found that represent indicators similar to those representing risk analysis. Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There are several indices in the group rounding up institutional resilience, which can partially compensate for the purpose of the group of indices named risk analysis, which was actively used in the analyzed papers.

The sublimation of methodological approaches relates to the use of the previously mentioned groups of indicators and the indicators themselves with their variations. Most, or nearly all, methodological approaches have been developed after 2010 and refer to the use of indices based on the need for which they were created. Methodological approaches have been translated into specific tools or frameworks. The approaches are almost always multidisciplinary and apply to all disasters. A smaller number of tools and frameworks have been developed exclusively for natural disasters and apply to specified areas or regions that face specific natural disaster threats. It is characteristic that fewer than ten tools developed from 2000 to 2010 are mentioned in the papers, while more than 35 tools have been registered from 2010 to 2024, excluding their adaptations, which are not considered new models, although they often significantly differ from the basic, initial model.

Several attempts have been made to measure disaster resilience by developing composite indicators, and these efforts are still in their early stages, as is what might represent a standard mechanism for measuring disaster resilience. The tools have applied various, and even opposing, approaches to fulfill the common goal of providing guidance for building resilient communities. This reflects the diverse origins of the tools, variations in the definition of community across the selected tools, and the diverse and opposing starting points that led to their development. More than half of the tools mentioned in the papers were developed for the needs of local communities in the United States. The initiators of their creation are mostly government institutions, while a certain number of tools were developed under the sponsorship of organizations concerned with environmental protection. Other tools have been developed in other developed countries. As the tools were mainly created in developed countries, there is concern about their applicability and generalizability to communities in less developed countries. Local authorities and community organizations are the main target group. There are also tools designed to inform other sectors, such as academia, aid agencies, and insurance companies.

3.3. The qualitative characterization of the use and modifications of the BRIC method

The DROP model, as the theoretical basis for the BRIC method, was designed to assess resilience to natural hazards, and the authors note that the model could also be applied to other sudden or long-term hazards. In the DROP model, communities are defined as "the totality of interactions of the social system within a defined geographic space, such as a neighbourhood, census district, town, or county" (Cutter et al., 2008, p. 599). BRIC has been applied at different levels and with various geographic units. The levels of analysis have ranged from entire countries to individual villages. Counties were the unit of analysis in the original BRIC study from 2010 and represented the most commonly used definition in subsequent research.

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The original BRIC study examined 36 indicators with their variables within five groups of indicators. The number of indicators used in the analyzed studies ranged from 3 to 49. Some studies in the literature have even employed up to 57 indicators. Table 5 presents the characteristic studies used in this review, along with the specific number of indicators for each group and other relevant details for each study.

Table 5. Characteristic Studies Used in the Review.

Author and Year	Territory	Resilience	Indicator Groups	Total Indicators
(Moghadas, Asadzadeh, Vafeidis, Fekete, & Kötter, 2019)	Iran/Region	Floods	Social 7; Economic 6; Infrastructure 6; Social Capital 8; Ecological 3.	22
(Csizovszky, 2023a)	Hungary/Whole Country	Disasters	Social 7; Economic 7; Infrastructure 8; Social Capital 7; Ecological 7.	36
(Aksha & Emrich, 2020)	Nepal/Whole Country	Natural Disasters	Social 9; Economic 4; Infrastructure 3; Social Capital 3; Ecological 3.	22
(Javadpoor, Sharifi, & Roosta, 2021)	Iran/Whole Country	Disasters	Social 12; Economic 7; Institutional 2; Infrastructure 9; Social Capital 4; Ecological 4.	35
(Sung & Liaw, 2020)	Taiwan/Region	Natural Disasters	Social 2; Economic 1; Institutional 2; Infrastructure 5; Social Capital 2.	12
(Singh-Peterson, Salmon, Goode, & Gallina, 2014a)	Australia/Region	Disasters	Social 6; Economic 6; Institutional 6; Infrastructure 5; Social Capital 4.	27
(Scherzer et al., 2019)	Norway/Whole Country	Natural Disasters	Social 8; Economic 7; Institutional 4; Infrastructure 9; Social Capital 10; Ecological 9.	47
(Cutter et al., 2014)	USA/Whole Country	Disasters	Social 10; Economic 8; Institutional 10; Infrastructure 9; Social Capital 7; Ecological 5.	49
(Cutter & Derakhshan, 2019)	USA/Whole Country	Disasters	Social 10; Economic 8; Institutional 10; Infrastructure 9; Social Capital 7; Ecological 5.	49
(Mavhura, Manyangadze, & Aryal, 2021)	Zimbabwe/Whole Country	Disasters	Social 10; Economic 8; Infrastructure 4; Social Capital 2; Health 5.	26

Basic research and the establishment of the DROP and BRIC methods by a group of authors, led by Susan Cutter from the University of South Carolina (USA), represent the foundational basis for the consideration and application of these methods. In this context, their 2014 work stands out, in which the BRIC method was applied across the entire United States, and a modification of the BRIC method was carried out, which served as the foundation for further use and modifications (Cutter et al., 2014). In that study, 49 indicators were developed across six groups, instead of the initial 36, aiming to encompass all the specificities for the entire U.S. territory to effectively measure resilience indices. Initially, 61 indicators were included, but after checking and analyzing the correlations, as well as expert review, the number was reduced to the aforementioned 49. This study is important for future approaches in selecting indicators because, in subsequent studies, the selection of indicators was made by experts using various methods (most commonly Delphi), by reviewing relevant literature, applying international organization guidelines, and calculating the correlation between indicators or indicator groups.

In the studies, starting from the first one led by Susan Cutter in 2010, when the BRIC method was established, the OECD guidelines were primarily used for assessing the quality of indicator selection and application. However, although these guidelines served as a foundation, not all recommended methodological steps were applied. In Cutter's first 2010 study, five OECD guidelines were applied. The author later increased the number of guidelines used in constructing the indicators, reaching up to eight in later studies (Cutter et al., 2014). The distribution of guidelines used in other

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studies ranges from three to nine. Roughly divided, about 20% of the studies used five, six, or seven guidelines. The guidelines most commonly omitted include: adding missing data, analyzing the reliability and sensitivity of the indicators, revisiting the data and ensuring transparency, and studying the data structure and linking it with other indicators.

The highest number of guidelines followed was in a study where the BRIC method was adapted for Norway. Nine guidelines were applied there, excluding the addition of missing data, where indicators with missing data were removed.

It is characteristic that in only seven studies from the analysis, the Delphi technique was applied, whereby experts from relevant scientific fields for each country or community being researched would determine appropriate indicators to measure the composite resilience index as the final result (Ciccotti, Cassia Rodrigues, Boscov, & Günther, 2020; Cohen, Leykin, Lahad, Goldberg, & Aharonson-Daniel, 2013; Pazhuhan, Moradpour, hesarakizard, & Ayyoob, 2023; Singh-Peterson, Salmon, Goode, & Gallina, 2014b; Talubo, Malenab, Morse, & Saroj, 2023; Tseng, Huang, Li, & Jiang, 2022).

Most of the studies used publicly available data, and simply, where data was not available, the OECD methodology was avoided, and such indicators were excluded without specific reasoning, and no effort was made to supplement the data with other available compatible data, as seen in studies (Aksha & Emrich, 2020; Bixler, Yang, Richter, & Coudert, 2021; Csizovszky, 2023b; Javadpoor et al., 2021; Scherzer et al., 2019; Weaver, 2016).

In some studies, indicators were excluded through the application of statistical methods if they did not provide appropriate results or were not valid indicators of resilience. A particular fact that might point to an inadequate selection of indicators in studies concerning their specific construction is the analysis of content from previously published research, synthesized through the processing of publicly available data. In these studies, by adopting the content of scientific works predominantly published in the USA and developed Western countries, the geographical, social, economic, and infrastructural differences, which are crucial for constructing optimal indicators for each country or community, were not adequately considered. The indicators obtained in this way were further shaped by the available public data, which, in poorer developing countries, are generally scarce and often of questionable value. Additionally, almost all the analyzed studies excluded fieldwork and surveys except for one study (Jepson & Colburn, 2013).

Their application, in situations where concrete publicly available data or a sufficient number of experts for the Delphi method are lacking, could lead to significant data for creating appropriate resilience indicators.

A fact that must be considered is, to a certain extent, the correct selection and use of indicators from each group, especially those related to geographical and social, but also other groups of indicators used to measure the resilience of local communities to natural disasters. The initial objectives of establishing the BRIC method and the theoretical foundation in the DROP model were designed to allow for the "localization" of indicators and their adaptation to the entity for which resilience measurement would be conducted, as done in the following studies for the DROP model (Mavhura et al., 2021; Siebeneck, Arlikatti, & Andrew, 2015).

Furthermore, after conducting a content analysis of the studies, the analysis of community resilience in Norwegian municipalities stands out as a characteristic study (Scherzer et al., 2019). The theoretical foundation was clear, and the authors explicitly stated that it was an adaptation of the BRIC model. The authors claimed that "the community resilience index for Norway should be specific to that country, and the finally selected indicators should be reasonable and justified in the context of Norway" (Scherzer et al., 2019). The starting point in the study was a list of indicators from the original BRIC study. A specificity was that indices for which complete data were not available were excluded from the analysis, unlike other studies that included indices without complete data by using the latest available or any available data (disregarding the time of data collection). Official data from institutions in Norway were used.

Of the initial 139 indicators considered, 27 were immediately excluded due to missing data. A total of 47 indicators grouped into six categories were used, which differed from the original BRIC method by emphasizing the indicator group labeled "Environment" (geographical and spatial

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characteristics). This number of indicators was reached by excluding indicators that did not provide relevant results or could not determine spatial differences for local communities. Some were excluded because it was assessed that they were not significant for a specific group of indicators. Unlike the original 2010 study, where the BRIC method was established, this study normalized the index values, and then they were assigned different weights based on their importance. Most studies normalized index values from 0 to 1, while a smaller number normalized them with a base value of 0 and a deviation from -1 to 1.

Only a few studies weighted the indices based on their significance, using the procedure developed by Becker as the leading author (Becker, Saisana, Paruolo, & Vandecasteele, 2017). Afterwards, a check of the comprehensiveness of the used indices and the definition of their values was performed. First-order sensitivity indices within groups were used to assess the importance of each indicator within its group. The resulting resilience index was compared with existing indices using Pearson's correlation coefficient to further exclude some indices, which was done for seven indices. The resilience index results were clearly presented on maps using standard deviation, showing the overall performance of the indices and the indicators they were based on.

Another notable and useful study is one analyzing community resilience in Hungary using the BRIC method (Csizovszky, 2023a). The theoretical foundation was clear, and the author explicitly stated that the study involved the adaptation of the BRIC model, taking into consideration previous studies that had adapted the original method, with the study on Norway serving as one example and foundation. The starting point in the study was a list of indicators from the original BRIC study.

After analyzing the literature, the author decided to use 36 indicators in five groups for Hungary. The model used for Norway and the method of excluding indicators until reaching an optimal number was not applied. Missing data were supplemented in a way that was not considered a key limitation; only the available data were used. Official data from institutions in Hungary were used. As in the study on Norway, index values were normalized from 0 to 1. Afterwards, the comprehensiveness of the used indices was checked. Throughout the process, the indices within groups were frequently adjusted to use relevant indices. All indices that had high or low values for each local community were excluded because they were not considered relevant for drawing conclusions. Unlike the study that adapted the BRIC method for Norway, the correlation was measured using Pearson's correlation coefficient, the Variance Inflation Factor (VIF), and the Kaiser-Meyer-Olkin (KMO) test, and some indices were excluded based on these tests. The resilience index results were clearly presented on maps using standard deviation, showing the overall performance of the indices and the indicators they were based on.

In addition to the mentioned studies, other useful studies that can be used as guides for research include those related to Nepal and Australia. The study on Nepal (Aksha & Emrich, 2020) due to the country's specifics, used primarily the theoretical DROP foundation and was not based on adapting the BRIC method. However, due to the quality of the approach, the research provides insight into one of the ways to use characteristic indicators and their variables for measuring community resilience indices. Regarding the research on Australia, it is notable that no modification of the indicators from the original BRIC study was made; rather, the indicator variables were simply adapted to the available statistical data, and the method's adaptation process was verified through expert interviews.

4. Discussion

The objectives of this paper relate to the analysis of scientific papers addressing the topic of indicators used for measuring the resilience of local communities and the practical application or adaptation of the BRIC method, derived from the DROP theoretical concept, in measuring community resilience to natural disasters.

After collecting and analyzing scientific papers based on established criteria, a critical review and analysis were conducted on a total of 37 papers, of which 12 specifically addressed the BRIC method and the DROP model as a theoretical basis and means of operationalizing the application of indicators. Out of this number, five papers focused on a specific region or local community. A

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noticeable increase in the number of papers related to the BRIC method began in 2019. The remaining 25 papers dealt with resilience indices, their analysis, and application. It is characteristic of these papers that, in 10 of them, the first author was from the USA. The distribution of papers by year of publication was consistent over the monitored period, starting from 2010. Out of the total number, eight papers focused on a specific region or local community. Furthermore, for the 37 observed papers, a multimethod approach was characteristic, used in a little over half of the papers, followed by a quantitative approach. Data were collected by processing available data from public and other institutions or through content analysis, which is typical for papers focused on indicators and employing a theoretical approach and qualitative research design.

The main methodological shortcoming observed in the analyzed papers is that OECD guidelines were predominantly omitted where there were challenges in data collection, assessing the quality of indicators, and comparing them— in areas where the limitations of scientific papers in selecting the most suitable indicators for measuring resilience are evident.

The next observed methodological shortcoming is the insufficient application of appropriate methods to obtain results that would allow the creation of optimal resilience indicators for a geographically defined location under investigation. What stands out is the insufficient use of the Delphi method, which is based on interviewing experts in the fields for which groups of indicators are defined in the papers. Additionally, there is a lack of fieldwork and surveys where publicly available data from government and other institutions are absent. In several papers, the need for deeper and more substantial data analysis and their verification, through qualitative research approaches, is emphasized. However, it is highlighted that a qualitative research design is desirable for a deeper exploration of specific groups of indicators and the proper selection of variables for the indicators.

In a few papers, particularly those mentioned in the qualitative analysis, the development of guidelines for selecting and using indicators (constructing and validating indices) is evident. The results of multivariate analyses should guide methodological decisions, such as grouping indicators and determining weights within the index (*Handbook on constructing composite indicators: Methodology and user guide*, 2008). In addition to the aforementioned, in order to reduce the number of indices being measured, Cutter and her colleagues published a scientific paper in 2022, which, along with previously mentioned methods for correlation, applied a statistical method called Principal Component Analysis (PCA). However, PCA did not result in factors that are conceptually justified and aligned with the contemporary understanding of community resilience and its drivers (Derakhshan, Blackwood, Habets, Effgen, & Cutter, 2022, p. 5).

In other words, the approach to selecting indicators and groups of indicators used in resilience assessment should be balanced and conducted in two ways. The first is through the application of statistical indicators and correlation measurement, while the second involves the use of the Delphi method and the consideration of expert opinions on which indicators should be included for measuring resilience. This method highlights the subjective and objective approaches to constructing resilience indicators (Béné et al., 2016). Subjective indicators are the result of expert effort, while objective indicators are the product of specific quantitative methods of calculation. For this reason, objective indicators can be more easily applied in broader geographical contexts, while subjective indicators are used in narrower geographical contexts, as they are derived from a deeper understanding of the circumstances in which a particular community operates.

Summarizing the results of the qualitative analysis of indicators and their corresponding variables used for measuring resilience, and placing them in the context of their use for resilience assessment, concrete conclusions can be drawn about which indicators were not developed in Susan Cutter's BRIC method from 2010, without considering her 2014 work, which represents an adaptation of the original method. Comparing the BRIC method's indicators with those of other methodological approaches for measuring resilience, such as the Climate Disaster Resilience Index (Prashar, Shaw, & Takeuchi, 2012), the Community Disaster Resilience Index (Mayunga, 2007), the Coastal City Resilience Index (A & Simonovic, 2013), the Climate Vulnerability and Capacity Assessment Index (*Handbook of Current and Next Generation Vulnerability and Adaptation Assessment Tools* 2007), as well as

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other relevant methodological approaches published in earlier periods where over 80 indicators were identified, reveals certain differences. These differences relate to the indicators and corresponding variables that are not applied in the BRIC method but have an impact on optimal resilience measurement, as they take into account or could take into account the specificities of a particular country or territory in relation to economic, social, geographical, demographic, and other characteristics. A review of these indicators is provided in Table 6.

Table 6. Groups of Indicators with Indicators Not Included in the BRIC Method.

Group of Indicators	Indicators Not Covered by the BRIC Method
Socio-demographic	Community preparedness for disasters (partial); previous experiences; social connectivity; percentage of population not speaking the national language (partial); special needs of certain segments of the population; access to specialized healthcare facilities; control of infectious diseases.
Economic	Budget and household subsidies; size of business organizations; territorial distribution of trade chains; resources available for post-disaster reconstruction; degree and diversity of economic resources; food security.
Institutional	First aid training preparation; access to healthcare assistance; immunization capacity; usable biological protection systems; capacity for disease research and prevention; management and regulations in natural resource management.
Infrastructure	Residential properties and land use; community resources; electricity supply; water supply; transportation; utility infrastructure.
Community Well-being	Risk awareness and preparation (partial); risk perception; religious beliefs; religious organizations; trust in authorities.
Geographical and Spatial Characteristics	Hazard intensity; hazard frequency; number of risks; size of available land; environmental protection services; biodiversity index.
Cooperation	Effectiveness of local institutions (partial); cooperation with other levels of government; connectivity of institutions and organizations (partial); institutional cooperation and coordination (partial); integration of special population needs into crisis plans; community volunteerism.

It should be particularly emphasized that the qualitative analysis of the papers in this critical review, which dealt with resilience indicators starting from 2010, led to the conclusion that the BRIC method lacks indicators from the group of Geographical and Spatial Characteristics, Cooperation, as well as Risk Analysis. In other words, there is partial coverage of these indicators by other indicators from different groups.

Overall, although the BRIC method ranks highly in terms of resilience indicators, it lacks comprehensive and universally applicable indicators that could be used for all countries or territories where disaster resilience is measured. The use and adaptation of the BRIC method and the theoretical DROP model developed by Susan Cutter and her colleagues require adjustments (improvements) for successful use in specific local contexts. To ensure successful application, the adaptation of these methods must focus on the indicators that the BRIC method does not cover, as identified in the qualitative analysis and presented in Table 5. The incorporation of certain mentioned indicators into the BRIC method's existing groups of indicators would allow for the localization of indicators that could be measurable and meaningful in a particular territory or country. The indicators used in modifying the method will depend on available data, statistical methods, the use of the Delphi technique, and fieldwork to determine the feasibility of data collection and to optimize the use of the index through the application of these tools.

Each local community is specific due to its geographical and spatial characteristics, as well as its social structure, which influences the development of infrastructure, cooperation, risk analysis capacities, the development of institutions, and social and economic specificities. The BRIC method, to some extent, lacks defined indicators for all of the above, which need to be implemented in modifications for the successful determination of resilience indices. "There is a clear distinction in

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how resilience to disasters caused by natural hazards manifests in urban and rural environments. The factors contributing to disaster resilience vary, highlighting the need for efforts to improve resilience to be adapted to the local context rather than being universally applied to all locations, including both urban and rural areas. The social, economic, and ecological processes that have transformed the nation provide the fundamental context for disaster resilience patterns: regional specificity, unique differences between urban and rural areas within and across geographical regions, and variations in factors among similarly classified areas such as rural counties (Cutter, Ash, & Emrich, 2016, p. 1251).

Due to the complexity of measuring the resilience of local communities, the multidimensional approach to selecting indicators has allowed for the inclusion of a larger and more adequate number of resilience aspects. The specificity lies in the fact that indicators are sensitive to methodological decisions in the construction of the index. BRIC was designed as a tool to support decision-making in disaster risk reduction, and as such, the authors clearly stated that some of their methodological choices were aimed at making the index transparent and intuitive for decision-makers (Cutter et al., 2010). Despite the limitations and compromises between methodological quality and ease of understanding in the selection of indicators, the improved version of the BRIC method by Susan Cutter has been incorporated into official disaster risk assessments in the USA.

The limitations of the critical literature review are based on the number of individuals who conducted it, the time frame of its preparation, and the availability of relevant scientific databases, which required subscriptions or institutional access, rather than individual access. Another limitation relates to language, as only scientific papers in English published in academic journals were included in the review. So-called gray literature, which includes a large number of papers not published in academic journals such as reports, working documents, bulletins, documents from official government institutions, and the like, was not considered. Due to the challenge of selecting keywords, as well as the limitations of the physical capacity to review the obtained results, a certain number of papers were identified through citation searches. The next limitation was the exclusive focus on the BRIC method and its adaptations. A large number of methods developed independently of this method with adaptations were excluded from the analysis. No attention was paid to the methodological quality of the papers, although significant deviations were observed during the review, which made the review more difficult to complete.

These limitations, primarily the lack of access to a certain number of papers, have contributed to the absence of a complete picture regarding the methodological approaches to selecting optimal groups of indicators, the indicators themselves, and their variations depending on the specificities of the country or region for which the BRIC method is being adapted. The data on the selection process would contribute to a higher quality approach in the selection of appropriate indices in the case of the Republic of Serbia.

5. Conclusions

Based on a detailed critical review of the literature, this paper deepens our understanding of the complexities of measuring the resilience of local communities to natural disasters, with a special emphasis on the application and adaptation of the BRIC and DROP models. The review identified a range of significant indicators that affect resilience, but it also pointed out some critical shortcomings in the existing research and models.

First, one of the fundamental shortcomings is the limited geographical and cultural scope of current research. The vast majority of the analyzed papers are focused on specific regions, such as the USA and Europe, which limits the applicability of the findings in different social and economic contexts. Future research should include more countries and regions, particularly those with different levels of development and specific socioeconomic conditions, in order to achieve a more comprehensive understanding of the applicability of the BRIC and DROP models in various contexts. Second, methodological limitations also represent a significant aspect that needs to be considered. Although the PRISMA methodology was used as the primary technique for conducting the systematic literature review, it is necessary to include other methods that can further enrich the

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analysis, such as the Delphi technique and case studies. This would allow for a deeper and more precise analysis of specific local contexts and their role in defining community resilience.

Third, the analysis indicated the need for further development and adaptation of existing indicators, especially in the context of social and infrastructural resilience. Indicators such as access to transportation, language competency, and communication capacities are not sufficiently addressed in the existing literature and require additional attention. Additionally, new indicators need to be developed to better reflect the complexity and multidimensionality of local community resilience, taking into account the specificities of different geographical areas. Measuring the resilience of local communities to natural disasters using the BRIC method and adapting the indicators for measuring the resilience index represents a challenge in itself. It is a process that cannot be directly observed but is concluded based on a larger number of factors. The very meaning of the term community resilience is still a subject of discussion and relatively uneven views. The main shortcoming in existing research lies in the implementation of tools for assessing community resilience and their ability to improve outcomes, that is, to select adequate indicators. The measurement of resilience in a given community is constantly evolving as a scientific field, and there is a lack of an adequate method to determine and adapt the indicators to be measured, which may be due to the overall development of society in the modern age and the changes in the ecological aspect conditioned by this development.

The main insight provided by the critical literature review points to current literature, the one that established the foundations and the one that represented an upgrade and the establishment of adequate guidelines for measuring the resilience of local communities to natural disasters. The obtained results, in addition to fulfilling the goals set in the paper, provide insight for new research in this area, namely how to approach the adaptation of the BRIC method, the selection of appropriate indicators, and the obtaining of a resilience index for a specific community when natural disasters are involved. In the context of institutional resilience, it was concluded that institutions need to develop more precise and comprehensive indicators that would provide better insight into their ability to respond to disasters. This includes improving existing emergency intervention plans and developing new approaches to assess and enhance institutional capacities at the local level.

Overall, this paper highlights the need for further research and the development of integrated approaches to measuring disaster resilience. Future research should focus on expanding the scope of analysis to different geographical and cultural contexts, as well as on developing new methodological tools that would allow for a more comprehensive assessment of local community resilience. In addition, it is recommended that the results of this review be used as a basis for developing practical policies and strategies that will improve disaster resilience, both locally and globally.

This review points to the importance of further development and application of models such as BRIC and DROP, but at the same time emphasizes the necessity of adapting them according to specific local and regional conditions to ensure effective disaster risk management and the improvement of community resilience worldwide.

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References

1. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. International Journal of Disaster Risk Management, 1(1), 32-50.
2. Arooj, P., & Simonovic, S. P. (2013). Coastal cities at risk (CCaR): generic system dynamics simulation models for use with city resilience simulator. *Water Resources Research Report*.
3. Aksha, S. K., & Emrich, C. T. (2020). Benchmarking Community Disaster Resilience in Nepal. *International Journal of Environmental Research and Public Health, 17*(6).
4. Aldrich, P. D. (2012). *Building resilience: Social capital in post-disaster recovery*. Chicago: The University of Chicago Press.
5. Alexander, E. D. (2013). Resilience and disaster risk reduction: an etymological journey. *Natural Hazards and Earth System Sciences, 11*, 2707-2716.
6. Asadzadeh, A., Kötter, T., Salehi, P., & Birkmann, J. (2017). Operationalizing a concept: The systematic review of composite indicator building for measuring community disaster resilience. *International Journal of Disaster Risk Reduction, 25*, 147-162.
7. Baseline Resilience Indicators for Communities. (2024). *https://sc.edu/*. Retrieved from https://sc.edu/study/colleges_schools/artsandsciences/centers_and_institutes/hvri/data_and_resources/bric/
8. Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological Indicators*, 12-22.
9. Béné, C., Al-Hassan, R., Amarasinghe, O., Fong, P., Ocran, J., Onumah, E., Mills, D. J. (2016). Is resilience socially constructed? Empirical evidence from Fiji, Ghana, Sri Lanka, and Vietnam. *Global Environmental Change*, 153-170.
10. Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards. *Social indicators research*, 391–409.
11. Bixler, P., Yang, E., Richter, S. M., & Coudert, M. (2021). Boundary crossing for urban community resilience: A social vulnerability and multi-hazard approach in Austin, Texas, USA. *International Journal of Disaster Risk Reduction*.
12. Cai, H., Lam, N. S. N., Qiang, Y., Zou, L., Correll, R. M., & Mihunov, V. (2018). A synthesis of disaster resilience measurement methods and indices. *International Journal of Disaster Risk Reduction, 31*, 844-855.
13. Chang, S. E., & Shinozuka, M. (2004). Measuring improvements in the disaster resilience of communities. *Earthquake Spectra, 20*(3), 739-755.
14. Ciccotti, L., Cassia Rodrigues, A., Boscov, M. E. G., & Günther, W. M. R. (2020). Building indicators of community resilience to disasters in Brazil: A Participatory Approach. *Ambiente & Sociedade*.
15. Cimellaro, G. P., Reinhorn, A. M., & Bruneau, M. (2010). Framework for Analytical quantification of disaster resilience. *Engineering Structure, 32*(11), 3639-3649.
16. Cohen, O., Leykin, D., Lahad, M., Goldberg, A., & Aharonson-Daniel, L. (2013). The conjoint community resiliency assessment measure is a baseline for profiling and predicting community resilience for emergencies. *Technological Forecasting & Social Change*.
17. Csizovszky, A. (2023a). Analysis of community resilience in Hungary – An adaptation of the basic resilience indicators for communities (BRIC), 2020. *Regional Statistics*, 752–778.
18. Csizovszky, A. (2023b). Have Hungarian districts become more resilient? - A comparison of the 2014 and 2020 Baseline Resilience Indicators for Communities (BRICs). *European Journal of Sustainable Development*, 185-197.
19. Cutter, S. L., Ash, K. D., & Emrich, C. T. (2014). The geographies of community disaster resilience. *Global Environmental Change*, 65-77.
20. Cutter, S. L., Ash, K. D., & Emrich, C. T. (2016). Urban-Rural Differences in Disaster Resilience. *Annals of the American Association of Geographers*, 1236-1252.
21. Cutter, S. L., Barnes, L., Berry, Melissa, Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 598–606.
22. Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. *Journal of Homeland Security and Emergency Management, 7*(1).
23. Cutter, S. L., & Derakhshan, S. (2019). Implementing Disaster Policy: Exploring Scale and Measurement Schemes for Disaster Resilience. *Journal of Homeland Security and Emergency Management*.
24. Cvetković, V., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. *Sustainability, 16*(7), 2620.
25. Cvetković, V. M., & Šišović, V. (2024). Community Disaster Resilience in Serbia. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
26. Cvetković, V. M., Renner, R., Aleksova, B., & Lukić, T. (2024). Geospatial and Temporal Patterns of Natural and Man-Made (Technological) Disasters (1900–2024): Insights from Different Socio-Economic and Demographic Perspectives. Applied Sciences, 14(18), 8129.

 doi:10.20944/preprints202410.2277.v1

27. Cvetković, V., Rikanović, S., Knežević, S. (2022). The resilience of society in disasters caused by nuclear accidents. IAI Academic Conference Proceedings, Budapest Conference, 5 May 2022.
28. Cvetković, V., Ivković, T. (2022). Social Resilience to Flood Disasters: Demographic, Socio-economic and Psychological Factors of Impact". 12th International Conference of the International Society for the Integrated Disaster Risk Management, Cluj-Napoca, Romania, 21-23 September 2022.
29. Cvetković, V., Grozdanić, G., Milanović, M., Marković, S., Lukić, T. (2024). Understanding Seismic Hazard Resilience in Montenegro: A Qualitative Analysis of Community Preparedness and Response Capabilities. *Open Geosciences*, 16 (1).
30. Cvetković, V. (2024). Disaster Resilience: Guide for Prevention, Response and Recovery. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
31. Cvetković, V. M. (2023). A Predictive Model of Community Disaster Resilience based on Social Identity Influences (MODERSI). International Journal of Disaster Risk Management, 5(2), 57-80.
32. Department of Economic and Social Affairs. (2024, јун 15). *United Nations*. Retrieved from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
33. Derakhshan, S., Blackwood, L., Habets, M., Effgen, J. F., & Cutter, S. L. (2022). Prisoners of Scale: Downscaling Community Resilience Measurements for Enhanced Use. *Sustainability*.
34. Grozdanić, G., & Cvetković, M. V. (2024). Exploring Multifaceted Factors Influencing Community Resilience to Earthquake-Induced Geohazards: Insights from Montenegro. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
35. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. International Journal of Disaster Risk Management, 1(2), 61-75.
36. *Handbook of Current and Next Generation Vulnerability and Adaptation Assessment Tools* (2007). London: Care International.
37. *Handbook on constructing composite indicators: Methodology and user guide*. (2008). OECD.
38. Holling, S. C. (1973, September). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 1-23.
39. Irwin, S., Schardong, A., Simonovic, S. P., & Nirupama, N. (2016). A Decision Support Tool for Estimating Resilience of Urban Systems. *Water, 8*.
40. IPCC (2023): Climate Change 2023. Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Online verfügbar unter 10.59327/IPCC/AR6-9789291691647.
41. Jaiye, D. J., & Benjamine, O. (2021). Building resilience through local and international partnerships, Nigeria experiences. International Journal of Disaster Risk Management, 3(2), 11-24.
42. Javadpoor, M., Sharifi, A., & Roosta, M. (2021). An adaptation of the Baseline Resilience Indicators for Communities (BRIC) for assessing the resilience of Iranian provinces. *International Journal of Disaster Risk Reduction, 66*.
43. Jepson, M., & Colburn, L. L. (2013). Development of Social Indicators of Fishing Community Vulnerability and Resilience in the U.S. Southeast and Northeast Regions. *NOAA Technical*.
44. Ji, T., Wei, H. H., Shohet, I. M., & Xiong, F. (2021). Risk-based resilience concentration assessment of. *Natural Hazards, 108*, 1731-1751.
45. Johansen, C., Horney, J., & Tien, I. (2017). Metrics for Evaluating and Improving Community Resilience. *Journal of Infrastructure Systems, 23*(2), 04016032.
46. Jülich, S. (2017). Towards a local-level resilience composite index: introducing different degrees of indicator quantification. *International Journal of Disaster Risk Science, 8*, 91-99.
47. Karanci, N., Ikize, G., Doğulu, C., & Özceylan-Aubrecht, D. (2016). Perceptions of Individual and Community Resilience to Earthquakes. *International Journal of Disaster Risk Reduction*, 108-114.
48. Kim, H., & Marcouiller, D. W. (2018). Mitigating flood risk and enhancing community resilience to natural disasters: plan quality matters. *Environmental Hazards*, 397-417.
49. Kabir, M. H., Hossain, T., & Haque, M. W. (2022). Resilience to natural disasters: A case study on the southwestern region of coastal Bangladesh. International Journal of Disaster Risk Management, 4(2), 91-105.
50. Macharia, D., Kaijage, E., Kindberg, L., Koech, G., Ndungu, L., Wahome, A., & Mugo, R. (2020). Mapping Climate Vulnerability of River Basin Communities in Tanzania to Inform Resilience Interventions. *Sustainability, 12*(10), 4102.
51. Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., & Shukla, P. R. (2018). *Global warming of 1.5°C*. Retrieved from Geneva:
52. Mavhura, E., Manyangadze, T., & Aryal, K. R. (2021). A composite inherent resilience index for Zimbabwe: An adaptation of the disaster resilience of place model. *International Journal of Disaster Risk Reduction*.
53. Mayunga, J. S. (2007). Understanding and Applying the Concept of Community Disaster Resilience: A capital-based approach. *Summer academy for social vulnerability and resilience building*.

 doi:10.20944/preprints202410.2277.v1

54. McAllister, T. P. (2015). *A Guide to Develop Community Resilience Performance Goals and Assessment Metrics for Decision Making*. Retrieved from Vancouver:
55. Moghadas, M., Asadzadeh, A., Vafeidis, A., Fekete, A., & Kötter, T. (2019). A multi-criteria approach for assessing urban flood resilience in Tehran, Iran. *International Journal of Disaster Risk Reduction*.
56. Mohamad, N., Jusoh, H., & Kassim, Z. (2019). Localizing of Community Resilience Indicators for Assessing the Urban Community Resilience in Putrajaya, Malaysia. *International Journal of Engineering and Advanced Technology*, 359-365.
57. Muttarak, R., & Lutz, W. (2014). Is education A key to reducing vulnerability to natural disasters and hence Unavoidable Climate Change? *Ecology And Society, 19*.
58. Olawuni, P., Olowoporoku, O., & Daramola, O. (2020). Determinants of Residents' Participation in Disaster Risk Management in Lagos Metropolis Nigeria. International Journal of Disaster Risk Management, 2(2), 1-18.
59. Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Brennan, S. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *Bmj, 372*.
60. Pazhuhan, M., Moradpour, N., hesarakizard, A., & Ayyoob, S. (2023). District-based Baseline Resilience Indicators for Communities (DBRIC) for assessment of a Global South city. *Sustainable Cities and Society*.
61. Prashar, S., Shaw, R., & Takeuchi, Y. (2012). Assessing the resilience of Delhi to climate-related disasters: a comprehensive approach. *Natural Hazards*, 1609–1624.
62. Quigley, M., Blair, N., & Davison, K. (2018). Articulating a social-ecological resilience agenda for urban design. *Journal of Urban Design*, 581-602.
63. Scherzer, S., Lujala, P., & Rød, J. K. (2019). A community resilience index for Norway: an adaptation of the baseline resilience indicators for communities (BRIC). *International Journal of Disaster Risk Reduction, 36*.
64. *Sendai Framework for Disaster Risk Reduction 2015-2030*. (2015). Retrieved from Geneva:
65. Siambabala , M. B. (2006). The concept of resilience revisited. *Disaster, 30*(4), 434-450.
66. Siebeneck, L., Arlikatti, S., & Andrew, S. A. (2015). Using provincial baseline indicators to model geographic variations of disaster resilience in Thailand. *Natural Hazards*.
67. Singh-Peterson, L., Salmon, P., Goode, N., & Gallina, J. (2014a). Translation and evaluation of the Baseline Resilience Indicators for Communities on the Sunshine Coast, Queensland Australia. *International Journal of Disaster Risk Reduction*, 116–126.
68. Singh-Peterson, L., Salmon, P., Goode, N., & Gallina, J. (2014b). Translation and evaluation of the baseline resilience Indicators for Communities on the Sunshine Coast, Queensland Australia. *International Journal of Disaster Risk Reduction*, 116–126.
69. Sung, C.H., & Liaw, S.C. (2020). A GIS Approach to Analyzing the Spatial Pattern of Baseline Resilience Indicators for Community (BRIC). *Water*.
70. Talubo, J. P., Malenab, R. A., Morse, S., & Saroj, D. (2023). Practitioners' Participatory Development of Indicators for Island Community Resilience to Disasters. *Sustainability*.
71. *Terminology on Disaster Risk Reduction*. (2009). Retrieved from Geneva:
72. Tseng, Y.P., Huang, Y.C., Li, M.-S., & Jiang, Y.Z. (2022). Selecting Key Resilience Indicators for Indigenous Community Using Fuzzy Delphi Method. *Sustainability*.
73. Weaver, R. (2016). Capacity Building and Community Resilience: A Pilot Analysis of Education and Employment Indicators Before and After an Extension Intervention. *The Journal of Extension*.
74. Zio, E. (2016). Challenges in the vulnerability and risk analysis of critical infrastructures. *Reliability Engineering and System Safety*, 137-150.