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Abstract

Resilience is now a ubiquitous concept in many science and policy circles. It is a polysemic concept that has been defined differently in different disciplines and contexts. An often used definition, in the context of community resilience, is provided by the National Academies. According to this definition resilience is “the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events” (the four abilities). Over the past two decades various tools have been developed for assessing community resilience. This study examines 36 selected community resilience assessment tools to find out if they are suitable for adequately addressing the four abilities of resilience. A framework, identifying various measures that can contribute to addressing each of the four resilience abilities is developed. Evaluating selected tools using this framework indicates only few of them are reasonably suitable for addressing measures related to the four resilience abilities. Overall performance of the selected tools is particularly poor in terms of addressing measures related to absorption and adaptation abilities. Detailed results related to performance of each tool are provided. Developers can use these results to understand shortcomings of their assessment tools and address them in the revised versions.

Keywords	community resilience assessment tool; criteria and indicators; planning; absorption; recovery; adaptation

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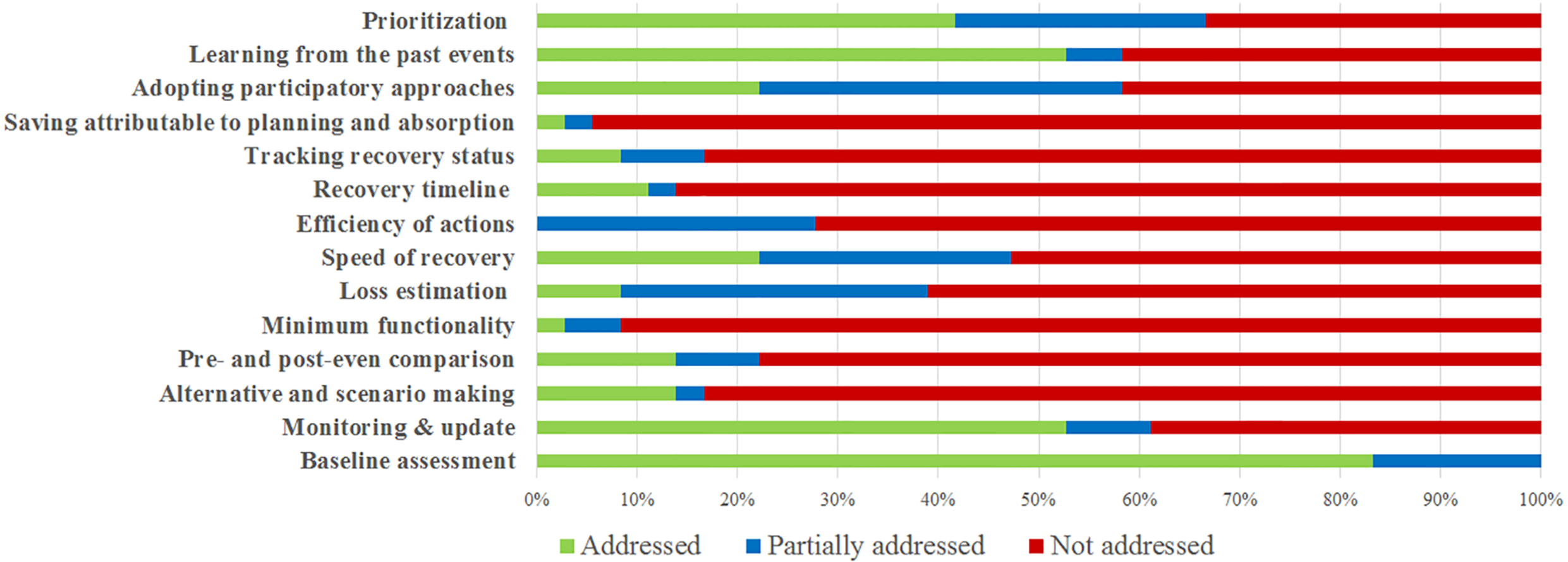
Highlights

- A framework for assessing suitability of resilience assessment tools is developed.
- Fourteen suitability measures are included in the assessment framework.
- Suitability of 36 selected community resilience assessment tools is examined.
- Only few of the suitability measures are appropriately addressed by the selected tools.

Graphical Abstract

The state of CRA tools' compliance with the suitability measures



On the suitability of assessment tools for guiding communities towards disaster resilience

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Abstract

Resilience is now a ubiquitous concept in many science and policy circles. It is a polysemic concept that has been defined differently in different disciplines and contexts. An often used definition, in the context of community resilience, is provided by the National Academies. According to this definition resilience is "the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events" (the four abilities). Over the past two decades various tools have been developed for assessing community resilience. This study examines 36 selected community resilience assessment tools to find out if they are suitable for adequately addressing the four abilities of resilience. A framework, identifying various measures that can contribute to addressing each of the four resilience abilities is developed. Evaluating selected tools using this framework indicates only few of them are reasonably suitable for addressing measures related to the four resilience abilities. Overall performance of the selected tools is particularly poor in terms of addressing measures related to absorption and adaptation abilities. Detailed results related to performance of each tool are provided. Developers can use these results to understand shortcomings of their assessment tools and address them in the revised versions.

Keywords: community resilience assessment tool; criteria and indicators; planning; absorption; recovery; adaptation

1. Introduction

Resilience is increasingly becoming a ubiquitous concept in many disciplines including, but not limited to, urban and community planning, sociology, psychology, healthcare, and disaster risk management. It is also frequently used, as a guiding concept, for developing policies, plans, and programs to deal with a diverse array of natural and man-made disasters that are progressively increasing in frequency and severity.

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Community resilience is a burgeoning field within the broader context of resilience. Across the globe, communities are recognizing resilience as an overarching concept that can play an essential role in guiding their sustainable development policies and disaster risk management activities [1]. The need to enhance community resilience is also highly emphasized in the Sustainable Development Goals (SDGs) that were recently adopted by the United Nations. SDG 11 aims to “make cities and human settlements inclusive, safe, resilient, and sustainable” [2]. Despite the omnipresence of the term “community resilience” in the current sustainability and disaster risk management discourses, there is still no universally accepted definition for the terms “community” and “resilience”. The term “community” is loosely defined in the literature and there is still no consensus among scholars on what constitutes a community. In the resilience planning literature, it is often conceptualized as a dynamic and place-based entity where a group of individuals who share common interests and partake in collective action live [1, 3-5]. It can be as small as an urban neighborhood or as large as a county [6]. Besides the normative and context-sensitive nature of the term, this wide variation can be explained by the fact that community boundaries can be defined according to various functional, psychological, and political measures [1].

Likewise, there is prolific literature on resilience which provides multiple definitions for it. Definitions of resilience vary from one discipline to another and are not always consistent with each other [7, 8]. One definition, which has been frequently used in the context of community resilience, is provided by The National Academies. It conceptualizes resilience as “the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events” [9]. A quick search for this definition in Google Scholar reveals that it has been adopted by more than 70 papers since 2012. Desirability of this definition can be attributed to the fact that it takes various stages of disaster management into consideration. In particular, it acknowledges the significance of adaptation (multiple-equilibrium/non-equilibrium) which can be regarded as a departure from earlier conceptualizations of resilience as the ability of a system to return to equilibrium state (s) following disruptive events [10]. Another merit of this definition is that it reflects both outcome-based and process-based conceptualizations of resilience. As would be explained in Section 2, in addition to outcome-based measures such as recovery speed and loss estimation, process-based measures such as adopting participatory approaches and social learning are also emphasized in this definition.

Community Resilience Assessment (CRA) is a relatively new, but growing field of research and practice. Since the turn of the century, several CRA tools have been developed to evaluate the extent of success of various policies, plans, and programs in terms of achieving resilience [11]. CRA can be practiced before and/or after disruptive events. Pre-event CRA can

be used for guiding future development plans. It can also provide multiple other benefits such as identifying areas that need further attention, assessing baseline performance and setting better performance targets, and benchmarking performance for facilitating learning and constructive competition [1]. Post-event assessment is also useful for multiple purposes such as examining effectiveness of pre-event preparatory efforts, measuring the speed of recovery, and prioritizing action plans and resource allocation [1]. CRA tools (both ex-ante and ex-post) can also be used to, among other things, reduce the complexities of the resilience concept, enhance the transparency of the decision making process, and provide opportunities for public participation and social learning [1]. Despite these multiple benefits, CRA tools have not yet been appropriately integrated into planning and policy-making processes. Around the world, several pilot assessments have been conducted. However, information on implementing CRA tools and incorporating assessment findings in the planning process is still scarce [1, 11].

Several studies exist that are focused on issues such as structure of CRA tools and their construct and content validity [1, 11, 12]. However, there is a paucity of studies that evaluate CRA tools in terms of their suitability for guiding communities towards disaster resilience. One of the few studies addressing this issue has been conducted by Larkin, Fox-Lent [13]. Their study analyzes seven resilience assessment frameworks developed by the US agencies to find out if they have addressed different abilities related to planning, absorption, recovery, and adaptation. Their findings indicate that in most of the assessment frameworks these four resilience abilities have not been appropriately considered. In particular, the adaptation ability is largely overlooked.

This study intends to provide further insight on the suitability of CRA tools for guiding community resilience. In Section 2 methods and materials used for the purpose of this study are explained and a framework is designed to examine suitability of selected CRA tools for guiding community resilience planning. Results of examining selected tools using this framework are presented in Section 3. Section 4 concludes the study by discussing the results and making suggestions for future research.

2. Materials and methods

2.1. Materials

As was discussed in the previous section, the term “community” has been defined in a variety of ways and may refer to different geographical scales such as neighborhood, district, and city. Specific search strings were designed in a way to retrieve tools related to different types of communities. Initial searches, carried out in Web of Science and Google (the first 20 hits) in June 2015, yielded 510 documents. Titles and abstracts of these documents were analyzed to find out if they have reported on CRA tools. To further narrow down the scope of the study, tools

designed to evaluate resilience of individual sectors such as water, energy, and infrastructure were excluded from this study. Further details on the procedure used for selecting these tools can be found in Sharifi [1]. Overall, 36 tools were selected for further analysis (Table 1). Content analysis of documents related to the selected tools was conducted to evaluate their performance against the framework explained below. Microsoft Excel spreadsheets were designed to note the state of compliance of each CRA tool with the suitability measures mentioned in Table 2. Documents (manuals and relevant academic papers if available) related to the selected CRA tools were thoroughly analyzed by the first author to determine if they have complied with the suitability measures. To avoid potential mistakes, two rounds of content analysis were carried out.

Table 1.CRA tools selected for analysis (adapted from [1])

Tool	Year	Primary developer (s)	Focus	Risk	Target audience	Ref
CRC	2015	Bushfire and Natural Hazards CRC	AU	Natural	Local authorities and councils	[14]
CRDSA	2015	Academia, Alshehri et al.	Saudi Arabia	Multiple	Local authorities	[3, 15]
DRI	2015	Earthquakes and Megacities Initiative (EMI)	Global	Multiple	Local, regional and national government agencies	[16]
CDR	2015	Academia, Yoon et al.	Korea	Multiple	Local authorities and public	[17]
NIST	2015	National Institute of Standards and Technology	US	Multiple	Local authorities	[18, 19]
RELi	2015	American National Standards Institute (ANSI)	US	Multiple	Developers	[20]
TCRI	2015	Australia Netherlands Water Challenge	AU	Multiple	Local, state and national government, international organizations	[21]
CoBRA	2014	UNDP | Drylands Development Centre	Horn of Africa	Drought	Community leaders/ governmental and non-governmental organizations	[22, 23]
CRF	2014	The Rockefeller Foundation, Arup	Global	Multiple	Local authorities	[24]
FCR	2014	International Federation of Red Cross and Red Crescent Societies (IFRC)	Global	Multiple	IFRC programs and national societies (of IFRC)	[25]
Grosvenor	2014	Grosvenor, real estate investor (industry)	Global	Multiple	Company officials, city authorities, aid agencies	[26]
ICLEI	2014	ACCCRN, Rockefeller Foundation, ICLEI	Global	Natural	Local authorities	[27]
UNISDR	2014	IBM and AECOM	Global	Natural	Local authorities, insurance companies, private industry	[28]
CRS	2013	Community and Regional Resilience Institute (CARRI); Meridian Institute; Oak Ridge National Laboratory	US	Multiple	Community leaders	[29, 30]
LDRI	2013	Academia, Orencio and Fujii	The Philippines	Multiple	Local authorities	[31]
USAID	2013	USAID	Global	Poverty	Government and non-governmental organizations, donors	[4]
CDRST	2012	Torrens Resilience Institute	AU	Multiple	Planners, local authorities, community members	[32, 33]
BCRD	2011	RAND corporation	US	Health	Community leaders/ governmental/non-governmental organization	[34]
CART	2011	TDC/ University of Oklahoma	US	Health	Community-based organizations	[35]
ResilUS	2011	US, Resilience Institute is part of Western Washington University's Huxley College of the Environment	US, Japan	Mainly Earthquake	Local authorities	[36], based on a prototype developed in 2006
ICBRR	2012	Palang Merah Indonesia (PMI) and Canadian Red Cross (CRC)	Indonesia	Multiple	Local authorities and public	[37, 38]
BRIC	2010	Academia, Cutter et al.	US	Multiple	Local authorities	[39, 40]
CDRI2	2010	Academia, Shaw et al.	South/ South East Asia	Multiple	Community leaders/ local authorities	[41]
CERI	2010	AWM (Advantage West Midlands) Strategy Team	UK	Recession	Local authorities	[42]
CDRI	2010	Coastal Services Center And The National Oceanic and Atmospheric Administration	US	Multiple	Community leaders	[43]
CRI2	2010	Academia, Sherrieb et al.	US	Multiple	Local authorities	[44]
CRI	2010	MS-AL Sea Grant/ National Oceanic and Atmospheric Administration (NOAA)	US	Coastal (natural)	Planners, policy makers, emergency service providers	[45]
PEOPLES	2010	National Institute of Standards and Technology (NIST)	US	Multiple	Planners and local authorities	[46]
CRT	2009	Bay Localize project of the Earth Island	US	Recession;	Planners, community	[47]

		Institute		natural	organizations, individuals, training centers	
SPUR	2009	San Francisco Planning + Urban Research Association	US	Earthquake	Local authorities, builders and developers	[48]
DFID	2009	Department for International Development and other agencies	UK	Natural	Academia, government and civil society organizations	[5]
CARRI	2008	Community and Regional Resilience Institute	US	Multiple	Community-based organizations	[49]
Hyogo	2008	UN/OCHA and UN/ISDR	Global	Natural	Local and national authorities, community-based organizations, non-governmental organizations	[50]
USIOTWT	2007	U.S. Indian Ocean Tsunami Warning System Program	South/ South East Asia	Coastal (natural)	Governmental and non-governmental organizations; International aid agencies, banks, and donors.	[51]
THRIVE	2004	Prevention Institute	US	Racial health disparity	Local government, NGOs	[52]
CRM	2000	Canadian center for Community renewal	Canada	Recession	Local authorities, community members	[53]

2.2. Framework for analysis

In this study suitability of assessment tools for guiding communities towards disaster resilience is explored by investigating whether they can evaluate communities' capacity to "prepare and plan for, absorb, recover from, and adapt to" disruptive events. In other words, effective and suitable assessment tools should be capable of informing communities on how to enhance these four abilities that are reflected in the definition of community resilience. In the following paragraphs, each ability is briefly explained to understand how it relates to resilience and how it can be measured. Therefore, what is discussed in the remainder of this section lays out the framework for evaluating the selected CRA tools.

- **Preparation and planning** refer to process-based activities focused on effective and efficient use of resources for the purpose of enhancing community resilience. Pre-disaster mitigation and planning efforts are needed to enable communities to, as much as possible, avoid and resist shocks [10, 54, 55]. However, it should be acknowledged that creating a disaster-proof community would be difficult, if not impossible. Therefore, the probability of disruption should not be dismissed and planning efforts should also inform communities on how to respond to change proactively [10]. Understanding baseline conditions is the first and most essential step that needs to be taken to identify community resources and assets. In addition, communities should adopt an iterative approach to assessment and regularly update their accounts to reflect the constantly changing conditions [56]. When collecting and updating baseline information, it is essential to acknowledge that resilience is a multi-dimensional concept and various social, economic, environmental, and institutional aspects should be taken into account [1, 57]. To facilitate proactive engagement in disaster risk reduction activities, CRA tools should also utilize forecasting methods that enhance their awareness of the requirements and implications of a variety of possible future scenarios [58]. Finally, CRA tools should be developed and applied in a participatory way. This is important

for enhancing accuracy of assessment findings and can facilitate implementation of action plans.

- The **absorption** ability comes into play in case the system fails to completely withstand the shock [10]. It relates to processes, actions, and interactions that need to be carried out in the immediate aftermath of the event. Unlike preparation/planning efforts that are usually undertaken over a long time period, absorption objectives should be fulfilled within a very short time frame. The ability to absorb shocks can be regarded as an outcome of resilience planning. It helps isolate the disruption from the whole system and avoid potential cascading impacts [10]. Absorption ability strengthens the system so that it can store large magnitudes of pressure without significantly compromising the overall functioning of the system[59]. This ability to accommodate initial shocks is also essential for facilitating a faster recovery process. CRA tools can employ several methods to understand if the system has the absorption capacity required to sustain a minimum satisfactory level of functioning. One way would be to compare performance levels before and after (immediate aftermath) the event. Simple methods such as calculating the ratio between these two performance scores or the mathematical difference between them can be used [60]. Simulations and models for estimating direct and indirect human, physical, and financial loss can also be utilized [55, 61]. Examples are the loss estimation model used by Chang and Shinozuka [61] for assessing resilience of water system following an earthquake and the work by Yoon, Kang [17] to find out the association between community resilience and disaster loss. These methods can also enhance awareness by calculating and showing potential savings in costs that can be attributed to implementing absorptive measures.

- **Recovery** ability is needed to restore system functionality, to its pre-event baseline conditions, within a short- to medium-term time frame [10, 62]. Clearly, access to pre-event baseline conditions is essential for developing recovery plans. Ability to recover is influenced by various factors, including the pre-disaster preparatory efforts and the amount of shock that is absorbed in the immediate aftermath of the event [10]. A successful recovery is characterized by its speed and efficiency and these two factors should be considered in the assessment process. An effective way of evaluating recovery ability would be to determine a maximum desirable recovery time according to the severity of the event [63] and monitor recovery status at regular time intervals [62]. In the absence of disaster (pre-event), it is still essential to prepare for different potential scenarios and develop recovery plans accordingly [62]. “Probabilistic approaches” can be used for this purpose [63]. Modelling and probabilistic approaches can also be used to show how pre-disaster planning and effective

absorption can reduce the time needed to recover baseline functionality following a disruptive event.

- The ability to **adapt** to adverse events refers to a series of continuous efforts ("responsive" and/or "anticipatory" [64]) that enable communities to not only bounce back from disasters, but also bounce forward to more desirable states [10]. This is vital for two reasons: first, because per-event conditions may not necessarily be acceptable and disaster can be seen as an opportunity to create more advanced communities. The second reason is that communities are dynamic and their constituent elements are constantly changing. Adaptation helps addressing issues related to the continually changing context of communities and acknowledging that community development is an evolutionary process [59]. This is often achieved through scenario planning that can enhance adaptation capabilities by facilitating better understanding of the non-linearity of the system functionality. Scenario planning also provides other benefits such as shedding light on uncertainties and complexities inherent in future pathways [59, 65]. Among other things, innovation, self-organization, learning, and collaborative planning are factors conducive to better achievement of adaptation ability [66]. The self-organization capacity can be strengthened through adopting participatory approaches to planning, monitoring, and assessment[56]. Therefore, CRA tools should be developed and applied in a participatory manner. Collaborative and participatory approaches also provide further co-benefits such as capacity building, community empowerment, and social learning. Learning from experience and past events is also essential for transition to a more desirable state [11]. Resilience assessment can include longitudinal analyses to understand if communities have learned from the past and display positive evolutionary trajectories in terms of responding to disasters.

The suitability measures described above are summarized in Table 2. As can be seen, one measure is 'comprehensiveness and multi-dimensionality' of the CRA tools. Five major resilience dimensions have been identified in the literature. These are, namely, environmental, social, economic, physical, and institutional. As shown in Table 4, these dimensions are divided into sub-dimensions and criteria [1, 67]. Evaluation against this measure requires investigating whether various resilience dimensions and criteria are integrated into assessment tools and how this integration contributes to enhancing the four resilience abilities. An existing list of resilience criteria was used for conducting this analysis. This list has been drawn from literature on urban community resilience [1]. Matrices were designed to indicate if the resilience criteria are related to the four resilience abilities. The rows and columns of these matrices represent resilience criteria and resilience abilities, respectively. For each criterion, related literature was reviewed to determine if relationship exists and the respective cell should be checked. The existence of

association is determined based on the author's analysis of the discussions and evidence provided in the reviewed literature. In addition to providing information on relationship between criteria and resilience abilities, results on the extent of inclusion of criteria in the CRA tools makes it possible to identify criteria that require further attention. This can also later be used for prioritizing criteria based on their relative importance.

Finally, the following procedure was used to provide approximate percentage values for the extent of compliance of each assessment tool with the four resilience abilities: for each CRA tool a value between 0 and 1 was assigned to each of the relevant measures (those checked in Table 2) depending on how the measure in question is addressed by the CRA tool. For all measures (except comprehensiveness and multi-dimensionality), value assignment was based on information provided in Table 3. Numeric values of 1 and 0.5 were assigned for complete and partial compliance with suitability measures, respectively. For the "comprehensiveness and multi-dimensionality" measure, values related to the extent of inclusion of resilience criteria in the respective CRA tools were used. Overall percentage values are calculated by dividing the cumulative values to the maximum achievable values and multiplying the obtained quotient by 100. As an example, for the CRC tool, the percentage value related to the ability to "prepare/plan for" is calculated as follows:

$$25 = \frac{1(baseline\ assessment) + 1(monitoring) + 0.23(extent\ of\ inclusion\ of\ resilience\ criteria \in CRC\ tool)}{9(¿\ planning \wedge preparation)} \quad (1)$$

$$total\ number\ of\ suitability\ measures\ relevant$$

(the same formula in image format)

$$25\% = \frac{1\,(for\ baseline\ assessment) + 1\,(for\ monitoring) + 0.23\,(for\ extent\ of\ inclusion\ of\ resilience\ criteria\ in\ CRC\ tool)}{9\,(for\ total\ number\ of\ suitability\ measures\ relevant\ to\ planning\ and\ preparation)}$$

Table 2. Measures for evaluating the assessment tool's suitability for providing guidance on the four abilities.

Measure	Prepare/plan for	Absorb	Recover	Adapt
Baseline assessment	√	√	√	
Monitoring and regular update of baseline conditions	√		√	
Comprehensiveness and multi-dimensionality	√			
Forecasting/ scenario making, probabilistic approaches	√	√	√	√
Comparing pre- and post-event performance		√		
Identifying a minimum satisfactory level of post-event functionality		√		
Loss estimation models	√	√		
Speed of recovery			√	
Efficiency of actions	√	√	√	√
Identifying recovery timeline (maximum desirability)			√	
Tracking recovery status at regular time intervals			√	

Savings in recovery time and budget attributable to planning and absorption	√		√	
Adopting participatory approaches	√	√	√	√
Learning from the past events (longitudinal analysis)				√
Prioritization	√		√	

3. Results

3.1. Compliance of the selected CRA tools with the suitability measures

The state of compliance of the CRA tools with the suitability measures (except comprehensiveness) is presented in Table 3. States are indicated as addressed, partially addressed, and not addressed. Partial compliance indicates that some limited efforts have been taken to address the given suitability measure. For instance, in order to completely address the ‘adopting participatory approaches’ measure participatory measures should be adopted during both development and implementation phases of CRA tools. Partial compliance means that participatory approaches have been taken only during one of these two phases.

It can be seen that assessing baseline conditions, acknowledging the need for monitoring and update, learning from the past events, and prioritizing actions for resilience planning have been reasonably well addressed across the selected tools. Adopting participatory approaches has also been to some extent addressed. However, only about 20% of the tools have paid attention to this issue during both development and implementation phases.

CRA tools do not perform well in terms of addressing the other suitability measures. Only few tools have paid limited attention to ‘efficiency of actions’ which is related to all resilience abilities. ‘Developing alternatives and scenarios’ is another measure that can enhance planning, absorption, recovery, and adaptation abilities. It can be seen that this measure has also been addressed by less than 20% of the CRA tools. As explained in the previous section, ‘comparing pre- and post-event performance’, ‘identifying a minimum satisfactory level of post-event functionality’, and ‘using loss estimation models’ are three measures that can be used for evaluating the absorption ability of communities. Results show that only few of the CRA tools have included these measures in the assessment process. Measures such as ‘speed of recovery’, ‘identifying recovery timeline’, and ‘ tracking recovery status at regular time intervals’ can be used to measure the recovery ability of community following disruptive events. Most of the selected CRA tools have also failed to include these measures in the assessment process.

Table 3. Compliance with the suitability measures across the selected CRA tools

Tool	*Baseline assessment*	*Monitoring & update*	*Alternative and Scenario making*	Pre- and post-even comparison	Minimum functionality	Loss estimation	*Speed of recovery*	Efficiency of actions	Recovery timeline	Tracking recovery status	Saving attributable to planning and absorption	Adopting participatory approaches	Learning from the past events	Prioritization
CRC	√	√	×	×	×	×	×	×	×	×	×	×	×	×
CRDSA	○	×	×	×	×	×	×	×	×	×	×	○	×	√
DRI	√	√	×	×	×	×	×	×	×	×	×	√	×	×
CDR	√	×	×	×	×	√	×	×	×	×	×	×	×	○
NIST	√	√	×	√	×	○	√	○	√	√	×	×	√	√
RELi	√	×	√	×	×	×	×	○	×	×	×	○	√	×
TCRI	√	√	×	√	×	×	×	×	×	×	×	×	√	√
CoBRA	√	√	×	×	○	○	×	○	×	○	×	√	√	√
CRF	√	×	×	×	×	×	○	×	×	×	×	○	√	○
FCR	√	×	×	×	×	×	×	○	×	×	×	○	×	○
Grosvenor	○	×	×	×	×	×	×	×	×	×	×	×	×	×
ICLEI	√	×	√	×	×	○	×	○	×	×	×	√	√	√
UNISDR	○	×	√	×	√	○	○	×	×	×	○	○	×	○
CRS	√	√	×	√	×	○	○	×	×	×	×	√	×	√
LDRI	○	×	×	×	×	×	×	×	×	×	×	○	×	√
USAID	√	√	×	×	×	○	×	×	×	×	√	○	√	×
CDRST	√	√	×	×	×	×	○	×	×	×	×	○	√	√
BCRD	○	√	×	×	×	×	○	○	○	×	×	×	×	√
CART	√	√	×	×	×	×	○	×	×	×	×	√	√	√
ResilUS	√	○	×	○	×	√	√	○	√	√	×	×	√	×
ICBRR	√	○	×	×	×	×	×	×	×	×	×	×	×	○
BRIC	√	○	×	×	×	×	○	×	×	×	×	×	×	×
CDRI2	√	√	×	×	×	×	×	×	×	×	×	○	√	√
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PEOPLES	√	√	×	√	×	○	√	×	×	○	×	×	√	×
CRT	√	×	○	×	×	×	×	×	×	×	×	√	○	○
SPUR	○	×	√	○	×	×	√	×	√	√	×	○	√	×
DFID	√	√	×	×	×	×	√	×	×	×	×	√	√	√
CARRI	√	×	×	×	×	○	○	×	×	×	×	×	○	×
Hyogo	√	√	×	×	×	○	√	○	×	×	×	×	√	√
USIOTWSP	√	√	×	○	×	○	√	○	√	○	×	√	√	√
THRIVE	√	√	×	×	×	×	×	×	×	×	×	○	×	√
CRM	√	√	×	×	×	○	×	○	×	×	×	○	√	○

√ addressed | **○ partially addressed** | **× not addressed or not enough information provided** | italic values extracted from [1]

As indicated in Table 2, 'comprehensiveness and multi-dimensionality' of assessment criteria is another measure that can be used for evaluating the suitability of CRA tools for guiding community resilience building activities. Table 4 shows how different resilience dimensions and sub-dimensions are related to the resilience abilities and to what extent they have been included in the selected CRA tools. It can be seen that criteria related to different resilience dimensions have, on average, been included in about one third of the selected CRA tools. Table 4 also provides some insights about resilience abilities that each dimension is most related to. For instance, it can be seen that criteria related to environmental and institutional dimensions are mainly related to the planning/preparation ability. However, criteria related to social, and economic dimensions are mainly related to the recovery ability of communities.

Table 4. Percentage of criteria under each sub-theme that are related to the resilience abilities

Dimension	Sub-dimension	Plan/prepare	Absorb	Recover	Adapt	*Average Inclusion %*	Ref
Environmental	Natural Assets (environment and resources)	100.0	87.5	50.0	62.5	*29.9*	[10, 65, 68-73]
Social	Social structure	33.3	83.3	100.0	16.7	*22.8*	[59, 62, 69, 71, 74-77]
	Community bonds, social support, and social institutions	90.9	81.8	100.0	72.7	*32.1*	[8, 10, 57, 62, 65, 66, 69, 75, 78-86]
	Safety and wellbeing	20.0	40.0	100.0	0.0	*35.6*	[62, 79, 87]
	Equity and diversity	100.0	75.0	100.0	75.0	*33.3*	[40, 59, 74, 87]
	Local culture	100.0	100.0	100.0	100.0	*21.8*	[10, 62, 65, 68, 69, 79, 86, 87]
Average social		*68.84*	*76.02*	*100.00*	*52.88*	*29.6*	
Economic	structure	100.0	100.0	100.0	33.3	*32.5*	[42, 43, 62, 66, 69, 71, 74, 77, 86, 88, 89]
	Security and stability	57.1	57.1	100.0	57.1	*31.7*	[5, 62, 69, 74, 75, 77, 89, 90]
	Dynamism	41.7	75.0	91.7	25.0	*22.4*	[24, 42, 45, 47, 62, 69, 74, 77, 85, 87, 90]
Average economic		*66.27*	*77.37*	*97.23*	*38.47*	*27.44*	
Infrastructure and physical	Robustness & redundancy	57.1	85.7	57.1	71.4	*36.0*	[29, 49, 59, 62, 77-79, 89, 91, 92]
	Efficiency	100.0	100.0	33.3	100.0	*26.0*	[57, 59, 87, 93]
	ICT	100.0	100.0	0.0	50.0	*51.0*	[57, 69, 71, 88, 94]
	Transport	50.0	100.0	50.0	50.0	*51.5*	[60, 62, 69]
	Land use & urban design	81.8	81.8	45.5	45.5	*20.6*	[10, 52, 57, 66, 69, 72, 88, 89, 95]
Average infrastructure and physical		*77.78*	*93.50*	*37.18*	*63.38*	*30.48*	
Institutional	Leadership and participation	100.0	66.7	100.0	83.3	*31.5*	[65, 66, 68, 79, 80, 85, 91, 95]
	Management of resources	50.0	75.0	100.0	50.0	*20.0*	[35, 59, 61]
	Contingency, emergency, and recovery planning	92.3	84.6	53.8	30.8	*29.7*	[45, 51, 57, 61, 62, 65, 66, 96]
	Collaboration	100.0	100.0	100.0	100.0	*35.3*	[8, 51, 57, 61, 80, 84, 91]
	Research and development	100.0	0.0	0.0	100.0	*30.5*	[50, 68, 91]
	Regulations/enforcement	100.0	100.0	50.0	50.0	*37.5*	[57, 62, 96]
	Education and training	100.0	83.3	66.7	83.3	*28.5*	[10, 57, 62, 66, 74, 79, 80, 84, 87, 89, 91, 96]
Average institutional		*91.8*	*72.8*	*67.2*	*71.1*	*29.7*	
Average (overall)		79.72	79.85	71.34	59.84	*29.37*	

3.2. Overall performance of the selected CRA tools

The formula presented in Section 2 was used to calculate overall performance of the selected CRA tools in terms of addressing the suitability measures related to the four resilience abilities. It can be seen from Table 5 that, on average, selected tools comply with 37%, 29%, 34%, and 31% of measures related to planning, absorption, recovery, and adaptation abilities, respectively. Relatively poor performance in terms of addressing measures related to the absorption ability can be explained by the fact that, as explained in Section 3.1, only few tools have utilized measures for 'comparing pre- and post-event performance' and 'identifying a minimum satisfactory level of post-event functionality'. It can be seen that CoBRA, ICLEI, CRI, and USIOTWSP are four tools that exhibit a reasonably good performance in terms of addressing measures related to the four resilience abilities. As a result, average values for all these four tools are above 50%. On the other hand the average values for Grosvenor and CRI2 are below 10%, indicating that they do not meet most of the suitability measures.

Table 5. The extent of compliance with the resilience abilities across the selected tools

	Extent of inclusion of resilience criteria in the CRA tool	**Resilience abilities**				
		Plan/prepare	Absorb	Recovery	Adapt	Average
CRC	0.23	25%	14%	20%	0%	15%
CRDSA	0.35	26%	14%	20%	13%	18%
DRI	0.25	36%	29%	30%	25%	30%

CDR	0.15	29%	29%	15%	0%	18%
NIST	0.49	50%	43%	65%	38%	49%
RELi	0.53	39%	43%	30%	50%	41%
TCRI	0.10	34%	29%	30%	25%	30%
CoBRA	0.27	59%	50%	55%	63%	57%
CRF	0.40	27%	21%	25%	38%	28%
FCR	0.28	31%	29%	25%	25%	27%
Grosvenor	0.15	7%	7%	5%	0%	5%
ICLEI	0.35	59%	57%	45%	88%	62%
UNISDR	0.31	42%	50%	35%	38%	41%
CRS	0.27	53%	50%	45%	25%	43%
LDRI	0.36	26%	14%	20%	13%	18%
USAID	0.36	48%	29%	35%	38%	37%
CDRST	0.17	41%	21%	40%	38%	35%
BCRD	0.32	37%	14%	40%	13%	26%
CART	0.36	48%	29%	45%	50%	43%
ResilUS	0.16	35%	43%	50%	38%	41%
ICBRR	0.20	24%	14%	20%	0%	15%
BRIC	0.35	21%	14%	20%	0%	14%
CDRI2	0.42	44%	21%	35%	38%	34%
CERI	0.09	29%	14%	25%	0%	17%
CDRI	0.32	31%	29%	20%	25%	26%
CRI2	0.18	13%	14%	10%	0%	9%
CRI	0.21	41%	57%	45%	63%	51%
PEOPLES	0.39	32%	21%	35%	25%	28%
CRT	0.28	36%	36%	30%	50%	38%
SPUR	0.09	23%	36%	40%	63%	40%
DFID	0.46	50%	29%	50%	50%	45%
CARRI	0.36	21%	21%	20%	13%	19%
Hyogo	0.40	49%	29%	45%	38%	40%
USIOTWSP	0.52	61%	50%	70%	63%	61%
THRIVE	0.30	42%	21%	35%	13%	28%
CRM	0.21	47%	36%	35%	50%	42%
Average		*37%*	*29%*	*34%*	*31%*	33%

4. Discussion and conclusions

The concept of resilience is frequently used in science and policy circles. As climate change advances, resilience is expected to become an even more ubiquitous concept. A vast body of literature is published on community resilience as one of the major strands of resilience. Part of this literature is focused on assessing community resilience. Resilience is a prominent theme in various influential frameworks such as “The 2030 Agenda for Sustainable Development”. The

need for measuring success in achieving the goals set out in such frameworks (e.g. SDGs 9 and 11) implies that CRA will gain even further traction in the future. Among other objectives, CRA tools aim to provide communities with guidance on how to improve their resilience by reducing disaster risk and enhancing capacity to cope with disruptive events [1]. The main objective of this study was to examine suitability of selected CRA tools for fulfilling this desired function.

It was discussed that suitable CRA tools should be able to enhance the ability of communities to "prepare and plan for, absorb, recover from, and adapt to adverse events". These four abilities are interwoven and related to different stages of the continuous cycle of disaster risk management. Fourteen different measures that can be used for evaluating the extent of addressing these four abilities were extracted from literature. These measures can be used to evaluate resilience planning activities in terms of both processes and outcomes. Each measure can be related to one or more resilience ability. For instance, 'adopting participatory approaches' is a measure that can contribute to addressing all the four abilities. On the other hand, 'speed of recovery' is only relevant to the community's ability to recover following a disruptive event.

Contents of documents related to the selected tools were analyzed to understand how they have addressed the fourteen suitability measures. Findings showed that only few of these measures have been appropriately addressed in the selected tools. Baseline assessment is the common method used by a large number of the selected tools. Monitoring and update of baseline profiles is acknowledged by about 50% of the tools. Communities are dynamic entities that may undergo rapid transformations. It should be noted that resilience is not a static property of communities. It is indeed a dynamic property that changes over time and across space. This dynamism means that further attention to longitudinal variations and continuous monitoring is needed to make communities better prepared to deal with disruptive events.

Further attention to adopting participatory approaches to development and implementation of CRA tools is needed. Although such approaches may prolong the resilience planning process, they can be effective for enhancing the reliability, acceptability, and applicability of the assessment findings and action plans. Stakeholder participation would also provide opportunities for social learning that is essential for longer term adaptation. These multiple benefits should be promoted in order to encourage adopting participatory approaches.

It was found that selected tools do not perform well in terms of loss estimation and providing information on potential savings attributable to planning and absorption efforts. Also, limited attention has been paid to the extent of efficiency of actions related to resilience planning. Among other things, economic benefits that may accrue from addressing these

measures could be used to foster their incorporation into CRA tools. Techniques such as using simulations, scenarios, and models can be used for the purpose of addressing these measures.

In order to be useful for post-disaster decision making purposes, CRA tools need to include strategies for developing a reasonable recovery timeline. These tools should enable planners and decision makers to regularly track recovery status. Regular updates provide information on the speed of recovery process and can be used for evaluating the efforts of planners and policy makers. It was also argued that in the absence of disasters, probabilistic approaches can be utilized by CRA tools to simulate how communities can/should recover from disruptive events.

'Absorption' is the ability, among the four abilities, that selected CRA tools have the least capacity to address. This could be explained by the fact that measures such as 'comparing pre- and post-event performance', 'identifying a minimum satisfactory level of post-event functionality', and using 'loss estimation models' have received very limited attention across the selected tools. 'Adaptation' is also not well addressed due to the fact that measures such as using 'forecasting/scenario making', considering 'efficiency of actions', and 'adopting participatory approaches' are not appropriately included in the assessment tools. Poor performance in terms of suitability to address the recovery ability can be explained by the lack of attention to measures such as 'identifying recovery timeline', 'tracking recovery status over time', and calculating 'speed of recovery'. Further attention to all these measures should be paid when revising the assessment frameworks.

Findings show that a multitude of resilience criteria exist that can contribute to enhancing the four resilience abilities. However, these criteria are not appropriately integrated into the selected CRA tools. In particular, less attention has been paid to criteria related to natural assets, social structure, local culture, economic dynamism, infrastructure efficiency, land use and urban design, resource management, contingency and emergency planning, and education and training. CRA tools need to adopt a broader understanding of resilience and include multiple resilience dimensions and criteria in their assessment framework.

Interesting results were obtained concerning the relationship between resilience criteria and the four resilience abilities. Different resilience dimensions and criteria exhibit different levels of contribution to the four resilience abilities. For instance, on average, relatively higher percentage of social and economic criteria are related to the recovery ability. Or, on average, relatively higher percentage of natural and physical criteria are related to the absorption ability. These results should be interpreted with caution as they do not intend to undervalue the significance of specific resilience dimensions and criteria for enhancing some of the four

resilience abilities. Ideally, attention should be paid to all criteria. However, this may not be possible due to certain organizational and economic limitations. Planners and decision makers may need to prioritize criteria that better contribute to particular abilities that are more concerned at certain stages of the disaster risk management cycle.

It is hoped that tool developers will use findings of this study when updating/revising the assessment tools. Also, the evaluation framework proposed in this paper can provide future developers with guidance on measures that need to be addressed in order to develop assessment tools suitable for guiding community resilience planning. The framework can also be used by researchers and policy makers for evaluating suitability of other CRA tools. In this study the selected CRA tools were analyzed using a theoretical framework. Another approach for examining suitability of assessment tools could be using empirical information obtained from real-world application of CRA tools. Such an approach would be useful and can provide complementary insights into suitability of CRA tools for guiding community resilience building activities. This is an important issue for future research.

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