Modelling a community resilience index for urban flood-prone areas of Kerala, India (CRIF)

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Abstract
Communities are ever-evolving, cities are constantly expanding, and the threat of natural hazards has escalated like never before. Cities can develop and prosper only if their society is resilient to external shocks. Measuring community resilience over time is crucial with the influence of technology and change in community lifestyles. With the frequent onset of floods in Kerala in recent years, the community must be well-prepared for future calamities. Thus, this paper develops a community resilience index for Kerala’s urban flood-prone areas (CRIF) through a rigorous bottom-up approach. The criteria for the index were developed using multi-criteria decision analysis that covered a fuzzy Delphi study, an empirical study using multi-variate probit regression, and an AHP analysis. The fuzzy Delphi study selected seven criteria: ‘social’, ‘economical’, ‘governance/political’, ‘health’, ‘communication/coordination’, ‘education’, and ‘infrastructure’ from 65 experts. The empirical study helped apprehend the public’s viewpoints under each criterion. Finally, the AHP analysis helped assign appropriate weights to the criteria which 28 experts designated. The index is also designed according to the Sendai Framework for Disaster Risk Reduction (2015–2030). Further, the CRIF Index is put into action through a case study of the Kochi Municipal Corporation area, and the results are also validated using the Spearman’s rank correlation coefficient method. Results from validation returned a value of 0.7209 for the perceived CRIF method and 0.5798 for the external validation method, which corresponds to a ‘high’ and ‘moderate’ correlation, respectively.

Keywords Multi-criteria decision analysis · Communities · Disaster mitigation · Empirical study · Validation

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1 Introduction

Community resilience is an ever-evolving term. It has been interpreted differently by various researchers. Rand Corporation defines community resilience as “… a measure of the sustained ability of a community to utilize available resources to respond to, withstand, and recover from adverse situations” (Rand 2021). Researchers have highlighted the importance of community resilience in several disaster mitigation studies, with greater importance given to the capacity of the community rather than external support (Bosher and Dainty 2011; Joerin et al. 2012; Alshehri et al. 2015; Ma et al. 2021). In the disaster risk reduction domain, studies now focus more on resilience than vulnerability as it includes pre- and post-disaster mitigation (Alshehri et al. 2015). The United Nations International Strategy for Disaster Reduction (UNISDR) has thus considered resilience as a critical element in implementing their disaster mitigation strategies (Alshehri et al. 2015).

Resilience can operate at various scales, from a national level to a smaller, community, or individual level (Long et al. 2010; Ali and George 2021a). The relationship between community and resilience is rapidly growing in recent studies, leading to several frameworks and indices (Paton 2006; Upadhyay and Sa-ngiamwibool 2021).

Several authors have stated that assessing community resilience is a strenuous job as it involves complex interaction within communities due to the uniqueness of the local environment (Cutter et al. 2008; Frankenberger et al. 2013). Measuring community resilience is vital as it exposes the weaknesses of the community (Kirmayer et al. 2009). Through the years, researchers have created several frameworks/models to measure community resilience (Cutter et al. 2014; Joerin et al. 2014; DasGupta and Shaw 2015; FAO 2016; Lam et al. 2016; Cissé and Barrett 2018; Craft 2019; Clark-Ginsberg et al. 2020). Most of these studies are focused on the earlier Hyogo Framework for Action 2005–2015 (HFA) developed by the UNISDR (United Nations 2005). However, the CRIF index follows the updated Sendai Framework for disaster risk reduction aimed at disaster risk reduction (DRR) in cities with a timeframe from 2015 to 2030 (Nations 2015). The Sendai Framework also stresses the importance of ‘building back better’ in rehabilitation, recovery and reconstruction, which were necessarily not objectives of previous frameworks.

Several pieces of literature show that increasing community awareness of disaster management leads to a higher resilient community (Lam et al. 2017; Antronico et al. 2020). Studies also show that communities with higher social, physical, and human capital are better prepared to manage disaster (Cohen et al. 2013). Thus, measures to enhance community awareness have become of paramount importance.

Through the years, community resilience has evolved from a ‘bounce back’ to a more robust and enhanced ‘bounce forward’ approach (Paton and Johnston 2001; Apostolopoulos et al. 2019). van de Pas et al. (2017) states that it is better to focus on ‘bounce back’ than ‘bounce forward’ since it helps maintain the status quo. However, the author argues that this may not be entirely true, and it is possible to focus on the bounce forward approach and even improve the status quo. References post-2016, including the Sendai framework, have focused on community resilience’s evolution from sustaining previous conditions to an anticipatory model for future adversities (Nations 2015; Matarrita-Cascante et al. 2017; Fazey et al. 2018; Adekola and Clelland 2019; Apostolopoulos et al. 2019).

As is the case worldwide, unprecedented events leading to disasters are on the rise in India due to population increase, higher density, and poorly planned cities (Kumar et al. 2021). Recent repeated flooding in Kerala, India (Ali and George 2021a), raises the importance of addressing the situation. Kerala has been experiencing floods in
2018 and 2019, resulting in more than 400 causalities due to the event (The World Bank 2018). There is a dire need to create a new model for Kerala that incorporates an integrative and comprehensive disaster resilience approach in disaster relief operations (Joseph et al. 2020).

Further, Almutairi et al. (2020) highlight the drawbacks of the current indices/frameworks related to community resilience. Considering these, the author has proposed a community resilience index for the state of Kerala. The index incorporates various objectives of the Sendai framework and has specifically focused on implementing the fourth objective, which is missing from all other existing frameworks. Just as the concept of community resilience has been evolving, Kirmayer et al. (2009) state it is essential to measure community resilience over time due to the influence of technology and change in community lifestyles. This frequent overhaul will help document any change in community cohesion, thereby helping disaster policy formulation and planning (Upadhyay and Sa-ngiamwibool 2021).

2 Kerala floods

Kerala is a South Indian state with more than 33 million population, with a geographic area extending to 39,000 km². It has a coast of 590 km, and the width of the state varies between 11 and 121 km. Kerala can be divided into three climatically distinct regions: the eastern highlands; rugged and cool mountainous terrain, the central midlands; rolling hills, and the western lowlands; coastal plains (Chattopadhyay and Franke 2006). About 90% of the rainfall in a year occurs during six monsoon months, from June to November. Kerala state has an average annual precipitation of about 3000 mm (Ministry of Earth Sciences 2019). Kerala, being a coastal city with a coastline of 590 km, is vulnerable to natural disasters such as floods, tsunamis, and even landslides along the slopes of the Western Ghats.

Out of all the disasters, floods are the most common disaster in Kerala. Close to 14.5% area of the state is prone to floods (Ministry of Earth Sciences 2019). Riverine flooding is a recurring event due to heavy or continuous rainfall. It leads to exceeding the percolation capacity of soil and the flow capacity of streams and rivers.

Before the flood of 2018 and 2019, the previous flood of such a devastating scale happened in 1924, almost a century ago. More commonly known as the ‘99 floods, since it happened in the Malayalam calendar year of 1099, the flood had deeply submerged many districts of Kerala from Thrissur to Alappuzha, even parts of Idukki. After 1924, the next major flood was in 1961 in the Kerala Periyar Basin, with a 52% increase in Monsoon rains. However, casualties were relatively lesser, at 110, than the previous event due to lesser urban densities in these areas.

The flood seems to be recurring at a closer frequency, especially when it happens back-to-back years. The year 2019 ran through a deficit of 29% rainfall on 1 August 2019 to no shortage on 14 August 2019, implying the excess rain was received in just two short weeks (Ministry of Earth Sciences 2019). Houses damaged due to flooding stood at 1789, and over 26,000 people have taken refuge in relief camps (Ministry of Earth Sciences 2019). Out of all the districts in Kerala, Kochi seems to be the most affected in infrastructure, transportation, and economic terms.
3 Developing the community resilience index (CRIF)

Developing a new quantitative adaptive strategy that helps to reinforce the relationship between the environment and the human community is necessary (Upadhyay and Sa-ngiamwibool 2021). Even though several studies that exhibit the inherent capabilities of communities to mitigate disasters are common, there exists a dire need for a scientific, multi-disciplinary, and knowledge-based approach that engulfs local knowledge and evaluates the operational management of the issue at stake (Upadhyay and Sa-ngiamwibool 2021). However, little guidance exists on creating and implementing interdisciplinary methodologies associated with the research on community resilience. Hence, the author has followed a specific approach in creating an index for community resilience that incorporates the existing research gaps (Fig. 1).

The recent reoccurring floods in Kerala were eye-opening for designing an index that adheres to disaster policymakers. The author has followed a multi-criteria decision analysis method to create the index, which started with a pilot survey, a focus group discussion, and a literature review to select the initial set of criteria. After that, the author conducted a fuzzy Delphi study that comprised 65 experts (Ali and George 2021b). They included subject experts, academicians, government officials, religious heads, and medical experts. The fuzzy Delphi survey resulted in selecting seven criteria, namely, ‘Social’, ‘Economic’, ‘Governance’, ‘Health’, ‘Communication’, ‘Education’, and ‘Infrastructure’. The seven selected criteria included 125 sub-sub-criteria under 29 sub-criteria.

After finalizing the criteria, the next step was to assign weights to the criteria. The weights derived from a Delphi or a fuzzy Delphi analysis cannot be assigned since the study is designed to select the relevant criteria from a pool of others. To address this issue, like from several pieces of literature, an analytical hierarchy process (AHP) is required. But before the initiation of this method, a new step was included to document the general public’s viewpoints. The author conducted an exploratory study in Kochi (one of the most severely affected cities during the 2018 flood in Kerala) using a Multi-variate Probit regression model. The study area covered the Kochi Municipal Corporation limits comprised of 74 ward units with a survey count of 750 (Ali and George 2021c). The exploratory research utilized the criteria selected from the fuzzy Delphi analysis to frame the questionnaire. The results examined several criteria that helped the general public the most during the flood of 2018 and 2019. Finally, these results and the initial set of criteria from the fuzzy Delphi study were then presented to a panel of experts to assign appropriate weights.

The paper includes assigning weights to the criteria using the AHP method. After that, the procedure of creating an index is explained. The index is designed according to the Sendai Framework 2015–2030 priorities: (a) Understanding disaster risk, (b) Strengthening disaster risk governance to manage disaster risk, (c) Investing in disaster risk reduction
for resilience, and (d) Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation, and reconstruction (Nations 2015).

To test the authenticity of the index created, it is validated with the help of a case study conducted in the Kochi Municipal Corporation area. The final results are presented, highlighting several disaster mitigating factors otherwise absent in the literature.

4 The analytical hierarchy process (AHP) model

The AHP receives a broader adoption and outcome satisfaction among the existing multi-criteria decision model (MCDM) methods (Sanneh et al. 2014; Liu et al. 2020). The AHP method can mix qualitative and quantitative features (Wedley 1990). Saaty’s nine-point scale helps convert qualitative elements into quantitative terms. It compares two distinct dimensions and helps prioritize one over the other (Shapira and Simcha 2009). Saaty (1990) explains this pair-wise comparison is the core of AHP. When making pair-wise comparisons, Saaty and Vargas (2012) suggest the maximum pair-wise comparison not to exceed seven as it might otherwise be difficult for experts to comprehend and analyse the data. Also, the maximum number of comparisons did not exceed seven in this study. AHP has also been used in similar studies for urban flood hazard assessment for Athens Bathrellos et al. (2016) and landslide susceptibility mapping in the Peloponnese region (Rozos et al. 2011).

Implementing the AHP method is done in four steps (Lin et al. 2010). Firstly, a hierarchy of the criteria and their divisions is constructed. Secondly, pair-wise comparisons are conducted using Saaty’s 9-point scale (Table 1). Thirdly, to obtain the set of weights, judgments are synthesized. And lastly, the consistency of the judgments is evaluated, which needs to be less than ‘0.1’.

4.1 AHP methodology

Based on the pilot survey, a focus group discussion, literature review, the fuzzy Delphi study, and the exploratory analysis, the list of seven criteria with 29 sub-criteria and 125 sub-sub-criteria was finalized (Ali and George 2021b). The next step, forming a significant part of this paper, was to assign weights to the selected criteria using the AHP method. For this, all the 65 experts who participated in the fuzzy Delphi analysis were invited to participate. All experts had at least five years of experience working in their respective fields. Pair-wise questionnaires were sent via personal emails. Thirty-two experts responded, but only 28 were selected since four of the responses did not satisfy

| Intensity of importance | Definition                  |
|-------------------------|-----------------------------|
| 1                       | Equal importance            |
| 3                       | Weak importance of one over the other |
| 5                       | Essential or strong importance |
| 7                       | Demonstrated importance     |
| 9                       | Absolute importance         |
| 2, 4, 6, 8              | Intermediate values         |

Table 1 Saaty’s 9-point scale (Saaty 2002)
consistency in their judgments (consistency values were more than 0.1). These experts include (a) stakeholders who have a direct say in policy formulation, (b) those involved in disaster mitigation teams, and (c) others who are approached for expert suggestions across various disaster management measures. All the experts have either directly experienced the Kerala flood of 2018 or have been involved in flood-related/flood-mitigating projects. ‘Expert Choice’ software was used to conduct the data synthesis and evaluate the judgments. The software is used for pair-wise comparisons and is used by researchers across several domains (Erdogan et al. 2017; Gupta and Vijayvargy 2021; Horňáková et al. 2021). Table 2 displays the selected 28 experts who participated, with their designation and organization mentioned, respectively. The panel consisted of experts from academia, the construction industry, government servants, the medical field, religious heads, and politicians. The expert panel even consisted of four international participants. Figure 2 shows the AHP methodology followed. Figure 3 displays a consolidated image of the criteria and sub-criteria for this study. (Numbers in parenthesis display the number of sub-sub-criteria under each corresponding sub-criteria.)

Table 2  Expert panel classification

| Expert       | Designation               | Institution/organization                                      |
|--------------|---------------------------|---------------------------------------------------------------|
| Academia     | Professor School of Planning and Architecture, New Delhi |
|              | Professor Indian Institute of Technology, Kharagpur        |
|              | Associate Professor National Institute of Technology, Calicut |
|              | Assistant Professor National Institute of Technology, Calicut |
|              | Assistant Professor Indian Institute of Technology, Kharagpur |
| Government   | Chief Executive Engineer Kerala State Electricity Board     |
|              | Chief Manager Bharat Petroleum Corporation Ltd., Kochi     |
|              | Consultant National Institute of Urban Affairs, New Delhi  |
|              | Chief Engineer Forest Department, Kollam                    |
|              | Superintendent of Police Kerala Police                      |
| Construction | Architect Freelance Architect                                |
|              | Architect ULCCS, Calicut                                     |
|              | Civil Engineer ULCCS, Calicut                                |
|              | Project Manager Central Public Works Department, Bangalore   |
|              | Assistant Urban Planner Department of Town & Country Planning, Kerala |
|              | Urban Planner WWF India                                      |
| Medical      | ENT Doctor District Hospital Kollam (India)                  |
|              | Medical Officer Community Health Center, Kollam              |
|              | Doctor Craft Hospital, Thrissur                               |
| Religious Head| Scrum Master Kerala Council of Churches                      |
|              | Member Kerala Muslim Jamaath                                |
|              | Secretary Kerala Muslim Jamaath                              |
| Political    | Youth Wing President Opposition Party Kerala                 |
|              | Member Ruling Party Kerala                                   |
| International| Research Associate Nanyang Technological University—NTU (Singapore) |
|              | Independent Consultant Freelancer (Switzerland)             |
|              | Architect Archistar.ai (Australia)                           |
|              | Architect Aukett Swanke (UAE)                                 |
Pair-wise matrices were built that compared criteria with each other, which were also done for the sub-criteria and sub-sub-criteria, creating a total of 37 matrices. After synthesizing the experts’ results, the expert choice software displayed results in the following manner. Out of the seven criteria, the criterion ‘Social’ resulted with the highest weight of 0.253 (Total of weights is equal to 1), followed by ‘Governance/Political’ with 0.213, ‘Economical’ with 0.162, ‘Education’ with 0.147, ‘Communication/Coordination’ with 0.089, ‘Health’ with 0.077, and finally ‘Infrastructure’ with 0.060 (Fig. 4).

Table 3 The individual sub-criteria weights with their corresponding sub-sub-criteria weights.

5 The community resilience index for flood-prone areas (CRIF)

Indices help summarize complex scientific and technical data into a simple and straightforward unit that makes it easy to understand and assists stakeholders in guiding policies (Mayunga 2007; Kusumastuti et al. 2014; Clark-Ginsberg et al. 2020). The versatility of an index lies in its multi-segmented nature, allowing researchers and practitioners to identify both areas of interest and drawbacks. The current study classifies the index into five classes: ‘zenith’, ‘high’, ‘medium’, ‘low’, and ‘nadir’, where zenith corresponds to the highest level of community resilience and nadir corresponds to the lowest level. The index score ranges from 0 to 100, and the corresponding assigned scores are described in Table 4. Survey
respondents have the option to choose from six options under each question ranging from 0 (meaning absence of particular criterion) to 5 (criterion performs most efficiently). Once the respondent completes the survey, the CRIF score can be calculated.

The following equations illustrate how to calculate the CRIF scores,

$$R = r_i$$

$$SC_j = \sum_{k=1}^{n} (R_k W_k)$$

$$C_i = \sum_{j=1}^{m} (SC_j)$$

$$CRIF = \sum_{i=1}^{l} C_i$$

Fig. 3 Consolidated visualization of criteria and sub-criteria
where $r_l = \text{Recorded score from the survey (} l = 0 \text{ to } 5\text{)},$ $R = \text{Weighted score of the corresponding } r_l \text{ value (0 for } r_0, \text{0.2 for } r_1, \text{0.4 for } r_2, \text{0.6 for } r_3, \text{0.8 for } r_4, \text{1.0 for } r_5\text{)}.$ $W_k = \text{Weight of corresponding sub-sub-criterion.}$ $n = \text{Ranges from 1 to maximum sub-sub-criteria under each sub-criterion.}$ $SC_j = \text{Score of corresponding sub-criterion.}$ $m = \text{Ranges from 1 to maximum sub-criteria under each criterion.}$ $C_i = \text{Score of an individual criterion.}$ $\text{CRIF = Community resilience index value (0–100).}$

The CRIF contains seven criteria that help identify the efficiency of each criterion for the different communities studied. The CRIF has also incorporated the Sendai framework into its model, which identifies the priorities for communities. Table 5 classifies the criteria under each priority list of the Sendai framework.

The CRIF is to be used to identify the level of community resilience present in a particular community. Due to the numerous definitions for the term ‘community,’ the author suggests using the explanation as given by ‘GOAL,’ an international organization founded in 1977 working on the upliftment of vulnerable communities (GOAL 2016). GOAL describes a community as, a) a group of people living in the same area who are exposed to the same risks, b) are governed by the same decision-making structure, and c) groups that experience the same set of shocks.
| Sub-criteria       | Sub-sub-criteria | Sub-criteria weight (out of 1) | Sub-criteria weight (%) | Global weight (out of 100%) |
|--------------------|------------------|--------------------------------|-------------------------|-----------------------------|
| **Social**         |                  |                                |                         |                             |
| Social preparedness| S1               | 0.241                          | 24.124                  | 1.898                       |
|                    | S2               | 0.108                          | 10.811                  | 0.851                       |
|                    | S3               | 0.281                          | 28.128                  | 2.213                       |
|                    | S4               | 0.168                          | 16.817                  | 1.323                       |
|                    | S5               | 0.104                          | 10.410                  | 0.819                       |
|                    | S6               | 0.097                          | 9.710                   | 0.764                       |
| Participation      | S7               | 0.097                          | 9.700                   | 0.452                       |
|                    | S8               | 0.333                          | 33.300                  | 1.550                       |
|                    | S9               | 0.570                          | 57.000                  | 2.653                       |
| Awareness          | S10              | 0.264                          | 26.400                  | 2.217                       |
|                    | S11              | 0.037                          | 3.700                   | 0.311                       |
|                    | S12              | 0.123                          | 12.300                  | 1.033                       |
|                    | S13              | 0.162                          | 16.200                  | 1.361                       |
|                    | S14              | 0.255                          | 25.500                  | 2.142                       |
|                    | S15              | 0.081                          | 8.100                   | 0.680                       |
|                    | S16              | 0.078                          | 7.800                   | 0.655                       |
| Social connectedness| S17             | 0.060                          | 6.000                   | 0.131                       |
|                    | S18              | 0.057                          | 5.700                   | 0.124                       |
|                    | S19              | 0.159                          | 15.900                  | 0.346                       |
|                    | S20              | 0.159                          | 15.900                  | 0.346                       |
|                    | S21              | 0.167                          | 16.700                  | 0.363                       |
|                    | S22              | 0.338                          | 33.800                  | 0.735                       |
|                    | S23              | 0.060                          | 6.000                   | 0.131                       |
| Networking         | S24              | 0.069                          | 6.907                   | 0.150                       |
|                    | S25              | 0.285                          | 28.529                  | 0.621                       |
|                    | S26              | 0.198                          | 19.820                  | 0.431                       |
|                    | S27              | 0.129                          | 12.913                  | 0.281                       |
|                    | S28              | 0.133                          | 13.313                  | 0.290                       |
|                    | S29              | 0.185                          | 18.519                  | 0.403                       |
| **Economical**     |                  |                                |                         |                             |
| Economic availability| E30            | 0.286                          | 28.60                   | 1.918                       |
|                    | E31              | 0.143                          | 14.30                   | 0.959                       |
|                    | E32              | 0.571                          | 57.10                   | 3.830                       |
| Diversity/equity   | E33              | 0.159                          | 15.90                   | 0.160                       |
|                    | E34              | 0.105                          | 10.50                   | 0.105                       |
|                    | E35              | 0.278                          | 27.80                   | 0.279                       |
|                    | E36              | 0.458                          | 45.80                   | 0.460                       |
| Task force         | E37              | 0.163                          | 16.30                   | 0.333                       |
|                    | E38              | 0.297                          | 29.70                   | 0.606                       |
|                    | E39              | 0.54                           | 54.00                   | 1.102                       |
| Investment         | E40              | 0.389                          | 38.90                   | 2.508                       |
|                    | E41              | 0.13                           | 13.00                   | 0.838                       |
| Sub-criteria                  | Sub-sub-criteria | Weight (out of 1) | Sub-criteria weight (%) | Global weight (out of 100%) |
|-------------------------------|------------------|-------------------|-------------------------|----------------------------|
|                               | E42              | 0.303             | 30.30                   | 1.954                      |
|                               | E43              | 0.178             | 17.80                   | 1.148                      |
| Criteria total                |                  |                   |                         | 16.20%                     |
| Governance                    |                  |                   |                         |                            |
| Government preparedness       | G44              | 0.329             | 32.90                   | 3.700                      |
|                               | G45              | 0.066             | 6.60                    | 0.742                      |
|                               | G46              | 0.085             | 8.50                    | 0.956                      |
|                               | G48              | 0.315             | 31.50                   | 3.543                      |
|                               | G49              | 0.205             | 20.50                   | 2.306                      |
| Government connectedness      | G50              | 0.402             | 40.16                   | 2.848                      |
|                               | G51              | 0.095             | 9.49                    | 0.673                      |
|                               | G52              | 0.079             | 7.89                    | 0.560                      |
|                               | G53              | 0.056             | 5.59                    | 0.397                      |
|                               | G54              | 0.158             | 15.78                   | 1.120                      |
|                               | G55              | 0.211             | 21.08                   | 1.495                      |
| Data sharing                  | G56              | 0.081             | 8.11                    | 0.242                      |
|                               | G57              | 0.242             | 24.22                   | 0.722                      |
|                               | G58              | 0.052             | 5.21                    | 0.155                      |
|                               | G60              | 0.159             | 15.92                   | 0.475                      |
|                               | G61              | 0.237             | 23.72                   | 0.707                      |
|                               | G62              | 0.114             | 11.41                   | 0.340                      |
|                               | G63              | 0.114             | 11.41                   | 0.340                      |
| Criteria total                |                  |                   |                         | 21.321%                    |
| Health                        |                  |                   |                         |                            |
| Physical health               | H64              | 0.443             | 44.34                   | 1.243                      |
|                               | H65              | 0.387             | 38.74                   | 1.086                      |
|                               | H66              | 0.169             | 16.92                   | 0.474                      |
| Work force                    | H67              | 0.333             | 33.30                   | 0.285                      |
|                               | H68              | 0.667             | 66.70                   | 0.570                      |
| Medical supplies              | H69              | 0.558             | 55.80                   | 0.253                      |
|                               | H70              | 0.122             | 12.20                   | 0.055                      |
|                               | H71              | 0.32              | 32.00                   | 0.145                      |
| Mental health                 | H72              | 0.268             | 26.83                   | 0.768                      |
|                               | H73              | 0.614             | 61.46                   | 1.761                      |
|                               | H74              | 0.117             | 11.71                   | 0.335                      |
| Hazard monitoring             | H75              | 0.05              | 5.01                    | 0.036                      |
|                               | H76              | 0.111             | 11.11                   | 0.080                      |
|                               | H77              | 0.16              | 16.02                   | 0.116                      |
|                               | H79              | 0.3               | 30.03                   | 0.217                      |
|                               | H80              | 0.274             | 27.43                   | 0.199                      |
|                               | H81              | 0.104             | 10.41                   | 0.075                      |
| Criteria total                |                  |                   |                         | 7.70%                      |
| Communication                 |                  |                   |                         |                            |
| Macro-level                   | C82              | 0.117             | 11.71                   | 0.563                      |
Table 3 (continued)

| Sub-criteria | Sub-sub-criteria | Sub-criteria Weight (out of 1) | Sub-criteria weight (%) | Global weight (out of 100%) |
|--------------|------------------|-------------------------------|--------------------------|----------------------------|
| C83          | 0.614            | 61.46                         | 2.954                    |
| C84          | 0.268            | 26.83                         | 1.289                    |
| **Authentication** |                |                               |                          |
| C85          | 0.109            | 10.90                         | 0.288                    |
| C86          | 0.185            | 18.50                         | 0.489                    |
| C87          | 0.082            | 8.20                          | 0.217                    |
| C88          | 0.341            | 34.10                         | 0.901                    |
| C89          | 0.177            | 17.70                         | 0.468                    |
| C90          | 0.106            | 10.60                         | 0.280                    |
| **Monitoring** |                |                               |                          |
| C91          | 0.354            | 35.40                         | 0.514                    |
| C92          | 0.084            | 8.40                          | 0.122                    |
| C93          | 0.235            | 23.50                         | 0.341                    |
| C94          | 0.052            | 5.20                          | 0.075                    |
| C95          | 0.094            | 9.40                          | 0.136                    |
| C96          | 0.181            | 18.10                         | 0.263                    |
| **Criteria total** |            |                               |                          |
| **Education** |                |                               |                          |
| Literacy     |                  |                               |                          |
| A97          | 0.059            | 5.89                          | 0.363                    |
| A98          | 0.217            | 21.68                         | 1.335                    |
| A99          | 0.522            | 52.15                         | 3.212                    |
| A100         | 0.203            | 20.28                         | 1.249                    |
| **Public responsibility** |         |                               |                          |
| A101         | 0.667            | 66.70                         | 0.961                    |
| A102         | 0.333            | 33.30                         | 0.480                    |
| **Research** |                |                               |                          |
| A103         | 0.2              | 20.00                         | 0.873                    |
| A104         | 0.8              | 80.00                         | 3.392                    |
| **Government responsibility** |          |                               |                          |
| A105         | 0.194            | 19.42                         | 0.531                    |
| A106         | 0.252            | 25.23                         | 0.690                    |
| A107         | 0.084            | 8.41                          | 0.230                    |
| A108         | 0.469            | 46.95                         | 1.284                    |
| **Criteria total** |            |                               |                          |
| **Infrastructure** |          |                               |                          |
| Planning and monitoring |   |                               |                          |
| I109         | 0.089            | 8.89                          | 0.080                    |
| I110         | 0.372            | 37.16                         | 0.334                    |
| I111         | 0.084            | 8.39                          | 0.076                    |
| I112         | 0.245            | 24.48                         | 0.220                    |
| I113         | 0.211            | 21.08                         | 0.190                    |
| **Waste management** |          |                               |                          |
| I114         | 0.072            | 7.20                          | 0.035                    |
| I115         | 0.113            | 11.30                         | 0.055                    |
| I116         | 0.179            | 17.90                         | 0.087                    |
| I117         | 0.277            | 27.70                         | 0.135                    |
| I118         | 0.359            | 35.90                         | 0.174                    |
| **Availability** |              |                               |                          |
| I119         | 0.118            | 11.80                         | 0.253                    |
| I120         | 0.288            | 28.80                         | 0.617                    |
| I121         | 0.444            | 44.40                         | 0.951                    |
| I122         | 0.086            | 8.60                          | 0.184                    |
6 Implementing CRIF—a case study of Kochi municipal corporation

6.1 Site selection

Kochi was one of the most severely affected cities during the Kerala flood of 2018. Due to the severity of the flood, the centrally located city of Kerala had divided the state into two, preventing commute and bringing the state functioning to a halt for at least two weeks. However, the community resilience shown by the residents was impeccable, and they received worldwide praise for their efforts (Ali and George 2021c). The study is undertaken in the Kochi municipal corporation limits comprising 74 wards (Fig. 5). Surveys were collected during the months of September–October 2021. Using Cochran’s (1977) formula, the calculated minimum sample size required for the questionnaire was 385 with a 95% confidence interval and a 5% margin of error. Hence, a total of 450 households who had experienced the flood of 2018/2019 (or both) were surveyed with the CRIF questionnaire. An added question to capture perceived community resilience was also included for validation purposes in the questionnaire.
| Priority list                                              | Sub-sub-criteria                                      | Total items | Total weight (%) |
|-----------------------------------------------------------|-------------------------------------------------------|-------------|------------------|
| 1. Understanding disaster risk                            | S1, S3, S12, G44, G61, C82-C86, C89-C91, C93-C96, A97-A100, A103, A104, I118 | 24          | 27.811           |
| 2. Strengthening disaster risk governance to manage disaster risk | S2, S7-S11, S14-S16, S19-S29, G45, G46, G49-G55, G62, G63, H67, H75, H81, C87, C88, A101, A102, A105-A108, I110 | 43          | 33.409           |
| 3. Investing in disaster risk reduction for resilience     | E30-E43, H68, H69, C92, I127-I129                      | 20          | 19.101           |
| 4. Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation, and reconstruction | S4-S6, S13, S17-S18, G48, G56-G60, H64-H66, H70-H74, H76-H80, I109, I111-I117, I119-I126 | 38          | 19.679           |
| Total                                                     |                                                       | 125         | 100.00           |
6.2 Results

The CRIF scores for the 74 wards were calculated (Fig. 6), which resulted in five wards (6.75%) under the Zenith class, 11 wards (14.86%) under the High class, 24 wards (32.43%) under the Medium class, 20 wards (27.02%) under the Low class, and 14 wards (18.91%) under the Nadir class. The highest score was 86.538 for Gandhi Nagar (ward 63), and the lowest 18.297 for Mattancherry (ward 5). The stretch from Kummumpuram to Mattancherry (wards one to five), which lies under the least resilient category, houses many slums. Even though the poor conditions are much better when compared to the slums of Dharavi (Mumbai) and Kirti Nagar (Delhi), a lot of the community resilient criteria are absent in these
areas, which resulted in low CRIF scores. The primary reasons are the lack of education and access to primary infrastructure. However, these communities’ social skills fared much better than several other Kochi Municipal Corporation wards.

Chambakkara (ward 50) and Poonithura (ward 51) also returned poor CRIF scores as they fared poorly under the Social and Governance criteria. When asked to the survey respondents, ‘corruptive’ practices by certain sections of the society were the primary concern for the reduced social ties among community members.

The central area of the Kochi Municipal Corporation returned high CRIF scores. These areas comprised Ernakulam North, Ernakulam Central, Ravipuram, Gandhinagar, and Elamkara South. These wards comprised the best infrastructure and followed a mixed housing pattern that included communities of different economic statuses and a mix of
religious settlements. Respondents scored high on social, infrastructure, and education criteria.

But modern infrastructure alone did not prove beneficial for the ward Kaloor North (ward 70). These areas housed multi-storeyed apartments and easy availability of urban resources. However, the lack of proper drainage sites, narrow roads, and high infrastructure density led to poor conditions during the 2018 flood. People were trapped at higher floors of apartments with water levels covering up to two-floor heights. High population density and low-lying areas further added to the damages suffered.

The highest number of wards falls under the Medium class. Commonalities found in these wards include good education and social criteria scores but fared moderately under the infrastructure, communication, and health criteria. These wards majorly had narrow roads and high-density settlements as well.

6.3 Validation

Validation of models is necessary as they judge the models’ accuracy while making predictions—most existing models on community resilience lack this aspect. However, validation is the only way model users and decision-makers can determine how well the model functions (Eddy et al. 2012). The study conducts three types of validation, namely (a) the Kruskal–Wallis (K-W) H test and Mann–Whitney (M–W) U test to check for significant differences between or among CRIF responses, (b) the perceived CRIF score test that compares CRIF scores with the calculated values using the Spearman’s rank correlation coefficient, and (c) external validation of the CRIF scores with an urban-flood vulnerability zoning map of Kochi Municipal Corporation as studied by Sowmya et al. (2015) again using the Spearman’s rank correlation coefficient. No matter how many validations are conducted, there will always be uncertainty regarding some aspects of a model (Eddy et al. 2012).

6.3.1 Kruskal–Wallis (K–W) H Test and Mann–Whitney (M-W) U Test

Stata13 software was used to conduct the Kruskal–Wallis (K–W) H test and the Mann–Whitney (M–W) U test. The K–W H test was used to identify if the five categories within CRIF were significantly different, and the M–W U test was used to determine if all the possible consecutive pairs within the categories were different or not. Both yielded a p-value less than 0.05 at a 95% confidence interval, meaning there was no statistical difference between the five categories or any two consecutive categories, making it redundant to test any non-consecutive pairs. The K–W H test also helped identify that heterogeneity did not exist within categories either (Table 6).

6.3.2 Perceived CRIF score

A perceived CRIF score was recorded among respondents and validated against the recorded scores using Spearman’s rank correlation coefficient. Forty-nine wards corresponded to the same CRIF classes as the recorded CRIF scores (Fig. 7). The Spearman’s rank correlation coefficient was calculated at 0.7209 (repeated ranks) and is statistically significant at a 95% confidence interval. The value strongly correlates with the calculated CRIF scores (Field Studies Centre 2021).
The perceived scores returned more moderate values and fewer extreme values than the calculated CRIF scores in general. For example, respondents from the wards around Mattancherry responded with ‘medium’ and ‘low’ community resilience scores even though the calculated scores were calculated to be ‘nadir’. This may be because the residents may be unaware of their safety and falsely believe they are better resilient than expected, or even because their conditions are already below par that even the occurrence of a flood event might not trigger worse conditions. However, these wards did fare well in the ‘social’ criteria due to strong social bonds and high social capital.

On the contrary, respondents from wards such as Ernakulam North and Gandhinagar responded with the best possible resilience scores due to the easy availability of urban infrastructure and better communication and governance. It is to note that these areas also house the district’s major administrative buildings and hence cannot collapse in a disaster. The added perks, however, benefit the ward residents as well.

### Table 6 K–W H test and M–W U test for CRIF scores

| Groups/classes          | p-value | Groups/classes          | p-value |
|-------------------------|---------|-------------------------|---------|
| All 5 CRIF categories   | 0.022   | ‘Zenith’ vs. ‘High’     | 0.001   |
| Zenith class (5 wards)  | 0.305*  | ‘High’ vs. ‘Medium’     | 0.015   |
| High class (11 wards)   | 0.421*  | ‘Medium’ vs. ‘Low’      | 0.009   |
| Medium class (24 wards) | 0.465*  | ‘Low’ vs. ‘Nadir’       | 0.027   |
| Low class (20 wards)    | 0.385*  | (Non-consecutive groups not required) |
| Nadir class (14 wards)  | 0.313*  |                         |         |

*No significant heterogeneity within category (95% CI)

### Fig. 7 Calculated and perceived CRIF scores

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6.3.3 External validation with the urban-flood vulnerability zoning map

A third and external validation technique was used to further validate the calculated CRIF scores. For this, an established work along the same line of study was used. The study conducted by Sowmya et al. (2015) demographically represented the urban-flood vulnerable zones around Kochi municipal corporation area. The vulnerability map was created using data such as elevation above MSL, population density, the density of drainage block sites per sq km, distance of drainage block sites, and distance from water bodies (Sowmya et al. 2015).

The vulnerability map was plotted against the calculated CRIF scores, and a Spearman’s rank correlation coefficient was used to compare the vulnerability scores. The data represented graphically was not ward-wise, and hence the author converted it accordingly based on the closest corresponding values possible. Figure 8 shows the conversion process involved.

On analysis, Spearman’s rank correlation coefficient showed a value of 0.5798, which is significant at a 95% confidence interval. This value reflects a ‘moderate’ correlation with the calculated CRIF scores. However, the vulnerability map does not capture the entire ground situation as social and economic variables are largely missing, which may also cause a reduced correlation value with the calculated scores. Wards with high vulnerability have also shown high community resilience values, which is a good thing as these are the wards where resilience should be higher to mitigate disasters. Further, with the help of the CRIF scores, decision-makers can focus on criteria that need addressing immediately or in the long run and implement policies accordingly. Table 7 displays the consolidated class’s from the calculated score (CRIF), the perceived score, and the vulnerability score corresponding to their wards allocated.

Fig. 8 Urban-flood vulnerability zoning, a original vulnerability map by Sowmya et al. (2015) (left), b vulnerability mapped zone-wise (centre), c reverse vulnerability map for comparison with calculated CRIF scores (right)
| Ward no. | Ward name                  | CRIF class | Perceived class | Vulnerability class |
|---------|----------------------------|------------|-----------------|---------------------|
| 1       | Fort Kochi                 | 5          | 4               | 2                   |
| 2       | Kalvathy                   | 5          | 3               | 2                   |
| 3       | Earavely                   | 4          | 3               | 4                   |
| 4       | Karippalam                 | 4          | 4               | 4                   |
| 5       | Mattanchery                | 5          | 5               | 2                   |
| 6       | Kochangadi                 | 3          | 4               | 2                   |
| 7       | Cheralayi                  | 3          | 3               | 1                   |
| 8       | Panayappilly               | 2          | 2               | 2                   |
| 9       | Chakkamadom                | 3          | 3               | 1                   |
| 10      | Karuvelippady              | 3          | 3               | 2                   |
| 11      | Thoppumpady                | 3          | 5               | 4                   |
| 12      | Tharebhagam                | 5          | 3               | 3                   |
| 13      | Kadebhagam                 | 5          | 5               | 5                   |
| 14      | Thazhuppu                  | 3          | 3               | 5                   |
| 15      | Eadakochi North            | 5          | 5               | 5                   |
| 16      | Edakochi South             | 4          | 4               | 4                   |
| 17      | Perumbadappu               | 5          | 4               | 5                   |
| 18      | Konam                      | 4          | 4               | 4                   |
| 19      | Palluruthy-Kacheripady     | 4          | 4               | 5                   |
| 20      | Nambyapuram                | 3          | 4               | 3                   |
| 21      | Pullardesam                | 4          | 4               | 3                   |
| 22      | Mundamvelly                | 4          | 3               | 3                   |
| 23      | Manassery                  | 4          | 4               | 5                   |
| 24      | Moolamkuzhy                | 2          | 3               | 2                   |
| 25      | Chullickal                 | 4          | 3               | 4                   |
| 26      | Nasrathu                   | 3          | 3               | 4                   |
| 27      | Fortkochi Veli             | 4          | 5               | 2                   |
| 28      | Amaravathy                 | 3          | 3               | 1                   |
| 29      | Island North               | 3          | 3               | 2                   |
| 30      | Island South               | 3          | 3               | 3                   |
| 31      | Vaduthala West             | 3          | 3               | 4                   |
| 32      | Vaduthala East             | 3          | 3               | 2                   |
| 33      | Elamakkara North           | 4          | 4               | 5                   |
| 34      | Puthukkalavattam           | 4          | 4               | 5                   |
| 35      | Ponekkara                  | 3          | 3               | 5                   |
| 36      | Kunnumpuram                | 5          | 5               | 5                   |
| 37      | Edappally                  | 5          | 5               | 5                   |
| 38      | Dhevankulangara            | 4          | 4               | 5                   |
| 39      | Karukappilli               | 4          | 3               | 4                   |
| 40      | Mamangalam                 | 3          | 3               | 5                   |
| 41      | Padivattam                 | 4          | 4               | 5                   |
| 42      | Vennala                    | 5          | 5               | 5                   |
| 43      | Palarivattam               | 3          | 3               | 5                   |
| 44      | Karanakkodam               | 3          | 3               | 5                   |
7 Discussion

Following the evolution of community resilience through the years, the author has focused on incorporating resilient criteria and highlighting areas that need addressing. This article introduces a detailed index and brings out several absent points from earlier established indices/frameworks. These include introducing modern-day technology to foster resilience, the inclusion of different sections of society such as religious, social, and even political institutions during and even before a disaster, and connectedness between various stakeholders. The need to adapt such cross-community cooperation to maximize opportunities by sharing resources and ideas is much acknowledged (Upadhyay and Sa-ngiamwibool 2021). The index considers the past and future conditions.
to support and enhance community resilience and indeed be able to achieve a ‘bounce forward’ approach. Several studies indicate a potentially important bond between resilience and context-based social cohesion (Upadhyay and Sa-ngiamwibool 2021).

The study, unlike others, has followed a very rigorous process in framing the index. Starting from the vast literature studied, focus group discussions, Delphi analysis with a high number of experts involved to select criteria, an exploratory study to capture the local responses and thoughts, an AHP study to assign weights to criteria, and finally, three statistically valid validations with the help of a case study of the index. However, the paper focuses only on the AHP analysis to the implementation part of the index as the previous works have already been explained in detail and published earlier in Ali and George (2021b) and Ali and George (2021c). Earlier frameworks/indices have been developed based on the Hyogo Framework for Action (2005–2015). However, the CRIF is based on its updated successor, the Sendai Framework (2015–2030). The Sendai Framework for Disaster Risk Reduction is based on four objectives that range from ‘understanding disaster risk’ to ‘building back better’. The CRIF criteria fall under these four objectives, respectively.

Most existing indices have selected their respective criteria either from literature studies or expert surveys, such as Delphi and AHP or even from a combination of both (Almutairi et al. 2020). However, such studies miss out on a critical element, including an empirical study. The CRIF index thus addresses this issue by incorporating an empirical study in formulating the index. Future studies in the disaster mitigation domain can follow a similar methodology or as applicable.

Most existing frameworks have derived criteria from the literature and other similar studies leaving behind an essential aspect of community resilience, local relevance. When it comes to community resilience, the crux of the framework/index should be the local applicability as they cannot be easily transferred from one place to another (Almutairi et al. 2020). There is no one methodology fits all solution. For example, take the case of this particular study itself. The governance rule followed in Kerala is mainly by two different parties with frequent changes in power due to the democratic nature and patterns of voting changes usually observed. The community of Kerala informally shows a voting pattern that is varying or cyclic and thus also brings out the importance of the need for the different political parties to work hand-in-hand to implement any valuable policies. The study area, the Kochi Municipal Corporation limits comprising of 74 wards, is governed by the United Democratic Front (UDF), the Left Democratic Front (LDF), the National Democratic Alliance (NDA), and other smaller parties. Under these, the UDF holds power in 30 wards, the LDF in 29 wards, the NDA in 5 wards, and other smaller parties presently have ten for the 2020–2025 term (One World 2021). Thus, when the governance duties are split across different parties, it is paramount to be on the same page, especially during a disaster. But suppose the same is compared to the community resilience framework for Saudi Arabia by Alshehri et al. (2015); in that case, the question of multiple parties involved in governance is entirely out of scope due to the rule of a monarch. Thus, such criteria are largely context-specific.

A consolidated study on different community resilience frameworks by Almutairi et al. (2020) shows the four primary criteria as ‘governance’, ‘social’, ‘infrastructure’, and ‘environment’. Our study partially follows this trend. The variation could be due to regional differences in the studies conducted. While ‘social’ and ‘governance’ criteria did top the charts, the CRIF had other plans for the remaining criteria leaving ‘infrastructure’ to be at the last position. Remember that this does not neglect the importance of the criteria ‘infrastructure’ and lies at the bottom only due to the relative nature of the AHP analysis.
Results from validation bring out several novel features. Even in places with low vulnerability, resilience levels were either moderate or high. This is a good outcome as vulnerable areas need to have higher community resilience to mitigate a disaster best. Validation of community resilience frameworks is also another aspect missing from existing frameworks/indices. This is important as only through validation can one determine how well the model functions (Eddy et al. 2012).

8 Conclusion

Studies on disaster risk reduction have at large focused on vulnerability and hazard aspects. But the trends have changed as it has come to the limelight that resilience, too, especially community resilience is necessary to rebuild an affected society to pre-disaster levels. The focus has thus shifted from tangibles to intangibles where stakeholders learn and adapt to community characters to cope with changes and incorporate modern ideas. Despite an overall commitment to sustainability, the advantage of community resilience is that it avoids the imposition of goals and stresses their emergence from local conditions. Community resilience should be focused on capacity development to meet social needs, social learning, and participatory deliberation to create new visions and values. Thus, the community resilience index for flood-prone areas in Kerala (CRIF) is created following these guidelines. Hence, local policymakers and authorities have at their disposal an index that can help them frame policies accordingly.

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References

Adekola J, Clelland D (2019) Two sides of the same coin: Business resilience and community resilience. J Conting Crisis Man 28:50–60. https://doi.org/10.1111/1468-5973.12275
Ali S, George A (2021) Social inclusivity: a case study on community resilience on Kerala Flood-2018. Lect Notes Civil Eng. Springer Singapore, Singapore, pp 109–131
Ali S, George A (2021b) Community resilience for urban flood-prone areas: a methods paper on criteria selection using the Fuzzy Delphi method. Contin Resil Rev 3:166–191. https://doi.org/10.1108/err-05-2021-0021
Ali S, George A (2021c) Fostering disaster mitigation through community participation—case of Kochi residents following the Kerala floods of 2018 and 2019. Nat Hazards. https://doi.org/10.1007/s11069-021-05058-0
Almutairi A, Moursheed M, Ameen RFM (2020) Coastal community resilience frameworks for disaster risk management. Nat Hazards 101:595–630. https://doi.org/10.1007/s11069-020-03875-3

Alshehri SA, Rezgui Y, Li H (2015) Disaster community resilience assessment method: a consensus-based Delphi and AHP approach. Nat Hazards. https://doi.org/10.1007/s11069-015-1719-5

Antronicco L, de Pascale F, Coscarelli R, Gullà G (2020) Landslide risk perception, social vulnerability and community resilience: the case study of Maiarella (Calabria, southern Italy). Int J Disast Risk Red. https://doi.org/10.1016/j.ijdrr.2020.101529

Apostolopoulos N, Newbery R, Gkartzios M (2019) Social enterprise and community resilience: examining a Greek response to turbulent times. J of Rural Stud 70:215–224. https://doi.org/10.1016/j.jrursstud.2018.03.017

Bathrellos GD, Karymbalis E, Skilodimou HD et al (2016) Urban flood hazard assessment in the basin of Athens Metropolitan city. Greece Environ Earth Sci. https://doi.org/10.1007/s12665-015-5157-1

Bosher L, Dainty A (2011) Disaster risk reduction and “built-in” resilience: towards overarching principles for construction practice. Disasters 35:1–18. https://doi.org/10.1111/j.1467-7717.2010.01189.x

Chattopadhyay S, Franke RW (2006) Striving for sustainability: environmental stress and democratic initiatives in Kerala. Concept Publishing Co., New Delhi

Cissé JD, Barrett CB (2018) The conjoint community resiliency assessment measure as a baseline for profiling and predicting community resilience for emergencies. Technol Forecast Soc. https://doi.org/10.1016/j.jtechfore.2012.12.009

Craft T (2019) Enabling resilience for pastoral communities in Ethiopia: PRIME impact and results report. Portland

Cutter SL, Barnes L, Berry M et al (2008) A place-based model for understanding community resilience to natural disasters. Global Environ Chang 18:598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013

DasGupta R, Shaw R (2015) An indicator based approach to assess coastal communities’ resilience against climate related disasters in Indian Sundarbans. J Child Fam Stud. https://doi.org/10.1007/s11852-014-0369-1

Eddy DM, Hollingworth W, Caro JJ et al (2012) Model transparency and validation: a report of the ISPOR-SMDM modeling good research practices task force-7. Med Decis Making 32:843–850. https://doi.org/10.1177/0272989X12454579

Erdogan SA, Šaparauskas J, Turskis Z (2017) Decision making in construction management: AHP and expert choice approach. Procedia Eng. https://doi.org/10.1016/j.proeng.2017.02.111

FAO (2016) RIMA-II: Resilience index measurement and analysis-II. UNDRR, Rome

Fazey I, Carmen E, Chapin FS et al (2018) Community resilience for a 1.5 °C world. Curr Opin Env Sust 31:30–40

Field Studies Centre B (2021) Spearman’s Rank Correlation Coefficient Rs and Probability (p) Value Calculator. https://geographyfieldwork.com/SpearmansRankCalculator.html. Accessed 13 October 2021

Frankenberger T, Mueller M, Spangler T, Alexander S (2013) Community resilience: conceptual framework and measurement. Westat, Rockville

GOAL (2016) Analysis of the resilience of communities to disasters (ARC-D) Toolkit User Guidance Manual. Dublin

Gupta S, Vijayvargy L (2021) Selection of green supplier in automotive industry: an expert choice methodology. IOP C Ser Earth Env 795:012036

Horníková N, Jurík L, Hrablik Chovanová H et al (2021) AHP method application in selection of appropriate material handling equipment in selected industrial enterprise. Wirel Netw 27:1683–1691. https://doi.org/10.1007/s11276-019-02050-2

Joerin J, Shaw R, Takeuchi Y, Krishnamurthy R (2012) Assessing community resilience to climate-related disasters in Chennai. India Int J Disast Risk Red. https://doi.org/10.1016/j.ijdrr.2012.05.006

Joerin J, Shaw R, Takeuchi Y, Krishnamurthy R (2014) The adoption of a climate disaster resilience index in Chennai. India Disast. https://doi.org/10.1111/dis.12058
Joseph JK, Anand D, Prajeesh P et al (2020) Community resilience mechanism in an unexpected extreme weather event: an analysis of the Kerala floods of 2018. India Int J Disast Risk Re 49:101741. https://doi.org/10.1016/j.ijdrr.2020.101741
Kirmayer LJ, Sehdev M, Whitley R et al (2009) Community resilience: models, metaphors and measures. Int J Indig Health 5(1):62–117. https://doi.org/10.3138/iijh.v5i1.28978
Kumar MD, Tandon S, Bassi N et al (2021) A framework for risk-based assessment of urban floods in coastal cities. Nat Hazards. https://doi.org/10.1007/s11069-021-05024-w
Kusumastuti RD, Viverita HZA et al (2014) Developing a resilience index towards natural disasters in Indonesia. Int J Disast Risk Re 10:327–340. https://doi.org/10.1016/j.ijdrr.2014.10.007
Lam RPK, Leung LP, Balsari S et al (2017) Urban disaster preparedness of Hong Kong residents: a territory-wide survey. Int J Disast Risk Re 23:62–69. https://doi.org/10.1016/j.ijdrr.2017.04.008
Lin HY, Lin SH, Chiu CY et al (2010) An AHP approach to industry-oriented management competence development in an institute of technology. World Trans Eng Technol Educ 8:339–343
Liu Y, Eckert CM, Earl C (2020) A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Syst Appl 161:113738
Longstaff PH, Armstrong NJ, Perrin K, Parker WM, Hidek MA (2010) Building resilient communities: a preliminary framework for assessment. Homeland Secur Affairs 6(3):1–23
Ma Z, Guo S, Deng X, Xu D (2021) Community resilience and resident's disaster preparedness: evidence from China's earthquake-stricken areas. Nat Hazards. https://doi.org/10.1007/s11069-021-04695-9
Matarrita-Cascante D, Trejos B, Qin H et al (2017) Conceptualizing community resilience: Revisiting conceptual distinctions. Commun Dev J 48:105–123. https://doi.org/10.1080/15575330.2016.1248458
Mayunga JS (2007) Understanding and applying the concept of community disaster resilience: a capital-based approach. Summer academy for social vulnerability and resilience building, pp. 1–16
Ministry of Earth Sciences G of I (2019) India Meteorological Department. https://mausam.imd.gov.in. Accessed 16 June 2021
Lam NNS, Reams M, Li K, Li C, Mata LP (2016) Measuring community resilience to coastal hazards along the Northern Gulf of Mexico. Nat Hazards Rev 17(1):04015013. https://doi.org/10.1061/(asce)nh.1527-6996.0000193
Nations U (2015) Sendai Framework for Disaster Risk Reduction 2015 - 2030. Geneva
One World (2021) Kochi corporation ward councillors list 2021. https://www.oneworld.website/keralapanchayatelection2020/kerala-corporation-election-2020-results/kochi_municipal_corporation/divisions-map/. Accessed 15 October 2021
Paton D (2006) Disaster resilience: integrating individual, community, institutional and environmental perspectives. Disaster resilience: An integrated approach
Paton D, Johnston D (2001) Disasters and communities: vulnerability, resilience and preparedness. Disaster Prev Manag 10:270–277. https://doi.org/10.1108/eum00000000005930
Rand (2021) Community resilience. https://www.rand.org/topics/community-resilience.html. Accessed 10 September 2021
Rozos D, Bathrellos GD, Skillogdimou HD (2011) Comparison of the implementation of rock engineering system and analytic hierarchy process methods, upon landslide susceptibility mapping, using GIS: a case study from the Eastern Achaia County of Peloponnesus. GREECE Environ Earth Sci. https://doi.org/10.1007/s12665-010-0687-z
Saaty TL (2002) Decision making with the analytic hierarchy process. Sci Iran 9:83–98. https://doi.org/10.1504/ijssci.2008.017590
Saaty TL (1990) How to make a decision: The analytic hierarchy process. Eur J Oper Res 48:19–43. https://doi.org/10.1016/0377-2217(90)90057-1
Saaty TL, Vargas LG (2012) The possibility of group choice: pairwise comparisons and merging functions. Soc Choice Welfare 38:481–496. https://doi.org/10.1007/s00355-011-0541-6
Sanneh ES, Hu AH, Hsu CW, Njie M (2014) Prioritization of climate change adaptation approaches in the Gambia. Mitig Adapt Strat Gl 19:1–16. https://doi.org/10.1007/s11027-013-9465-z
Shapira A, Simcha M (2009) AHP-based weighting of factors affecting safety on construction sites with tower cranes. J Constr Eng Manag 135:307–318. https://doi.org/10.1061/(asce)0733-9364(2009)135:4(307)
Sowmya K, John CM, Shrivasthava NK (2015) Urban flood vulnerability zoning of Cochin City, southwest coast of India, using remote sensing and GIS. Nat Hazards 75:1271–1286. https://doi.org/10.1007/s11069-014-1372-4
The World Bank (2018) Kerala Post Disaster Needs Assessment- Floods and Landslides August 2018. Thiruvananthapuram
United Nations (2005) International Strategy for Disaster Reduction Hyogo Framework for Action 2005–2015: Building the Resilience of Nations. World Conference on Disaster Reduction (A/CONF206/6)

Upadhyay A, Sa-ngiamwibool A (2021) A systematic literature review of community disaster resilience: main and related research areas and agendas. Contin Resil Rev. https://doi.org/10.1108/CRR-03-2021-0011

van de Pas R, Ashour M, Kapilashrami A, Fustukian S (2017) Interrogating resilience in health systems development. Health Policy Plann. https://doi.org/10.1093/heapol/czx110

Wedley WC (1990) Combining qualitative and quantitative factors-an analytic hierarchy approach. Socio Econ Plan Sci 24:57–64. https://doi.org/10.1016/0038-0121(90)90028-6

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