RESILOC

*Resilient Europe and Societies by Innovating Local Communities*

| Grant Agreement No. | | 833671 | |
|---|---|---|---|
| **Start date** | 01.06.2019 | **End date** | 30.11.2022 |

# D3.1 – RESILOC Resilience Indicators

Due date of deliverable: 31/03/2021

Submission date: 02/02/2022

Western Norway Research Institute, Norway

| Revision | Organization & Person | Date |
|---|---|---|
| Written by | WNRI, Rajendra Akerkar | 28/01/2022 |
| Checked and approved by | NKUA, Vassilis Papataxiarhis | 31/01/2022 |
| Validated and released by | FhG, Karsten Uhing | 02/02/2022 |

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 833671

# I. Deliverable Information

| | |
|---|---|
| **Deliverable Number** | D3.1 |
| **Work Package** | WP3 |
| **Date of Issue** | 02/02/2022 |
| **Version Number** | V7.0 |
| **Nature of Deliverable** | Report |
| **Dissemination Level (PU / RE / CO)** | PU |

| | |
|---|---|
| **Author(s)** | Uberto Delprato (IES); Joe Cullen (TIHR), Thomas Spielhofer (TIHR); Daniele Del Bianco (ISIG); Rajendra Akerkar (WNRI); Nadia Miteva (BILSP); Zlatka Gospodinova (BILSP) |
| **Keywords** | Resilience indicators, community resilience, conceptual framework, resilience indicators matrix. |

**Abstract**

The deliverable takes the outcome of the work carried out in the 'Studies' phase of the RESILOC project – the learning derived from studies involving literature reviews, expert interviews, a survey of citizens and case studies – and applies these results to elaborate a framework, methodology and tools to enable communities to self-assess their resilience 'assets' and to support them to develop strategies to increase their resilience going forward. The building blocks of this tool are a set of 'indicators', and associated 'proxies', to measure community resilience. This 'matrix' of indicators and proxies is the core output of Task 3.1 and the focus of this Deliverable. The matrix contains a total of 70 indicators and 260 associated proxy measures across 6 resilience dimensions: Disaster Risk Reduction (DRR), Economic, Environmental, Governance, Infrastructure, and Social. The next steps in the ongoing evolution and application of the matrix entail further validation of the matrix in RESILOC Task 3.2.

# II. Document History

| Date | Version | Modified by (first name, name, organization) | Remarks |
|---|---|---|---|
| 28.09.2020 | 0.9 | Hoang Long Nguyen, WNRI | Literature review |
| 21.02.2021 | 1.0 | Uberto Delprato, IES | Introduction of the RESILOC framework |
| 21.03.2021 | 1.1 | Uberto Delprato, IES | Progressive inclusion of sections by T3.1 partners |
| 22.04.2021 | 1.2 | Uberto Delprato, IES | Draft for review |
| 13.12.2021 | 2.0 | Thomas Spielhofer, TIHR | Table of contents |
| 21.12.2021 | 3.0 | Rajendra Akerkar, WNRI<br>Joe Cullen, TIHR<br>Salvatore Marchese, IES<br>Zlatka Gospodinova, BILSP<br>Daniele Del Bianco, ISIG<br>Marco Romano, UNICT | First draft of the resilience indicators |
| 07.01.2022 | 3.1 | Joe Cullen, TIHR<br>Thomas Spielhofer, TIHR | Completion of general sections and methodology |
| 11.01.2022 | 4.0 | Thomas Spielhofer, TIHR | Completion of indicators for social dimension |
| 12.01.2022 | 4.1 | Uberto Delprato, IES | Completion of indicators for DRR dimension |
| 12.01.2022 | 5.0 | Riccardo Laterza, ISIG | Completion of indicators for governance dimension |
| 12.01.2022 | 5.1 | Uberto Delprato, IES | Formating and editing |
| 12.01.2022 | 5.2 | Nadejda Miteva, BILSP | Completion of indicators for infrastructure dimension |
| 12.01.2022 | 5.3 | Hoang Long Nguyen, WNRI | Completion of indicators for environmental dimension |
| 14.01.2022 | 5.4 | Uberto Delprato, IES<br>Marco Romano, UNICT | Completion of indicators for economical dimension |
| 14.01.2022 | 6.0 | Karsten Uhing, FhG | Editing and graphics |
| 17.01.2022 | 6.1 | Oliver Ditz, FhG | Proof reading and editing |
| 19.01.2022 | 6.2 | Rajendra Akerkar, WNRI<br>Hoang Long Nguyen, WNRI | Minor amendments |

| | | | |
|---|---|---|---|
| | | Thomas Spielhofer, TIHR<br>Nadejda Miteva, BILSP | |
| 20.01.2022 | 6.3 | Helena Marruecos Clemente, FhG<br>Cornelia Reimoser, FhG | Ethics check |
| 24.01.2022 | 6.4 | Karsten Uhing, FhG | Editing and graphics |
| 27.01.2022 | 6.5 | Joe Cullen, TIHR<br>Uberto Delprato, IES | Improvements in conclusions |
| 28.01.2022 | 6.6 | Thomas Spielhofer, TIHR<br>Nadejda Miteva, BILSP | Minor amendments |
| 31.01.2022 | 6.7 | Uberto Delprato, IES | Graphics added, overall review |
| 01.02.2022 | 6.8 | Uberto Delprato, IES<br>Hoang Long Nguyen, WNRI<br>Nadejda Miteva, BILSP<br>Joe Cullen, TIHR<br>Karsten Uhing, FhG | Minor amendments after quality assurance |
| 02.02.2022 | 7.0 | Karsten Uhing, FhG | Ready for submission |

# III. Table of Contents

# IV. List of Figures

# V. List of Tables

# VI. List of Acronyms

| Acronym | Meaning |
|---|---|
| ARC-D | Analysis of Resilience of Communities to Disasters |
| BILSP | Balkan Institute for Labour and Social Policy |
| BREEAM | Building Research Establishment Environmental Assessment Method |
| BRIC | Baseline Resilience Indicators for Communities |
| CARRI | Community And Regional Resilience Initiative |
| CART | Communities Advancing Resilience Toolkit |
| CDCRF | Climate-related Disaster Community Resilience Framework |
| CDRI | Community Disaster Resilience Index |
| CoBRA | Community Based Resilience Analysis |
| CoE | Council of Europe |
| CCRAM | Conjoint Community Resilience Assessment Measurement |
| CRDSA | Community Resilience to Disasters Saudi Arabia |
| CRI | City Resilience Index |
| CRS | Community Resilience System |
| D | Deliverable |
| DROP | Disaster Resilience of Place |
| DRR | Disaster Risk Reduction |
| EC | European Commission |
| ECA | Electricity Critical Asset |
| EU | European Union |
| EUROSTAT | European Statistical Office |

| | |
|---|---|
| EW | Early warning |
| EWS | Early Warning Systems |
| FCR | Framework for Community Resilience |
| FRMC | Flood Resilience Measurement for Communities |
| FRMT | Flood Resilience Measurement Tool |
| GA | General Assembly |
| GDP | Gross domestic product |
| GDPR | General Data Protection Regulation |
| GEDI | Global Entrepreneurship and Development Index |
| GEM | Global Entrepreneurship Monitor |
| IES | Intelligence for Environment and Security Solutions |
| IFRC | International Federation of Red Cross and Red Crescent Societies |
| IMF | International Monetary Fund |
| ISIG | Istituto di Sociologia Internazionale di Gorizia |
| KOM | Kick Off Meeting |
| LEED | Leadership in Energy and Environmental Design |
| LRT | Local resilience team |
| MRT | Middle Range Theories |
| NaHRSI | Natural Hazard Resilience Screening Index |
| NGO | Non-governmental organisation |
| NORADAPT | Norwegian Centre on Sustainable Climate Change Adaptation |
| NUTS2 | Nomenclature of territorial units for statistics |
| NZRI | New Zealand Resilience Index |
| Obj. | Objective |

| | |
|---|---|
| OECD | Organisation for Economic Co-operation and Development |
| PD | Personal data |
| PO | Project officer |
| PPCS | Purchasing power consumption standard |
| RCA | Rail critical asset |
| REDi | Resilience-based Earthquake Design Initiative |
| RELi | Resilience rating system called RELi |
| RESILENS | Realising European ReSILiencE for Critical INfraStructure project |
| RM | Resilience Matrix |
| SCCN | School-Community Collaborative Network |
| SCOPD | Special categories of personal data |
| SMART | Specific, measurable, attainable, relevant, time bound |
| SMS | Scientific Methods Scale |
| T | Task |
| TA | Territorial Authority |
| TEA | Total early-stage Entrepreneurial Activity |
| THRIVE | Tool for Health and Resilience In Vulnerable Environments |
| TIHR | Tavistock Institute of Human Relations |
| UNDP | United Nations Development Programme |
| UNDRR | United Nations Office for Disaster Risk Reduction |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNISDR | United Nations Office for Disaster Risk Reduction |
| USAID | U.S. Agency for International Development |
| WNRI | Western Norway Research Institute |

| | |
|---|---|
| WP | Work Package |
| ZFRA | Zurich Flood Resilience Alliance |

The terminology used within this report is defined within the Base and Project Glossaries[1]. The terms and phrases used within this document have the meanings described by the glossary unless explicitly described otherwise in the relevant text.

[1] https://www.resilocproject.eu/publication/

# 1 Document Summary

This Deliverable – D3.1: RESILOC Resilience Indicators – presents the results of the initial Task implemented in work package 3 of the project (Task 3.1: Definition of resilience indicators and matrix). Task 3.1 and D3.1 take the results of the work carried out in the project 'Studies' phase – the learning derived from studies involving literature reviews, expert interviews, a survey of citizens and case studies – and apply these results to provide a framework, methodology and tools to enable communities to self-assess their resilience 'assets' and to support them to develop strategies to increase their resilience going forward. The building blocks of this tool are a set of 'indicators', and associated 'proxies', to measure community resilience. This 'matrix' of indicators and proxies is the core output of Task 3.1 and the focus of this Deliverable.

The work carried out in Task 3.1 to produce this deliverable involved the following activities: developing an approach and methodology to produce the Resilience Indicators Matrix; validating the approach and methodology through a review of the literature on resilience assessment and working with users to pilot one of the dimensions of the Resilience Indicators Matrix; applying the validated approach and methodology to collect data to populate the Resilience Indicators Matrix; and integrating the results of the data collection to produce a first consolidated draft of the RESILOC Resilience Indicators Matrix.

The conceptual framework that underpins the approach and methodology used to develop the RESILOC Resilience Indicators matrix draws on theory and practice in 'operationalisation' - the process through which abstract (fuzzy) concepts are translated into measurable variables and indicators. An initial 'grounding' literature review was carried out to validate the applicability and relevance of this conceptual framework to the resilience field. A key conclusion of this 'grounding' literature review is that assessment approaches based solely on 'indices' – which struggle to model the contextual variety of different local communities – or approaches based solely on 'scorecards' – which struggle to work effectively in strategic planning scenarios – will not support the RESILOC vision and its objectives. RESILOC's direction of travel should therefore adopt a 'flexible toolkit' approach to community resilience assessment.

Starting with the six 'dimensions of resilience' identified through WP2 of RESILOC, a set of indicators and proxies were developed for each dimension using the 'operationalisation' methodology. The indicators developed were then validated through desk research, involving, firstly, a second round of focused literature reviews carried out for each of the six dimensions to assess their relevance and appropriateness, and, secondly an assessment of the quality of the indicators using a set of Measurement Quality Criteria. The desk research validation was supplemented with user-focused co-design, involving feedback workshops with user groups.

The outcome of this implementation process is the RESILOC Resilience Indicators matrix. This contains a total of 70 indicators and 260 associated proxy measures across 6 resilience dimensions: Disaster Risk Reduction (DRR), Economic, Environmental, Governance, Infrastructure and Social.

The next steps in the ongoing evolution and application of the matrix entail further validation of the matrix in RESILOC Task 3.2 – Definition of new strategies for improving resilience. Task 3.2 will also involve working with users in 'co-design' mode to explore how the matrix can be used to apply the tool in co-design activities to identify new strategies to improve community resilience. Further piloting and validation of the matrix will be implemented through the field trials in work package 5.

# 2 Background

## 2.1 RESILOC Indicators in the Overall Context of the Project

The overall objective of RESILOC is to identify new strategies to better prepare communities against disasters and to better support European and international policies on resilience in societies. In order to achieve this overall objective, RESILOC has five specific objectives. These are incorporated within an integrated over-arching conceptual framework that describes the progressive evolution of the project over its life cycle as a series of phases or 'modes' that cover studies, methods, software and trials. Each of these modes links to the project implementation plan, which defines the operational activities – work packages – through which the project objectives are achieved. Figure 1 illustrates this over-arching methodological framework and the inter-relationships between objectives, phases/modes and project activities.

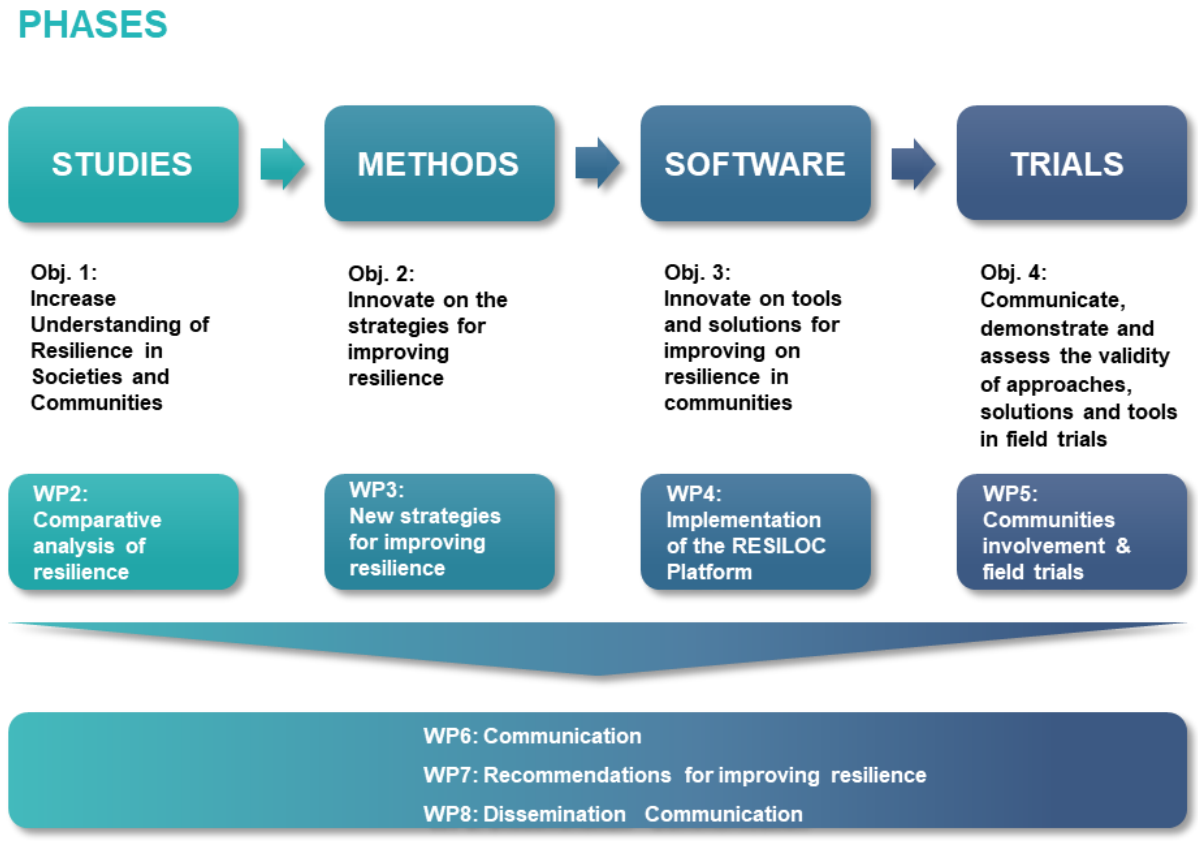



*Figure 1 RESILOC conceptual framework*

As Figure 1 shows, RESILOC's specific objectives are:

1. Increase the understanding of resilience in societies and local communities – it does this through studies involving literature reviews, expert interviews, a survey of citizens and case studies, to add to the knowledge base on resilience (work package 2)
2. Innovate on the strategies for improving resilience – it does this by using the results from Objective 1 to develop indicators to measure community resilience; designing an interactive tool for knowledge sharing and developing processes to engage citizens in the co-creation of the RESILOC tools (work package 3)

3. Innovate on tools and solutions for improving on resilience in communities - it does this by developing two main software tools – an Inventory of information on resilience and a Cloud-based platform to support the utilisation of this information to create local projects that increase community resilience (work package 4)
4. Communicate, demonstrate and assess the validity of approaches, solutions and tools in field trials - it does this by implementing field trials of the tools in four different locations (work package 5)
5. Have an impact and define concrete steps towards a more resilient society - it does this through an integrated communication, dissemination and sustainability plan that includes production of scientific papers; participation in conferences; meetings and workshops with policymakers and wide dissemination of recommendations for improving community resilience (work packages 6, 7 and 8).

This Deliverable – D3.1: RESILOC Resilience Indicators – presents the results of the initial Task implemented in work package 3 of the project (Task 3.1: Definition of resilience indicators and matrix). As shown in Figure 1, Task 3.1 and D3.1 are located within the 'Methods' phase of the project and aim to contribute to RESILOC Objective 2: Innovate on the strategies for improving resilience. They build a bridge between the 'Studies' phase of the project and the 'Software' phase. They take the results of the work carried out in the Studies phase – the learning derived from studies involving literature reviews, expert interviews, a survey of citizens and case studies – and apply these results to provide a framework, methodology and tools to enable communities to self-assess their resilience 'assets' and to support them to develop strategies to increase their resilience going forward. The building blocks of this tool are a set of dimensions, indicators, and associated 'proxies', to measure community resilience. This 'matrix' of dimensions, indicators and proxies is the core output of Task 3.1 and the focus of this deliverable. The matrix provides one of the key foundations of the RESILOC platform implemented in WP4, and which will subsequently be validated in a series of field trials involving local communities in WP5.

## 2.2 The 'Presenting Problem' and D3.1's Contribution to It

As highlighted in Section 2.1 above, Deliverable 3.1 – and the set of dimensions and indicators presented below in this deliverable – plays a pivotal role in RESILOC. A useful way of describing this role is to situate the deliverable, and Task 3.1, within the project 'Theory of Change'. Theory of Change is a way of describing a project's 'story' as it progresses from a 'presenting problem' to the expected change it hopes to make at the end of its journey and beyond - i.e., the project's expected 'impacts' (Weiss, 1995; Sullivan and Stuart, 2006).

Connecting the presenting problem and expected impacts are:

- Activities – actions carried out by RESILOC, that lead to …
- … Outputs – things that are produced by these activities, that lead to …
- … Immediate outcomes – changes in awareness and knowledge, that lead to …
- … Intermediate outcomes – changes in behaviour and structures.

Underlying this 'change journey' are 'theories' (assumptions and hypotheses), for example:

- A theory of what is causing the 'presenting problem'
- A theory of what is needed to bring about the desired solution

- Assumptions that if we take Action 'X', this will produce Output 'Y', which will then lead to Outcome 'Z'.

A simplified Theory of Change for RESILOC is presented in Figure 2 below.

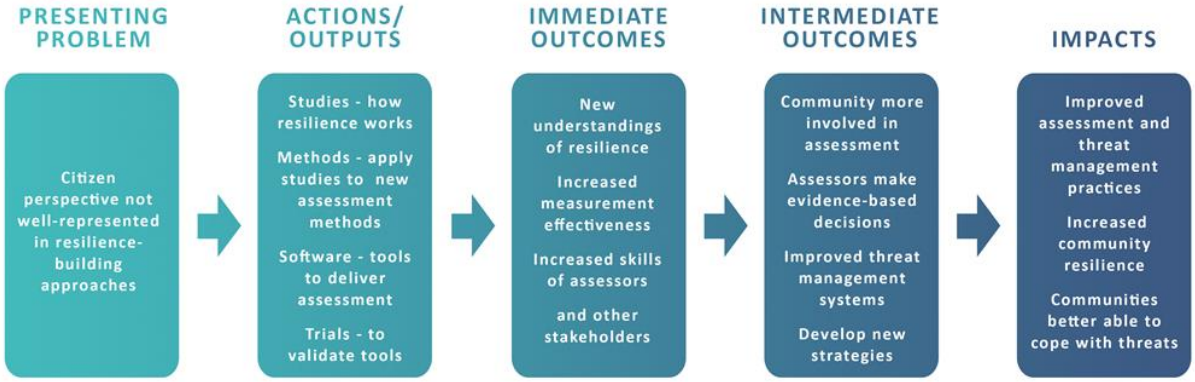



*Figure 2 RESILOC's 'Theory of Change'*

It should be emphasised that Figure 2 is for illustrative purposes. It simplifies the RESILOC 'change story' as a linear progression, from the presenting problem the project wants to address to the changes it hopes to make to that problem at project end. In reality, this change story is cyclical in nature, as the project evolves through several iterations and through different trajectories. As it evolves, interactions between the resources provided by the project, how these are used by actors in the project, and how these actions then lead to changes in behaviours and structures – in other words the project 'mechanisms' (Astbury and Leeuw, 2010) – create feedback loops that affect the change journey itself.

As Figure 2 shows, the 'presenting problem' RESILOC aims to address can be briefly summarised as follows:

> *Traditional threat management approaches struggle to cope with complex and unpredictable multiple hazard situations. This is partly because the 'human' element and the citizen perspective are not sufficiently well-represented in threat management strategies.*

The expected change RESILOC hopes to make to this presenting problem is to deliver new strategies for community resilience that improve understandings of resilience and which, ultimately, when applied in practice, increase community resilience before, during and after threat situations, and therefore improve the effectiveness of threat management strategies.

The RESILOC 'change journey' – from the 'presenting problem' it aims to address at project start, to the change it expects to make to this problem at project end – the project's key 'impacts' – can be defined by four main stages, each of which entails implementing specific activities that lead to the production of key project outputs (as noted above in Section 2.1):

- **Studies** – entail collecting and analysing information to define a classification for the functions that are critical to the resilience of communities. They feed into:
- **Methods** – the definition of a set of new methods and strategies to allow the assessment of community resilience to be carried out, together with 'what-if' simulations of what is likely to happen to the resilience of a community if certain measures are taken. They in turn feed into:
- **Software** – the development of two software tools: the RESILOC Inventory (a tool for collecting and classifying data on the resilience of cities and local communities) and the

RESILOC cloud-based Platform (a tool for assessing the resilience profile of any participating city or community, which in turn provides support for developing localised strategies and verifying their impacts on the resilience of the community)

- **Trials** – the tools are then assessed and validated in desk-top exercises and field trials that involve communities and other stakeholders. The results of the trials feed into the production and dissemination of guidelines and recommendations to support the free use of the tools throughout the EU and beyond.

The 'Methods' element of this journey builds on the results of the research carried out in the 'Studies' phase of the project. This research combined collecting information about approaches to resilience; exploring how citizens perceive risk in their community and how this relates to their awareness of local hazards and expected behaviours; reviewing relevant approaches and methodologies for data collection and segmentation and evaluating approaches to support greater stakeholder participation – especially citizen participation – in community resilience assessment and strategy-building. Taken together, the results of the studies have contributed to the work carried out in the 'Methods' phase of the project in the following ways:

- by grounding the project's definition of 'community resilience' within an evidence-based conceptual framework, so as to set the parameters for the purposes and scope of the tools developed and validated in the 'Software' and 'Trials' phases
- by furthering our understanding of the relationship between 'perceived risk', 'preparedness', 'vulnerability' and 'resilience', and hence how to better define, describe and assess these key elements and their inter-relationships within the context of developing the RESILOC tools
- by capturing the 'lived experience' of users with regard to threats, so as to help us better define the appropriate scenarios of use for the RESILOC tools; user expectations of the purposes, utility and benefits of the tools and the potential contribution users could make to providing data input to the tools
- by providing an over-arching framework for defining the range of dimensions, indicators and proxies that needs to be incorporated within the RESILOC 'Inventory', as well as a specification for the RESILOC 'Inventory' and a supporting element for the design of the RESILOC 'Cloud Platform'.

Taking these results forward, the 'Methods' phase of the project covers the work carried out in work package 3. The objectives of work package 3 are:

- Drawing on the results of the studies carried out in work package 2, to develop a framework, methodology and tool to self-assess community resilience, including defining the indicators and proxies needed to measure it – the RESILOC 'Indicators matrix' – based on the resilience 'dimensions' identified through the 'Studies' phase
- To validate the tool with stakeholders, including local communities
- To apply the tool in 'co-design' activities with stakeholders in order to define new strategies for improving community resilience, including formulating actions to mitigate and overcome identified resilience gaps and shortcomings
- To explore the use of supplementary data – for example from remote sensors and social media – to be integrated in future technical adaptations and field trials of the RESILOC tools

- To feed the results derived from work package 3 – including the results of validating the resilience indicators – into a set of specifications for the RESILOC platform.

The activities carried out to deliver these objectives are summarised in Figure 3.

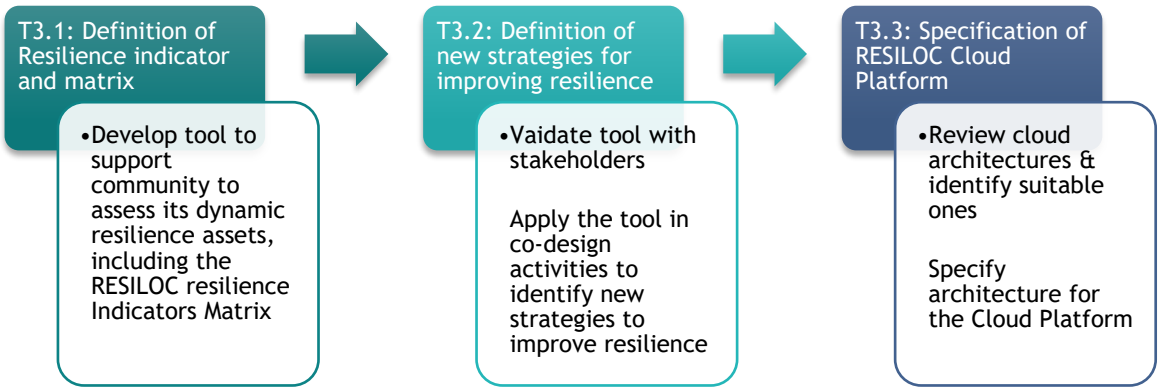



*Figure 3 RESILOC Work Package 3 tasks*

This Deliverable - D3.1: RESILOC Resilience Indicators – reports on the work carried out in Task 3.1 and presents the main output of this work – the RESILOC Resilience Indicators Matrix. The work involved the following activities:

- Developing an approach and methodology to produce the Resilience Indicators Matrix
- Validating the approach and methodology through, firstly, a review of the literature on resilience assessment and, secondly, working with users to pilot one of the dimensions of the Resilience Indicators Matrix
- Applying the validated approach and methodology to collect data to populate the Resilience Indicators Matrix
- Integrating the results of the data collection to produce the final Resilience Indicators Matrix.

## 2.3 Structure and Contents of This Deliverable

This Deliverable is set out as follows:

- Following this Background, Section 3 sets out the conceptual approach and methodology applied to produce the Resilience Indicators Matrix
- Section 4 describes a review of the literature on resilience assessment frameworks and tools that was carried out to validate the overall conceptual approach and methodology and adapt it to the resilience domain. Additional focused literature reviews were subsequently carried out for each of the dimensions in the Indicators matrix (reported on in Section 6)
- Section 5 describes how the approach and methodology was validated with the 'social' dimension of the matrix and the involvement of users
- Section 6 provides a brief description of how the validated approach and methodology was applied to collect data to develop indicators and proxies for each dimension in the Resilience Indicators matrix

- Section 7 presents the results of the implementation of the approach and methodology – i.e., the lists of indicators and proxies developed for each dimension in the matrix
- The concluding section – Section 8 – covers the next steps, including measures for applying the Resilience Indicators matrix in work package 4 – implementation of the RESILOC platform – and work package 5 – communities involvement and field trials
- Annex I presents in more detail the literature review referred to in Section 4.

# 3 Developing RESILOC Indicators: Approach and Methodology

## 3.1 Conceptual Framework

To work well, the RESILOC resilience indicators need to accurately and meaningfully assess resilience. This presents a challenge from the outset. Resilience is a 'fuzzy concept'. If there's one thing that's agreed about measuring it, it's that there's no agreement (Kuhlicke et. al., 2020). Making the transition from a concept that no-one agrees on to a practical tool that users trust will credibly measure the concept requires operationalization of that concept. The starting point for developing the conceptual framework for the RESILOC Resilience Indicators matrix therefore goes back to first principles of 'operationalisation'. Operationalisation, simply put, is the process through which abstract (fuzzy) concepts are translated into measurable variables and indicators (Jonker and Pennink, 2010). Operationalisation involves the following steps (Sarantakos, 1998; Bryman, 2012; Ragin, 2014; Allen, 2017).

- Identify the main concept(s) of interest
- Break down the concept(s) into component parts, making 'rational' decisions legitimating the choices
- For each component, choose variables that can be measured
- For each variable, choose relevant indicators that can measure its attributes and the measures to be used
- Apply criteria to assess the 'quality' of these measures
- Validate all of the above through comparison with state of the art and testing with experts, users and other stakeholders.

To do this requires:

- Clear definitions of the elements we are using to construct the resilience indicators and matrix and the inter-relationships between these elements
- A credible and robust methodology to construct the indicators and matrix
- Methods and tools to assess whether the indicators are fit for purpose
- A validation plan.

### 3.1.1 Definitional Constructs and Their Relationships

Figure 4 shows the key elements that need to be considered and defined in the operationalization process and the relationships between them. To a large extent these elements represent a hierarchical process that transitions from the highest level of abstraction – the concept – and narrows down to elements that are grounded in empirical reality – measures and what they reveal.

At the top of the hierarchy is the ***concept***. The concept is defined as the abstract idea or phenomenon of interest, variously described as "abstract categories of behaviours, attitudes or characteristics" (de Vaus, 2002), and "a generally accepted collection of meanings or characteristics associated with certain events, objects, conditions, situations, and behavior" (Leggett, 2011). It is assumed as a given that this over-arching concept for the purposes of RESILOC is defined as 'resilience'.

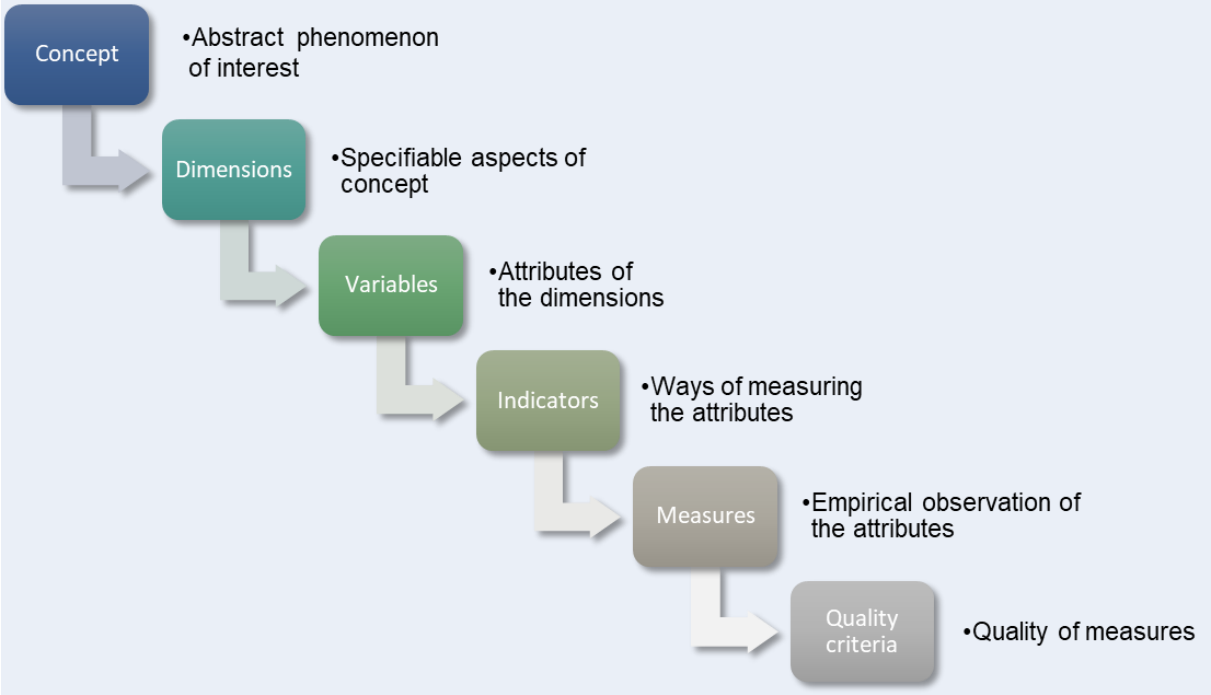



*Figure 4 Definitional constructs and their relationships*

This concept is then broken down into ***'dimensions'***, defined as 'a specifiable aspect of a concept' (He and van de Vijver, 2012). A major problem in operationalization is to ensure that dimensions adequately reflect the theoretical concept. The choice of dimensions is ultimately a subjective decision based on knowledge and experience – which needs to be backed up as far as possible by evidence, for example through a review of state of the art. In RESILOC, through the work carried out in work package 2, six dimensions were identified, covering Social, Economic, Infrastructure & Networks, Governance, DRR and Environment.

Each dimension needs to be unpacked in relation to its constituent variables, which define the properties or attributes of the dimension that can subsequently be empirically assessed (Bryman, 2012). Variables should be seen as the precursor to this assessment since they do not directly measure the dimension but define and describe the characteristics that need to be measured. For each variable specific ***indicators*** need to be defined that reflect its attributes. Indicators are ways of measuring variables – defining an "empirical measurement of a variable" (Sarantakos, 1998). They represent operational definitions of a concept and its dimensions that allow their measurement.

However, for practical purposes, in terms of developing the RESILOC Resilience Indicators Matrix, it is proposed that the 'variable' component of the Matrix is 'hidden' at the operational level. As noted above, variables define the properties or attributes of a dimension that can subsequently be empirically assessed. They are the precursor to this assessment – but they do not directly measure the dimension. Since they do not play a role in the actual assessment of resilience, there is no reason why users of the RESILOC self-assessment tool – which depends on the indicators matrix to work effectively – should be expected to engage with them. Incorporating variables within the tool is likely to add a layer of complexity that potentially could create 'user confusion', increase the time and resources needed to work with the tool and, subsequently, reduce the motivation of users to work with it (Iyengar and Leppar, 2000). Variables can be a useful way of thinking about how indicators are conceptually related to each other within the context of a dimension, but they have limited utility in terms of how the RESILOC tools work on the ground.

In order to make indicators practically operational, they need to be converted into ***measures*** – defined as empirical observations of the real world for the purposes of describing the attributes composing the variable (Bulmer, 2001). Selection of appropriate measures depends on three key factors: the purposes of measurement; the attributes of the variables and indicators to be measured, and the context in which the measurement takes place. Unsurprisingly, there is considerable variation in the literature on the different types of measure that can be used, how they can be used and when. Definitions of these different types vary and the terms are often used interchangeably (Azadzadeh et. al., 2017). Broadly, the literature presents measurement in terms of a hierarchy of robustness, much as how research methodologies in general are presented, for example as in the Maryland Scientific Methods Scale (SMS) which progresses from the lowest level, describing evaluations based on simple cross-sectional correlations, to the highest level based on randomised control trials (Sherman et. al., 1997). Measures based on directly observable characteristics – for example the height of a high-rise building – take precedence over measures based on indirectly observable characteristics – for example the level of trust in a community. In the resilience field, three main types of operational measures can be identified: common context measures – reflecting values that are quantified against a standard (OECD, 2002); metrics – composite measures based upon two or more indicators or measures (USAID, 2009) and proxies – an approximation to a common context indicator which provides sufficient information to allow the assessment of a relevant contextual aspect (EC Directorate-General for Agriculture and Rural Development, 2016).

In reality, given the 'fuzziness' of the resilience concept, resilience assessment frameworks often incorporate all three types. As an example, the City Resilience Index (CRI) developed by Arup and supported by the Rockefeller Foundation uses four dimensions to represent resilience and a combined total of 52 indicators to assess these dimensions. The assessment is operationalized by combining two sets of measures. Assessors on the one hand score their city's resilience on a five-point scale for each indicator, reflecting its position on a 'best case' and 'worst case' scenario. On the other hand, they can quantify their city's resilience using quantitative metrics which allow them to establish a baseline, identify aspects of their resilience profile that may need strengthening, compare performance between jurisdictions and track their progress over time. These quantitative metrics are in fact proxies that are assigned by city assessors. (Arup, 2017).

The measures adopted and operationalized will only be as good as their ***quality***. In operationalization terms, quality focuses on the reliability and validity of measurements – ensuring the measures capture only the concept of interest, and that the data captured can be repeated, as well as the precision and accuracy of the information (Bryman, 2012). In the resilience field, quality of measurement has been neglected (Nardo et. al., 2008): "there is currently no quality assessment of composite indicators which has been cited as sufficiently comprehensive by multiple scholars within the literature" (Asadzadeh et. al., 2017).

However, three other aspects of quality need to be taken into consideration in addition to this 'technical' aspect. The first aspect is ***fitness for purpose***. This links to the 'technical aspect' described above but broadens its scope to explore the extent to which measures included in the resilience assessment framework can be efficiently and effectively operationalized. There are a number of ways of doing this – one of the most widely-used being the 'SMART' method – which assesses the extent to which indicators and their measures are Specific (to the concept being measured); Measurable (and unambiguous); Attainable (and sensitive); Relevant (and easy to collect); Time bound (Doran, 1981).

The second aspect is a ***normative*** one. Several reviews of the literature on resilience assessment frameworks highlight a tendency to embed normative values into resilience

indicators, so that the assessment process reflects a desired 'end state' to which users of the assessment tools should aspire. In the CRI case, the indicators developed for the assessment index integrate what are termed the seven qualities of resilient systems (e.g., robust, inclusive, flexible) that Arup's empirical research has identified as of vital importance. These qualities are seen as particular characteristics that cities need to acquire in order to be resilient. Similarly, the Flood Resilience Measurement Tool (FRMT) developed by the Zurich Flood Resilience Alliance uses five dimensions that reflect over-arching community 'capitals' – human, social, physical, natural, and financial – that link to the Sustainable Livelihood Framework and in turn can be mapped against the four properties of a resilient system: Robustness, Redundancy, Resourcefulness, and Rapidity (Campbell et. al., 2019). The UNDRR Disaster Resilience Scorecard for Cities is structured around UNDRR's 'Ten Essentials for Making Cities Resilient" which are themselves aimed at supporting the Sendai Framework for Disaster Risk Reduction: 2015-2030 (UNDRR, 2017).

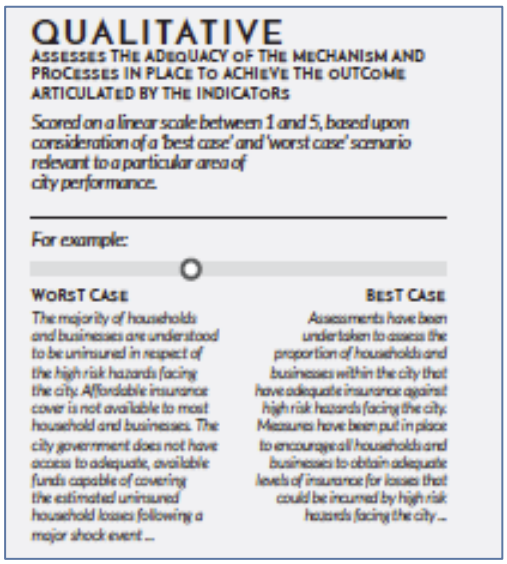
The third quality aspect has also been largely neglected in the resilience literature and signals a need for indicators to reflect – and measure – the embedded (or embodied) adaptive behaviours of community actors. Although it is possible to find references to grass roots engagement in the design of resilience assessment frameworks and tools (the Zurich FRMT, for example, involves users in both the design of the assessment framework and as trained practitioners working within communities with community stakeholders), there is little evidence that this involvement captures and represents community behaviours within the indicators and measures it uses to frame resilience. As has been argued in D.2.1, community engagement needs to move beyond just being involved and being counted towards dynamic representation of behavioural actions: "resilience is a dynamic process and measurement frameworks need conceptually (to) focus on transition from merely a pre-event inherent resilience (robustness) to a post-event adaptive capacity (transformation), and consideration of the term as both static results and dynamic processes" (Asadzadeh et. al., 2017).

Let's call this third aspect ***explanatory*** quality. It can be thought of as the other side of the 'normative' coin. If, as in the case of the Arup CRI framework, the 'qualities' embedded in the assessment indicators imply collective behaviours at the urban level that lead to a desired state of optimal resilience, then it follows that 'intentional' behaviours at the individual or community levels need to be reflected in the indicators applied in the RESILOC framework and how they are measured. So, an indicator that is designed to measure, say, civic engagement should reflect the behavioural attributes that are assumed to mediate progression towards a desired resilience end-state – for example the level of participation in community activities and events - and why this is likely to contribute to resilience.

To assess this explanatory quality, we need to consider the 'mechanisms' through which behaviour leads to resilience. In the evaluation field, mechanisms are defined as 'underlying entities, processes, or structures which operate in particular contexts to generate outcomes of interest' (Astbury and Leeuw, 2010). They specify the 'resources' available to actors to change their behaviour, and the 'reasoning' – the processes through which resources are applied to change awareness, attitudes and behaviours – which in combination lead to behavioural changes. The way the mechanism works depends on the 'context' in which it operates. There is always an interaction between context and mechanism, and that interaction is what creates outcomes: Context + Mechanism = Outcome. In research more broadly, mechanisms equate to 'middle range theories' (MRTs). As originally defined by Merton, MRTs are theories that lie between day-to-day analyses of life on the ground and grand all-inclusive theories that try to explain all observed uniformities of behaviour, social organization and social change (Merton, 1967). They allow us to generate propositions which account for a degree of regularity across time and place (Pawson, 2000). MRTs are always implicitly embedded in measures. For example, civic engagement as measured by the % of households participating in community

activities and events assumes that access to community activities and events (resources) will lead to increases in community engagement skills, increased awareness of threats and eventually to increased resilience (reasoning). Unveiling such MRTs that underlie measures is therefore crucial in determining whether these measures are effectively measuring resilience.

An example of how this might work is the Arup Cities Resilience Index (Figure 5).




As noted above, assessors score their city's resilience on a five-point scale for each indicator, reflecting its position on a 'best case' and 'worst case' scenario. The best- and worst-case scenarios are normative descriptions of the two polarities of a scale to measure the indicator '% of buildings with insurance cover for relevant high-risk hazards'. Both best- and worst-case scenarios are illustrated by a descriptive guideline that helps the assessor situate their city on the scale. Each description implicitly incorporates a 'mechanism' – or MRT about how insurance cover is expected to impact on resilience. In the worst case, a high level of uninsured buildings is assumed to pose a high risk in a disaster situation, which leads to reduced resilience.

*Figure 5 Implicit Medium Range Theories in the Arup Cities Resilience Index*

Parsons et al. (2016, p.5) have also developed a useful set of criteria which to assess the quality and relevance of indicators selected for inclusion:

| Criteria for indictor selection | Requirements |
|---|---|
| 1. The indicator reflects a justifiable element of natural hazard resilience | • The relationship between the indicator and natural hazard resilience has been verified in the academic/ professional literature |
| 2. The indicator can track change and variability in natural hazard resilience | • Change in the indicator can be determined and associated with change in resilience spatially and temporally |
| 3. The indicator is relevant to the scale(s) of assessment | • The indicator aligns with the scale at which the assessment is undertaken. There may be a requirement for an indicator to remain valid across scales (e.g. local to national). |
| 4. The indicator is measurable and readily interpretable | • The indicator is specific and precisely defined.<br>• The indicator is quantifiable and spatially referenced<br>• The indicator is easy to define, understand and communicate |
| 5. The measurement method for the indicator is robust | • Measurement is reliable (and verifiable) and representative of reality<br>• Measurement occurs regularly enough for the purpose<br>• Measurement is methodologically sound |
| 6. The indicator is achievable – data are available, accessible and cost effective | • Data are available at the required scales across most of the study area<br>• Data are readily available from secondary sources<br>• Data can be accessed within the cost and resource framework |

*Figure 6 Generalised criteria for indicator selection (Parsons et. al., 2016)*

We have developed an initial set of criteria to assess the measurement quality of the resilience indicators developed for the matrix, drawing on Figure 6, together with criteria that reflect

'normative' and 'explanatory' aspects. This will be further developed through co-design with users as part of Task 3.2, WP4 and WP5.

### 3.1.2 Implications for the RESILOC Indicators Matrix and Tools

Operationalising Resilience along the lines outlined above has an effect on the design of the RESILOC indicator matrix and, subsequently, the RESILOC tools. In essence, this marks a shift from a reductive to a co-created knowledge-based orientation. Measures are developed for each indicator, including, if appropriate common context indicators and metrics that are standard across communities. Common contextual indicators are quantifiable variables which are used to help describe and measure wider social, environmental, economic, physical, and demographic contexts in which a particular phenomenon is operating. They allow measurement of a phenomenon over space and/or time, so as to support comparison against a baseline (Hincks, 2014). It may be possible to develop a set of such indicators – and proxies – that can be applied at different scales and contexts across the spectrum of participating communities in RESILOC.

Most measures, however, are likely to be proxies which need to be developed through a co-creation process involving community decision-makers, trained practitioners and community representatives. The indicators and measures also need to be checked against RESILOC's technical, fitness for purpose, normative and exploratory quality criteria using a rigorous validation methodology, and the selection of each indicator needs to be supported through a clear MRT, which explains the proposed theory linking an indicator with an increase or decrease in community resilience at the local level.

## 3.2 Implementation Methodology

This section sets out the practical steps that needed to be taken by partners to develop the RESILOC Indicators matrix for the six dimensions, which include:

- The Disaster Risk Reduction (DRR) dimension
- The economic dimension
- The environmental dimension
- The governance dimension
- The infrastructure and networks dimension
- The social dimension.

Each dimension needed to be unpacked in relation to its constituent indicators and, in order to make them practically operational, proxies – defined as empirical observations of the real world for the purposes of describing the attributes composing each indicator (Bulmer, 2001) needed to be specified for each indicator. However, these were not meant to be exhaustive as they will need to be adapted to each community and each scenario and will be further developed during the trial phase (WP5).

Partners involved in developing the indicators were guided to adopt the following seven steps:

- **Step 1: Define the Dimension**. This involves exploring the particular aspect of resilience each dimension is intended to represent. The initial definition should be as specific as possible and detail the aspect of the concept that is to be operationalised – however, this initial definition subsequently needs to be refined once indicators have

been developed to ensure that the definition fits with the operationalisation of the dimension via said indicators.

- **Step 2: Develop and/or revise list of indicators**. This involves identifying the key properties or attributes of each dimension that can be empirically assessed. This can be done based on existing knowledge and experience as well as by reviewing the most recent draft of the six dimensions against the available evidence in the literature and to make an assessment of the relevance and appropriateness of these indicators: to identify any that should be discarded and whether there are gaps that need to be filled.
- **Step 3: Define each indicator**. The next step is to provide a definition of all indicators in such a way that they can be clearly linked with the overarching dimension and that they can be assessed on a qualitative or quantitative from scale, for example, from high to low, or from 1 to 5.
- **Step 4: Rationale for inclusion (MRT)**. This involves providing a clear rationale, where possible based on existing literature, on the reason for why this indicator has been included as a key property or attribute of this dimension. Ideally, this should draw on evidence from previous studies linking this indicator with higher or lower levels of resilience of a community.
- **Step 5**: **Operationalise indicators**. This involves providing some examples of proxies that could be used to measure or assess each indicator. Once again, these can be drawn from previous assessment frameworks, or by reviewing existing lists developed by the RESILOC project to date. The main purpose of these is to provide practical illustrations of how each indicator could be operationalised, depending on available data and disaster scenarios. These are not meant to be exhaustive. They will need to be adapted to each community and each scenario and will be further developed during the trial phase.
- **Step 6: Review the definition and indicators**. The next step is to review all the results of the five previous steps to ensure that the definition of the dimension fits with the indicators used to assess that dimension, and that definitions of the indicators are clear and fit with the proxy/measures included as examples.
- **Step 7**: **Complete summary table and commentary**. The final step is to complete the summary table (see below) to contain the definition of the dimension, each of the indicators alongside their definition and rationale for inclusion, and some example proxies. In addition, you will need to complete a short summary (around 1000 words) of the steps taken to identify the indicators and proxies and the main rationale for selecting them, as well as a list of all the documents reviewed (see Section 6 below).

The intended end result was information that could be used to complete the following table for each of the six dimensions.

*Table 1 A table template for dimension, indicator and proxy presentation*

| Definition: | | | |
|---|---|---|---|
| **Indicators** | **Description** | **Why is this important?** | **Example proxies** |
| | | | |
| | | | |

The following section provides an illustration of the process of developing an indicator and the intended end result of this process with reference to some of the indicators developed for the 'social dimension'.

### 3.2.1 Developing the Social Dimension Indicators

The social dimension was developed over several months by the Tavistock Institute with input from several other RESILOC partners – following the seven steps outlined above. It started from the initial definition of 'community resilience' provided in D2.1:

Community resilience refers to the capacities of local communities as complex systems (involving the actions and interactions of local agencies, citizens, the built environment and critical infrastructures) to mitigate, withstand, and recover from the impacts of a disaster or emergency, as well as to adapt or transform themselves to be less vulnerable to future disasters or emergencies.

#### 3.2.1.1 Step 1: Define the Dimension

The following definition of the social dimension was developed – initially based on a review of the literature, the writing of Deliverable D2.1 and our own experience of assessing resilience in social contexts (see Section 6.1. for a more detailed account of this process). This was then revised after developing and revising the indicators following the validation task performed in collaboration with users:

"This dimension describes the social capacities of a community that help to increase its resilience to different types of disasters. This includes the social relationships and networks aiding cooperation, solidarity, and trust at the local level, and the extent to which citizens are actively engaged in community organizations and volunteering activities and whether there is a culture of supporting each other in general or in times of crisis. Of particular importance is also the level of trust in the authority and other organizations locally which informs the extent to which citizens are likely to listen and respond to instructions or advice provided by them to guide behaviour in preparation for, and in response to, particular risks and hazards".

It is worth noting that this definition was devised both to operationalise the concept of community resilience – note the reference, for example, to 'social capacities' in the opening sentence – and to the final list of indicators included in this dimension.

#### 3.2.1.2 Step 2: Develop and/or Revise List of Indicators

Currently, the social dimension includes the following list of indicators which together aim to capture the key properties of a community that can affect its resilience to different types of disasters:

- Community engagement
- Social connectedness
- Trust in authority
- Place attachment
- Community competence
- Adaptive behaviour

- Risk awareness

This list has been adapted over time – including the wording of some of them – partly as a result of further reading, but also based on the validation exercise described in Section 5 below. It is expected that future sprints conducted as part of WP4 and, in particular, the trials (WP5) will be used to finalise this list. As an example, the indicator 'community competence' was previously named 'disaster efficacy' – however, feedback from end-users revealed that this label was not clear as it could be confused with some of the competencies held by authorities. It was, therefore, changed to reflect the focus on knowledge and skills held among citizens within the community. The clarity of this revised label will be explored during the trial phase.

#### 3.2.1.3 Step 3: Define Each Indicator

The next step was to define each indicator very clearly while keeping in mind the following factors:

- The definition needs to provide a clear description of what properties or attributes each indicator is aiming to assess.
- It needs to be worded in such a way that it clearly describes a scale, so that the community can be assessed as either being high, medium or low on this scale. This meant that an indicator initially included – 'community profile' – was removed as it did not meet this requirement.
- The indicator needs to be relevant to the assessment of community resilience, and not just describe a feature of the community with no clear link with either the increased or reduced level of resilience of that community.

In assessing the relevance and quality of each indicator we kept the six criteria identified by Parsons et al. (2016) – see Table 1 above – in mind, which include:

- The indicator reflects a justifiable element of natural hazard resilience
- The indicator can track change and variability in natural hazard resilience
- The indicator is relevant to the scale(s) of assessment
- The indicator is measurable and readily interpretable
- The measurement method for the indicator is robust
- The indicator is achievable – data are available, accessible and cost effective

As an example – we defined the indicator 'community engagement' as the 'Level of engagement of the local population in the community, including volunteering and attending community groups and events'.

#### 3.2.1.4 Step 4: Rationale for Inclusion

The next step involved providing clear rationales for each indicator included in the form of MRTs, where possible based on existing literature, on the reason for why this indicator has been included as a key property or attribute of this dimension. This was done by drawing on evidence from previous studies linking this indicator with higher or lower levels of resilience of a community. This was then summarised in a clear but succinct statement making a clear link with how any change in that indicator is assumed to impact on the resilience of the community.

#### 3.2.1.5 Step 5: Operationalise Indicators

A further way to ensure that the indicators chosen to fulfil the criteria of relevance and validity was to provide some examples of the kinds of proxies that could be used to assess this indicator. At this stage of the process, we were not looking at an exhaustive list, but instead intended to provide some examples of how the indicator could be assessed and the types of proxies that could be used to do so.

#### 3.2.1.6 Step 6: Review the Definition and Indicators

The next step was to review all the results of the five previous steps to ensure that the definition of the dimension fit with the indicators used to assess that dimension, and that definitions of the indicators were clear and fit with the proxies included as examples. As such the exercise had to be conducted in an iterative way – starting with a definition to identify indicators, trying to define these indicators, reviewing these definitions in light of the chosen dimension definition, checking that the indicators fit with this definition, looking at the literature to see how to justify our selection and modifying the indicator labels or definitions if need be, then once again trying to find proxy examples, checking if these truly fit with the indicator description and rationale, etc.

#### 3.2.1.7 Step 7: Complete Summary Table and Commentary

The final step was to insert the definition of the dimension, each of the indicators alongside their definition and rationale for inclusion, and some example proxies, into the summary. The following table provides one of the seven indicators identified for the social dimension to illustrate the intended result of the process described in this section.

*Table 2 Example summary table for social dimension for one indicator*

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Community engagement | Level of engagement of the local population in the community, including volunteering and attending community groups and events. | Community engagement facilitates collective action for mutual benefit and helps citizens to adaptively learn and transform in the face of threats or hazards. | • % population who vote in local elections<br>• Number of NGOs per 1000 population for pre and post-disaster response<br>• % population undertaking voluntary work |

# 4 The Approach in Context – A Review of the Literature

This section presents the results of a preliminary review of the literature on assessing resilience in community settings. The purpose of this review was to ground the overall approach to developing the RESILOC resilience indicators matrix – outlined above in Section 3 - within the resilience field in order to validate its applicability to this field. Additional focused literature reviews were subsequently carried out for each of the six dimensions covered in the RESILOC resilience indicators matrix in order to assess the applicability and relevance of the indicators developed for each dimension. These focused literature reviews are reported on in Section 6.

The 'grounding' literature review, reported on below, covers three themes:

- First, we look at how resilience has been considered conceptually and operationally at the community level
- The second section focuses specifically on frameworks that have been developed and applied to measure disaster resilience
- The third section considers how these frameworks have then been operationalised to measure resilience in practice.

## 4.1 Literature Review of Resilience at the Community Level

The conception of community resilience receives much consideration in studies and applications due to its capability to support preparedness against hazards, to protect our life against risks, and to bound back to stable living circumstances. However, community resilience is complicated, contextual, multifaceted, and thus challenging to identify, understand, and operationalise. A crucial benefit of having a comprehensive process for community resilience is the ability to be aware of and react properly in times of adversity. By modelling, measuring, and visualising community resilience to determine components, assess value, and represent information, respectively, communities can determine significant components of resilience, optimise available local and natural resources, and alleviate the impact of impairments effectively and efficiently.

Acknowledging the importance of community resilience, researchers and practitioners have made substantial endeavours in not only studies but also practical matters. Particularly, the purpose of the literature review is to give an examination and a more thorough picture into the state-of-the-art, accessible, and emerging works that are subjected to a three-step sequential process (i.e., modelling, measurement, and visualisation) to make community resilience. The modelling represents what is likely to be components and properties that communities should focus on to assure their resilience. Further, the measuring phase helps communities in recognising where they are standing. Eventually, the visualisation targets at assisting communities in deriving insights into essential information promptly and precisely with minimum efforts.

**Conclusions**

Based on this skeleton, communities can opt for most applicable methodologies, which are presented in detailed in the Annex B, to embed into their processes. Additionally, below are critical points that were distilled herein for either research or practical uses.

- The number of components identified in the modelling step is diverse depending on a specific community at a particular time point for certain risks/targets. Nevertheless, we should not define too many components because they can be overlapping and complicated to break down into lower-level elements. Furthermore, end-users and

stakeholders may find it difficult to understand and monitor many components for giving precise actions, specifically in the time of adversity.

- Different terminologies are available for modelling community resilience, some of which are, but not limited to, index, dimension, capital, capacity, and domain. The selection of the term highly relies on our practical use. For instance, the resilience index, which is usually a combination of indicators, is appropriate for a quantitative assessment. On the other hand, resilience dimension/domain is more descriptive and suitable for qualitative approaches. In addition, resilience capital/capacity well expresses the potential and abilities of a community to achieve something.
- To measure community resilience, we can leverage not only static (e.g., vulnerabilities, hazards, and exposed values) but also dynamic information (e.g., trust in authorities extracted by analysing social media data) at different scales. Information collected at the community level regularly tends to be more informal, undocumented, and implicitly understood than higher scales. It is necessary for us first to determine the goals of our community, target potential end-users, and then stick into them before deciding on any approaches to measure resilience.
- The literature review presented many studies that aimed at visualising correlation, hierarchy, and geospatial information; however, we should also pay attention to understanding and representing temporal information. Temporal information visualisation can depict common patterns and look for specific sequences, such as the dynamic of community resilience value by time. Area chart and polar area diagram are pragmatic and effective techniques to portray temporal information of community resilience.

## 4.2 Literature Review of Disaster Resilience Measurement Frameworks

The concept of disaster resilience has progressively gained a wider interest and has become more popular among academic researchers and practitioners. Although the literature on urban studies and also the practical planning documents recurrently refers to resilience concept as a managerial principle behind making resilient cities and regions, operationalizing this concept in urban and regional planning context raises critical challenges in terms of its determinants and assessment.

Some disaster resiliency frameworks and indicator sets exist with different degree of comprehensiveness, accuracy and validity. Studies are still ongoing to refine and develop more applicable resilience models (Gilbert, 2010). Moreover, some disaster resilience models are being applied to real-life communities and places for purposes of research and/or policy analysis (Manyena, 2006, Renschler et al., 2010b).

A critical literature review was conducted, leading to eight models and frameworks for measuring and assessing disaster resiliency as the more cited. Since the principal motivation for understanding the drivers and processes of disaster resilience is to develop plans to improve resiliency, assessments need to evaluate not only the baseline conditions but also adverse impacts, and factors that inhibit effective response (Clark et al., 1998). The transition from conceptual models to resilience measurement and assessment is challenging due to the multifaceted nature of resilience (Cutter et al., 2010).

The majority of assessment techniques is quantitative and uses indicators or variables as proxies since it is often difficult to quantify resilience in absolute terms without any external reference with which to validate the calculations (Schneiderbauer and Ehrlich, 2006). As a result, indicators are typically used to assess relative levels of resilience, either to compare between places, or to analyse resilience trends over time (Birkmann, 2006). The mentioned eight models have been evaluated according to the following criteria: comprehensiveness, structure and indicator building methods, scale and unit of analysis, dynamic, data requirements, validation and operationality, and actual and potential applications.

- The comprehensiveness of disaster resilience models can be assessed based on different dimensions of resiliency included in the models such as built environment, economic, social, organizational and different temporal phases of disaster (mitigation, preparedness, response, recovery) for different types of disasters (e.g., geological, climatic).
- A proper resiliency index should identify the distinct dimensions and related key indicators and also aggregates the dimensions in ways that reflect community realities.
- Disaster resilience is often allocated to *technological units* and *social systems*. In smaller scales like when we consider critical infrastructures, the focus is mainly on technological aspects. And in larger scale like when we consider the whole community, the scope will be expanded to include the interaction of multiple systems – human, environmental, and others which together add up to ensure the resiliency of a community (Renschler et al., 2010c).
- Resilience can be considered as dynamic quantity that changes over time and across space. The conditions defining resilience are dynamic and ultimately change with differences in spatial, social, and temporal scales (Renschler et al., 2010a). A society may be deemed as resilient to environmental hazards at one time scale (e.g., short-term phenomena such as severe weather) due to mitigation measures that have been adopted but not another (e.g., long-term such as climate change). The temporal scale at which resilience is measured is an important issue, since it will affect the selection of variables and parameters in index construction. Although resilience is a dynamic process, but for measurement purposes, it is often viewed as static phenomena (Cutter et al., 2008a).
- Researchers in this area often meet the difficulties in gathering data on resilience indictors for input into their models (Cutter et al., 2008a). However, the availability and accessibility of the data has been one of the most important criteria for indicator construction (Mayunga, 2009). In general, data for these models fall into four types: case studies, insurance claims, direct measurements, and survey methods (Gilbert, 2010).
- Many research works in developing composite indices in resilience studies, fail to empirically validate the measures especially in terms of incremental validity. This is one of the major flaws of using composite indexes as there is no simple way to get scientific validation of a particular index (Davidson and Shah, 1997). The absence of validation is a major concern. In many circumstances, the index relies on empirical data that is far from perfect. Many assume that because numbers have been derived using some basic statistical procedure, the overall results of the index is valid and reliable. However, some qualitative methods such as in-depth surveys and case studies can be used to validate the index.

- Considering the range of issues facing communities in the event of disasters, the spectrum of applications which can be addressed by current models is not broad. These issues can be categorized into two major groups in loss reduction and quick recovery after disaster (Gilbert, 2010). The resiliency models can be utilized to assess the strategies, actions and policies for loss reduction and recovery acceleration through different scenario development or by modifying land use plans and building control arrangements. This can help to not only mitigate the exposure but also to maintain functioning of the urban system during and after a disaster (Coaffee, 2008, March et al., 2011).

The review revealed that most of the frameworks for measuring disaster resiliency are generic and broader in the context of environmental hazards. Defining a proper context and scale for resiliency models seems necessary to take the most useful and applicable output of the model and also to provide a consistent basis for data development required for assessment. More specifically the variables and attributes of some of the frameworks are very broad and often not workable at the community level for measurement purposes. Therefore, their application becomes clumsy at this level particularly where indicators can also be criticised for difficulty of meaningful interpretation or the lack of causal linkages between the indicator values and the policy relevance of outcomes.

**Conclusions**

For making local communities more resilient, RESILOC aims at implementing needed tools for evidence-based policy making, analysis and evaluation of a large variety of issues and criteria. From the literature review, the “framework-oriented” model stands out as the more promising approach, in particular for its ability to capture the underlying constructs local communities are rich in.

The effort of capturing such constructs represents an ambition goal of the project and a scientific added value to research. The review of practical approaches to measuring resilience further shapes the path RESILOC will follow for the design, implementation and application of the intended tools.

## 4.3 Measuring Resilience in Practice: A Review of Approaches to Resilience Assessment

Resilience is a social construct that describes a system’s capacity in relation to a disruption (another social construct). Therefore, resilience can only be “measured” by observing the properties that might influence resilience (Martin-Breen and Andries, 2011). Characterising resilience by assessing its components and determinants means gathering data points across the system of interest (Prior and Hagmann, 2014).

There are four major approaches to resilience assessment:

- scorecards (e.g., UNISDR city disaster resilience scorecard, UNISDR, 2014);
- indices (e.g., Cutter, 2016);
- composite indicator (Becker et al., 2017);
- models (e.g., NIST, 2015; Rose and Liao, 2005);
- and toolkits (e.g., the Earthquakes and Megacities Initiative, Khazai et al., 2015 and the Rockefeller City Resilience Framework, TRF, 2014).

**Scorecards** are used to assess performance against pre-defined criteria associated with resilience (Sharifi 2016). They often consist of a number of questions or assessment criteria, usually with a set of scaled answers from which to select. The result can be a single 'score' or a collection of scores within a number of target areas. Drawing heavily on primary data collection means that scorecard data is relatively current. Scorecards tend to be simple to administer and useful in areas that do not have regular or reliable data collection. With scorecards there is a trade-off between comprehensiveness, cost, and respondent burden (Stevenson et al., 2015). One of the most widely used community resilience scorecards is the UNISDR Disaster Resilience Scorecard for Cities, in various stages of implementation in over 200 cities globally (UNISDR, 2017).

**Indices** are another common tool for assessing resilience. An indicator is a quantifiable variable that represents a characteristic of a system or phenomena. Indicators are combined to construct an index or composite indicator to capture the multidimensional nature of a system, while distilling it into a single metric (Tate, 2011). Unlike scorecards, indices more often draw on secondary data, and can be designed to facilitate standardised comparisons across space and time. Data often needs to be aggregated from a number of sources, with different periodicity, spatial extent, and quality. If not carefully managed, this can lead to compounding uncertainties, which can undermine the validity of the results (Barnett et al., 2008). Additionally, unlike computational models, indices have no in-built forecasting ability (Stevenson et al., 2015).

Resilience assessments that produce a standardised output (e.g., a quantitative 'resilience score' or similar) allow observers to establish a common baseline and language to facilitate mutual learning and exchange across places, institutions, and people. A tool that is widely applied for developing basic comparable measures of complex phenomena is the composite indicator (Becker et al., 2017). **Composite indicators** are formed by compiling a set of indicators that capture different aspects of a multi-dimensional concept (e.g., resilience) into a single index. Composite indicators are valued for their ability to simplify the measurement of concepts that are difficult to grasp (Nardo et al., 2005). They are additionally valued for their ability to facilitate communication with the public and focus the attention or "catch the eye" of decision makers (Booysen, 2002, p. 115; Becker et al., 2017; Saltelli, 2007). Composite indicators are relatively simple to construct. It can, however, be difficult to provide the quantity and quality of data needed for statistically meaningful and representative analyses (Saltelli, 2007). Despite the proliferation of information technologies and the massive production of big data in almost every activity of our lives, those trying to construct resilience assessment frameworks reliably face issues with data availability, consistency, reliability, quality, compatibility, and sampling coverage (OECD, 2003; Brooks and Adger, 2003; Seville and Wilson, 2006). There is also a constant negotiation between quality and practicality.

Composite indicators are excellent tools for distilling and communicating a complex concept like resilience and starting a consistent and meaningful conversation that informs action. They are useful tools for tracking trends over time and, when constructed carefully using indicators that are empirically linked to resilience outcomes, can give communities insights into their areas of strength and areas where they need to invest more energy.

**Computational models** will often draw on indicators of system function (e.g., infrastructure systems functionality, economic productivity) and simulate the speed, efficacy, and efficiency of the system's recovery following a hypothetical disruption. For example, Miles and Chang (2011) used a series of input-output functions to assess the various probable impacts of a hazard event.

**Stochastic models** were used to simulate the recovery dynamics, showing a sequence of possible events where the probability of each event depends on the state attained in the previous simulation (i.e., Markov chains in the ResilUS community based disaster resilience model). Fragility curves were used to calculate the potential damage and related injury or death resulting from building or lifeline damage (Miles and Chang, 2011). Models such as these are computationally expensive and take a high degree of expertise to design, implement, and interpret. They can be very useful for understanding limited case studies for which rich datasets are available but become less useful when trying to apply to larger areas or for having general discussions with resilience practitioners about strategy development.

Finally, **toolkits** can include any of the above resilience assessment methods but also provide guidance on how to conduct assessments. Additionally, they often provide guidance on how to transition from assessment into the design and implementation of resilience enhancement interventions. They may also include advice on how to monitor and evaluate those interventions once they are implemented (Sharifi, 2016). The Communities Advancing Resilience Toolkit (CART) integrated system, for example, includes community-based surveys, key informant interviews, the collection of secondary data, community workshops, aggregation and evaluation of infrastructure and ecological maps, and other capacity and vulnerability assessments (Pfefferbaum, R, Pfefferbaum, B and Van Horn, 2011). Again, like scorecards these systems can provide high-quality up to date assessments for a community. They are very difficult and costly to implement over a large spatial scale or over time.

**Conclusions**

On the basis of the literature review, the approach purely based on indices appears to be not the best choice for RESILOC, mainly because of its limitations in allowing a full representation of the social specificities of local communities and in supporting the identification of strategies for reaching the aspirations and goals of a community in terms of resilience, and the practical challenges posed in collecting the data needed to reflect these specificities. Moreover, the scorecards approach has an intrinsic limitation in the use of its results for strategic planning and simulations of the impact of desired actions.

As a conclusion of the review, the definition and development of a toolkit for resilience assessment is the most promising approach for RESILOC.

In itself, being a toolkit a combination of several approaches with the aim of picking the best of each of them, is very flexible and offers the ability of defining different methods for the different dimensions of resilience as assessed in RESILOC. In particular, the adoption of scorecards and composite indicators have their merits in the operationalisation of resilience assessment; the introduction of the Community aspirations by means of targets to the indicators creates a synergy between collected data and desired results that is at the core of RESILOC. This decision is at the same time an enrichment of the approaches adopted so far and also a solid basis for the operationalisation of a composite method for integrating objective data with the aims and aspirations of a community. This is reflected in the definition of a number of specific aspects of resilience (dimensions) that are studied and assessed via indicators but are not defined as composite indicators, so that they keep the richness of information offered by the use of indicators while offering an immediate understanding of the strengths and weaknesses of a community in specific domains.

In addition to that, the indicators contributing to the RESILOC dimensions can be considered as “composite indicators” based on a number of proxies and on the localised factors (relevance and compliance to targets) that local communities can define in a cooperative way. This adds a level of richness to resilience assessment because it allows the capturing of local instances, such as the definition of integration policies or the prioritisation of investments on social actions

rather than on strengthening physical infrastructures, while keeping the simplicity of the bottom-up construction of the indicators. Actually, the quantification of proxies can be carried out with a variety of methods, including the scorecards, the distribution of surveys and other more specific methods, such as sentiment analysis, that RESILOC will implement.

Finally, the toolkit approach supported by this literature review will allow both “vertical” assessments (e.g., based on the scenarios identified in D2.5) and “horizontal” assessments, such us the social elements contributing to resilience and not specifically linked to the scenarios.

# 5 Validation of the Approach and Methodology

## 5.1 User-Focused Validation Methodology

The methodology outlined in Section 3 above set out the general approach for developing the RESILOC dimensions, indicators and proxies. While such an approach provides a scientific basis for the overall framework, it also needs to be validated via engagement with end-users. This is important not only to ensure that the framework and its constituent parts (i.e. the dimensions, indicators and proxies) are understood, but also that they are fit for purpose for assessing the resilience of local communities facing different types of natural hazard scenarios – and that they meet all the criteria outlined in Section 3 above. The validation exercise needs to be facilitated by a RESILOC partner with good links with the community and involve a good cross section of end-users of the community.

This section therefore sets out the proposed methodology for validating each of the six dimensions, while Section 5.2 provides the results of an initial piloting of this methodology with regard to an initial draft of the 'social dimension'.

### 5.1.1 Relevance, Usefulness and Importance of Indicators

As a first step, end-users should be asked to focus on a recent disaster experienced by the community and to assess the relevance, usefulness and importance of each identified indicator for assessing the resilience of the community to such a disaster in future. The validation task facilitator should use the feedback from participants to then complete Table 3 below. More specifically:

- In Column A: they should specify whether the indicator was viewed by the users as relevant in their assessment of the community's level of resilience when facing a disaster – and write 'Y' (for Yes) and 'N' (for No') for each indicator listed.
- In Column B: they should specify whether the indicator is used in practice by the users in their assessment of the community's level of resilience – and write 'Y' (for Yes) and 'N' (for No') for each indicator listed.
- In Column C: they should specify how important the users rated each indicator in terms of how it affected the resilience of their community in a recent disaster by ranking each indicator from 1 (most important) to 8 (least important).
- In Column D: for each of the indicators described as not relevant in Column A, they should specify the reason(s) why the indicator was seen as not relevant by the users.
- In Column E: for the four indicators described as the most important in Column C (i.e., ranked 1, 2, 3 and 4), they should specify the reason(s) why the indicator was seen as important.

*Table 3 A table template for indicators relevance, usefulness and importance*

| List of indicators | A. Relevance (Y/N) | B. If used (Y/N) | C. Importance (Rank 1-8) | D. Why not relevant | E. Why Important |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

### 5.1.2 Indicator Contribution to Resilience

The next step is to ask participants in what ways the factors reflected by the indicators have contributed to the resilience of the end-user's community in a recent disaster, from the perspective of the end-user. The facilitators should complete Table 4 by summarising in Column A what contribution, if any, each indicator in the list made to increasing or reducing the resilience of the community to a disaster, from their perspective.

*Table 4 A table template for contribution to Resilience*

| List of Indicators | A. Impact on community resilience |
|---|---|
| | |
| | |
| | |

### 5.1.3 Missing Indicators

The facilitators should also explore whether the end-user identified additional indicators they felt were missing from the framework and summarise this information in Table 5 below – and provide a clear description of the indicator in Column B, and some examples of how it could be assessed in Column C.

*Table 5 A table template for additional Indicators*

| A. Indicator Name | B. Description | C. How this would be assessed |
|---|---|---|
| | | |
| | | |

### 5.1.4 Proxy Measures

The next step is to ask end-users to explore the suggested proxies to assess each indicator in terms of their relevance and availability. In Column A, the facilitator should add comments on the relevance of particular proxy measures for that indicator, and then detail in Column B how easy it would be for them to collect or provide such data (on a scale of 1 to 3: 1 – Easy, 2 – Difficult, 3 – Impossible), and in Column C what alternative measures could be used instead.

*Table 6 A table template for Indicator Measures*

| Indicator | Measures | A. Relevance | B. Ease of collection | C. Similar data available |
|---|---|---|---|---|
| *Name of indicator* | *List of proxies* | | | |
| *Name of indicator* | *List of proxies* | | | |

### 5.1.5 Descriptions and 'Mid Range Theories'

The next steps are to collect end-user observations on the appropriateness of the indicator descriptions, and, second, their observations on the text used to define why each indicator is important. This reflects what we would call the 'mid range theory' (MRT) behind an indicator – i.e., the assumptions behind why, for example, an increase in civic engagement would lead to increased resilience. A key aim of the user feedback is to collect what kind of these 'causal explanations' are in the minds of end users when they think about resilience and how it can be measured. This information should be captured by the facilitator by completing Table 7 below and specifying in Column A any suggested changes to the indicator descriptions from the user perspective and in Column B any suggested changes that to the MRTs.

*Table 7 A table template for descriptions and 'Mid Range Theories'*

| Indicator | Description | Why is this important? | A. Description changes | B. MRT changes |
|---|---|---|---|---|
| | | | | |
| | | | | |

### 5.1.6 Overall User Feedback and Recommendations for Improvement

This final section covers end-user perceptions of the proposed framework and recommendations for improvement.

- In Column A, the facilitator should write down any other comments, observations made by the end-user that are not recorded elsewhere in the template.
- In Column B, they should summarise end-user observations and comments about the usefulness of the information in the framework in helping the community prepare for a disaster.
- In Column C, they should specify any suggestions provided by end-users on how the framework and the information it contains could be made more useful.

*Table 8 A template for overall user feedback and recommendations for improvement*

| A. Overall observations | B. Usefulness | C. Recommendations for Improvement |
|---|---|---|
| | | |

## 5.2 Pilot Testing the Validation Approach: the 'Social' Dimension

This section presents the results of the first pilot testing of the validation methodology outlined above, which will need to be applied for the finalised list of six dimensions as part of Task 3.2 (see Section 8 below). The task involved asking end-users to reflect on the first draft of the 'social dimension' and its associated eight indicators and suggested proxy measures (see Appendix C) using the reporting template described above (Appendix D). All end-users provided informed consent of participating in this exercise (Appendix E).

Table 9 below provides an overview of end-users engaged in this task between April and May 2021 in four communities and who facilitated these discussions:

*Table 9 Validation group participants and facilitators*

| Area | Facilitator organisation | Roles of end-users |
|---|---|---|
| Gorizia | ISIG | 3 representatives of Civil Protection services and Municipality |
| West Achaia | TIHR | 1 representative of Municipality |
| Tetovo | BILSP | 6 representatives of Civil Protection services and Municipality |
| Kamnik | TIHR | 4 representatives of Civil Protection services and Municipality and their advisors |

### 5.2.1 Relevance of Indicators

The following table shows how the different areas rated the relative importance of the eight suggested indicators. It shows that '**civic engagement'**, '**disaster preparedness'** and '**risk awareness'** were rated as very important by most of the areas. '**Social support'** was generally also seen as an important indicator of resilience.

As regards, 'civic engagement', respondents in Gorizia for example stated that: "experience in the field shows that such a 'factor'/'feature' is stronger in small communities and weaker in large communities. It is per se fundamental in strengthening resilience at local level". West Achaia, similarly, emphasised the importance of 'risk awareness': "Increased public awareness about risks (e.g., forest fires in summer) is very important … since it can literally save lives" and also 'social support': "It is important because it is linked to social capital (i.e., norms and networks) that facilitate collective action in disaster response. For example, in case of an earthquake, people will run to help the elderly or those living alone".

*Table 10 Relative importance of seven indicators*

| Indicator | Very important | Neutral | Not so important |
|---|---|---|---|
| Community profile | | G / K / T | A |
| Civic engagement | A / G / K | T | |
| Social support | A / G | K / T | |
| Trust | K / T | A / G | |
| Place attachment | A / G | K | T |
| Risk awareness | A / K / T | G | |
| Disaster efficacy | A / K | T | G |
| Disaster preparedness | A / K / T | | G |

Legend: G (Gorizia), K (Kamnik), A (West Achaia), T (Tetovo)

None of the areas rated '**community profile'** as very important – however, it is worth noting that some explained that the reason for this is that it is dissimilar from the other indicators. Hence, West Achaia for example explained that it is dissimilar as: "it does not provide info about the kind of resources one can mobilise in cases of crisis". Others explained that the profile of a community is important, but it underlies all or most of the other indicators. Furthermore, the category itself cannot be judged on an ordinal scale, for example from 'high', 'medium' to 'low', compared with the other indicators in this table. Instead, it would seem that it contains valuable contextual information of relevance when considering the resilience or vulnerability of a community but in itself and in its current form does not function as an 'indicator of resilience' as the others do.

There was also some disagreement among participants of the importance of '**trust'** as an indicator. While no-one suggested that it was not relevant, it was deemed to be more or less important depending on the context of the community. Some respondents in Tetovo, for example, deemed this to be the most important: "Trust in institutions is the most important"; in contrast, in West Achaia it was said to be not so important as "within the Greek context where people have little trust in authorities, this indicator is not as important as others".

There was also some disagreement over the interpretation and relevance of the indicators: '**disaster efficacy**' and '**disaster preparedness'**. In Gorizia, disaster efficacy and preparedness were judged to be of low importance – the former was said to be not clearly articulated; furthermore, the end-users challenged the concept of "'citizens competences', as 'competences' is interpreted as an element that stays with the authorities". This would suggest that from the end-user perspective, the responsibility for ensuring resilience of citizens lies mainly in the hands of the authority. As regards 'preparedness' it was stated that: "unfortunately experience shows that communities tend to 'prepare' themselves only after they have suffered the impacts of a disaster. In communities that have not yet faced the impact of different disasters such [an] element is difficult to identify/assess/etc". In contrast, both of these were rated as very important in Kamnik: "Disaster preparedness of citizens and personal and mutual protection against natural and other disasters contributes to a better and efficient response to disasters, lowers the impact of the disaster and enables a better recovery and reconstruction

process (BBB - Build Back Better)" and "It's important that citizens have as broad as possible relevant skills or competences to protect themselves and others before, during or after an emergency".

There was also some disagreement over the value and importance of **'place attachment'** as an indicator of resilience. In West Achaia it was rated as important as: "this informs (and is informed by) place identity, place dependence and place ties, all of which affect how a community responds to a disaster, how well-prepared it is and how it recovers". In contrast, a respondent in Tetovo thought it was not so important because: "A person can be emotionally attached to many places at the same time. On the other hand, a person may not be attached to the place where they live". Similarly, in Kamnik, too high levels of place attachment were also seen as leading to increased vulnerability: "In 2000, a water and mud flow rushed into a village in Western Slovenia and the civil protection agency told people to leave, but some older residents refused to leave: 'I was born in this house, and I will die in this house'".

### 5.2.2 Availability of Data

Respondents in all four areas stressed that they currently did not have access to data relevant to most of the suggested proxy measures for these indicators. The only exception of this was the 'community profile' for which data was mostly available. Otherwise, all areas recognised that there was no available data for most other indicators requiring "the need for specific data collection actions, which may pose different levels of difficulty to the end-user in gathering such data". However, several were concerned about the resource implications of collecting such data: "Some data gaps can be filled through targeted surveys; however, there are obvious resource implications about conducting these".

### 5.2.3 General Comments and Observations

Overall, most of the areas indicated that the social dimension and the indicators were useful tools to assess a particular aspect of the resilience of their community – although they were interested to see the other proposed dimensions to gain a more complete picture. Some areas said this dimension brought together the kind of information they already consider, but in a more systematic way: "a summary is useful, because end-users have [so far] thought about those indicators partially, but not as systematically as here".

Critical comments included that the indicators seemed more relevant to urban settings and less applicable to rural or more dispersed communities – suggesting a need for areas to adapt the indicators to different settings.

The feedback from end-users was used to revise the social dimension and the results of this are presented in Section 7.1 below.

# 6 Implementing the Approach and Methodology

This section outlines the approach taken by partners for each of the six dimensions to develop the indicators and proxies following the overall implementation strategy outlined in Section 3.

## 6.1 Development of the Governance Dimension

### 6.1.1 Implemented Methodology

The identification and selection of relevant indicators and proxies in the sphere of governance partly builds upon the previous work done for RESILOC Task 2.2 – Analysis of Vulnerability – which included a literature review, initial exploration of indicators and proxies for assessing resilience and the involvement of end-users in validating these initial indicators and proxies. This preliminary work was built on through a focused literature review on governance aspects, operationalisation of the governance dimension, and validation including end-users of the indicators and proxies developed through the operationalisation process.

### 6.1.2 Literature Review on Institutional Vulnerability

According to the theoretical framing of institutional vulnerability defined for the purpose of RESILOC T2.2 – Analysis of Vulnerability, the dimension of institutional systems vulnerability has been probably the least explored in literature among the ones considered by the project. The difficulty in framing institutional vulnerability may derive from the fact that the area of governance often overlaps with other dimensions, such as social, economic, and cultural. Institutions are the regulative framework of our society (Jessop, 2001). They regulate the social and economic behaviour of individuals, playing an important role in the development of the society, of organizing structures that may optimize the social and economic behaviour by reducing, for example, complexity, and therefore, uncertainty in life (Papathoma-Köhle & Thaler, 2018). Such a contribution is clearly related with the increasement – or decrease – of resilience in a community in relation with natural hazards.

Several studies suggest that “good” institutions may contribute to the reduction of damages and losses deriving from natural disasters. Kahn (2005), for instance, investigated 4,300 catastrophic events from 1990 to 2002 in 57 countries, and concluded that countries with better institutions suffered fewer deaths from natural disasters. This was done by testing the correlation between the number of human losses and metrics such as the democracy level, income inequality, ethnic fragmentation, and the World Bank indicators of good governance for each nation. The World Bank indicators included: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption (Kraay et al., 2010).

Stemming from these premises, RESILOC vulnerability indicators and proxies related with the institutional dimensions were selected and aggregated as the result of a quasi-systematic literature review (Snyder, 2019) which took into consideration 32 sources among academic papers, as well as book, chapters and NGOs working documents, written in English. Academic sources, books and chapters were all digitally available through Google Scholar. Indeed, Google Scholar is attested as the largest academic database (Gusenbauer, 2019), it is freely available and it allows for the replicability of the methodology deployed for the purpose.

All the sources are presented in the Institutional Vulnerability Literature Review Sources section.

### 6.1.3 End-users' Validation of Vulnerability Indicators and Proxies

As a result of this first recognition, 14 indicators and 175 proxies pertaining to the Institutional/Governance dimension were catalogued in the Resilience Matrix database.

A preliminary process of validation of indicators and proxies by the end-users was developed in the framework of RESILOC T2.2 – Analysis of Vulnerability, when RESILOC local partners were asked to evaluate, modify and refine the list in an interactive approach, according to availability and relevance to the context of the specific communities. The results of this exercise are presented in depth in Chapter 4 of D2.2 – Analysis of Vulnerability.

This process included evaluation of proxies, active research on the part of local partners, and repeated interviews between ISIG team and local partners, with the aim of editing and eventually validating both the methodological tools for data collection as a whole, and the proposed sets of indicators and proxies. Interviews were held online.

Indicators and proxies were validated according to:

- Availability of sources according to different units of analysis.
- The degree of relevance of every proxy according to the specific context (community and hazard characteristics).
- The degree of relevance of the different units of analysis.

Local partners had the chance to propose adjustments and reformulations of indicators and proxies according to the abovementioned insights, advancing the dialogue with ISIG team. The heterogeneity of data measurement/availability among different communities posed the most relevant challenges in this phase, reinforcing thus the working hypothesis of standardising indicators, while allowing more flexibility on the selections of proxies through which measure the indicator itself.

### 6.1.4 Operational Definition of Governance Dimension

For the purpose of the definition of RESILOC Resilience Matrix, the governance dimension was framed as follows[2]:

- Good governance elements at local/community level, describing/assessing the overall local governance system of a community.
- Risk governance elements at local/community level, describing/assessing the approach to risk governance mechanisms within a community (i.e., focus on risk disaster management within the overall local governance system of the community at stake).

[2] See the working document released in July 2020 by ISIG, where the rationale on the concepts of (Good) Governance, Risk Governance and Social Capital was outlined. The three concepts were intended as the elements shaping the dimension of governance resilience. The working document provided also a preliminary list of indicators and proxies for governance dimension.

- Social capital elements at local/community level, describing/assessing the resources (i.e., in terms of trust, citizenship, etc.) and capacities (e.g., existing networks) within a community that interact/influence the overall governance mechanism/system in a given context.

The abovementioned elements are briefly described in the following paragraphs.

**Good Governance**: According to Kaufmann et al. (2010), "Governance consists of the traditions and institutions by which authority in a country is exercised". From this perspective, governance, lato sensu, entails, among others:

- The processes related to (all levels of) government(s) elections – the way they are selected, monitored and replaced.
- The capacity of (all levels of) government(s) to design, implement (and monitor) policies.
- The trust in and respect of, by both citizens and the state, the institutions that govern the interaction among them (i.e., between citizens and the state).

Furthermore, the concept of governance is highly related to democratic values and standards, as «Good governance has become a paradigm for giving real effect to the values and standards of democracy, human rights and rule of law» (CoE, 2007, p. 1).

According to the Worldwide Governance Indicators (Kaufmann et al., 2010), the indicators upon which governance can be assessed are grouped in 6 clusters (entailing the above-mentioned elements), as follows:

- Voice and Accountability
- Political Stability and Absence of Violence
- Government Effectiveness
- Regulatory Quality
- Rule of Law
- Control of Corruption

It must be stressed that these macro-indicators (i.e., clusters of indicators describing governance) are reflected as well across different frameworks concerned with the analysis of governance (e.g., CoE 12 principles for Good Governance) and they will be reflected in the approach of analysing governance within the RESILOC resilience matrix.

For the purpose of the RESILOC resilience matrix, the concept of governance will be focused mainly on a local perspective (i.e., focus on community resilience, in line with the RESILOC definition of resilience).

Although «governance is a requirement at all levels of public administration, at local level it is of fundamental importance because local government is closest to citizens and provides them with essential services and it is at this level that they can most readily feel ownership of public action» (CoE, 2007, p. 1).

**Risk governance** is understood as elements and processes that foster an integrated, multi-risk and participatory strategy to disaster risk (OECD, 2018).

The following national targets for ensuring a performant risk governance framework, set by OECD, could be adapted for the local level, for the purpose of RESILOC, as indicated by OECD itself when presenting Resilient Cities[3]:

- Clear leadership and management – that ensure a clear long-term vision.
- Strategic and integrated approaches are taken by leaders – implying that the collaboration with other levels of government is in place.
- Public sector has the right skills – implying that the public sector has proper resources.
- Government is open and transparent – implying that citizens are encouraged to participate.

Further targets/goals for ensuring a performant risk governance framework could be identified in the Recommendations issued by the OECD (2014). Although the recommendations are issued for the national level, they could be adapted for the local/community level:

- Establish and promote a comprehensive, all-hazards and transboundary approach to country risk governance to serve as the foundation for enhancing national resilience and responsiveness.
- Build preparedness through foresight analysis, risk assessments and financing frameworks, to better anticipate complex and wide-ranging impacts.
- Raise awareness of critical risks to mobilise households, businesses and international stakeholders and foster investment in risk prevention and mitigation.
- Develop adaptive capacity in crisis management by coordinating resources across government, its agencies and broader networks to support timely decision-making, communication and emergency responses.
- Demonstrate transparency and accountability in risk-related decision making by incorporating good governance practices and continuously learning from experience and science.

**Social capital**: According to CoE (2020), social capital describes the collective value of 'social networks' as well as the norms of reciprocity deriving from such networks, at community level; it refers to the stocks of social trust, norms and networks that people can draw on to solve common problems. They are all elements that contribute in shaping the resilience framework of a community.

### 6.1.5 Final Operationalisation of the Dimension: Definition and Selection of Indicators and Proxies

Taking into account all the previous analyses, including work carried out in RESILOC work package 2, the Governance dimension is defined as relating to:

- Characteristics of local governance systems, structures and agencies.
- The level of cooperation and coordination within the community, participatory processes and multi-stakeholder collaboration.

[3] OECD – Resilient cities (https://www.oecd.org/regional/resilient-cities.htm)

- The institutional and political resources the community could access to support decision-making processes, before, during and after emergency situations (thus entailing both policy making and policy implementation processes).

Indicators and proxies are then selected and organised according to this definition.

### 6.1.6 Final Discussion and Validation

The set of indicators and proxies defined following the above presented steps has been the object of a validation process involving:

- Gorizia LRT Coordinator, in a face-to-face workshop held by ISIG on 16th December 2021.
- All Gorizia LRT members, in an online meeting held by ISIG on 17th December 2021.

The participants positively evaluated the proposed framework, which is presented in Section 7.1 below.

## 6.2 Development of the Social Dimension

### 6.2.1 Approach of the Development of the Social Dimension

Defining the social dimension of Resilience, and the subsequent selection of indicators and proxies of said dimension, has been an iterative process. This approach can be seen as having had the following components:

1. An initial literature review on risk perception and related concepts, such as adaptive behaviour, carried out as part of D2.1, from which the initial theoretical underpinnings of and definition of the social dimension were derived.
2. A review of literature of previous frameworks used to assess the social resilience of communities to disasters
3. From the aforementioned reviews of literature, the development of an initial definition of social resilience, indicators, and proxies was produced for end-user validation (see Section 5.2)
4. Based on end-user feedback, the definition, indicators, and proxies were refined. Further, a methodology for indicator and proxy development and selection was derived from this process and shared with RESILOC partners (see Section 3.2).
5. The Social Dimension and its relevant indicators and proxies underwent a final process of review and validation from RESILOC consortium partners.

The following discussion outlines the key theoretical conclusions of the literature reviews on risk perception and existing resilience frameworks; the initial social dimension definition and indicator/proxy selection; key findings from the end-user validation process; the revision of the social dimension-based end-user feedback and a refined methodology for indicator selection; and the final version of the indicators/proxies.

### 6.2.2 First Draft of the Social Dimension.

The literature review conducted by the Tavistock Institute on Risk Perception as part of Deliverable 2.1 was instrumental in the initial formulation of the social dimension. While the literature review was principally concerned with risk perception, it also sought to explore how risk perception links with individual and community preparedness, adaptive behaviour, and resilience. To this end, the literature review explored the following key components of prominence within discursive trends on risk perception:

- **Lifeworld**: There is a link between previous experience of disasters, risk perception and people's future behaviour – this is more likely to be informed by emotional memories rather than rational assessments of potential hazards.
- **Spatiality**: There exists a link between disaster proximity and risk perception and preparedness. Thus, recent experiences of disasters are linked with greater awareness of risk and usually preparedness.
- **Inter-subjectivity**: Increased trust in local officials can increase levels of risk perception, encourage citizens to be more attentive to hazard-related information and increase preparedness to disasters.
- **Embodiment**: The evidence suggests a link between socio-economic and other characteristics and people's level of risk perception and preparedness. In particular, risk perception is often higher among women and those from lower socio-economic groups in societies.
- **Temporality**: The evidence suggests that there is a temporal dimension to risk perception in relation to natural hazards.

Alongside the theoretical conclusions drawn on the social element of resilience from this literature review, the social dimension drew on existing literature explicitly mapping indices and proxies that were pertinent. On the one hand, established frameworks and matrices of Resilience were reviewed. The City Resilience Framework, for example, was drawn on as a key example of a framework in alignment with RESILOC's ethos and intended application, within which a social dimension of resilience was drawn upon, within which collective identity and mutual support are used as key components of its mechanisms, in alignment with the conclusions of the D2.1 literature review.

Reference was also made to the The Australian Disaster Resilience Index (Parsons et al., 2016) which includes several relevant indicators – split between those related to 'coping capacity' and 'adaptive capacity'. This includes, for example, indicators related to the 'social character' and 'community capital', as well as the 'social and community engagement' of a community.

On the other hand, broader theoretical reviews of the conceptual understanding of social resilience were examined, including the key works of Cutter et al (2008; 2010; 2016), and literature reviews conducted by Aslam Saja et al (2018) and Khoja et al (2020) on the assessment of social resilience.

This resulted in the following initial list of indicators for the social dimension (as well as a list of suggested proxies for each indicator):

- Community profile: to provide a demographic overview of the local population, with reference to particular characteristics that can increase or reduce levels of resilience, such as age, levels of mobility, socio-economic characteristics, etc.

- Civic engagement: to assess the of engagement of the local population in the community, including volunteering and attending community groups and events.
- Social support: to assess the extent to which the local population provide support to each other and in particular to more vulnerable members of the community.
- Trust: to assess the level of trust between citizens and local authority representatives and emergency services.
- Place attachment: to assess the extent to which citizens in the community feel a sense of belonging to where they live and have strong links with their neighbours and neighbourhood they live in.
- Risk awareness: to assess the extent to which citizens are aware of different potential hazards and their likelihood and know what to do to mitigate the effects of such hazards.
- Disaster efficacy: to assess the extent to which citizens have relevant skills or competences to protect themselves and others before, during or after an emergency.
- Disaster preparedness: to assess the extent to which citizens have taken (or are willing to take) active steps to protect themselves and their property from the negative impacts of disasters.

### 6.2.3 Validation and Refinement of the Social Dimension

As discussed in Section 5.2 above, this initial list of indicators was updated and refined as a result of an engagement with end-users from four of the five pilot communities between April and May 2021. This reflection engaged with the definition of the dimension; the indicators initially selected; and the suggested proxy measures.

The following key conclusions that informed the revision of the social dimension indicators are as follows:

- Overall, most end-users found the indicators relevant to assessing resilience in their community, although some were judged to be more relevant than others by different respondents.
- The extent to which particular indicators were deemed to more or less relevant could depend on the role of end-users – for example, whether they have more strategic or operational responsibility in the municipality.
- The biggest issue was the lack of availability of data to measure most of the indicators identified – this meant that it would need to be collected via survey or some other means and that this could be very time intensive.
- Another concern was that some of the indicators may be more relevant for urban areas and less so for very rural communities such as West Achaia; this would suggest a need to adapt the indicators and measures to such areas.
- The indicators also raise the question of what can be done to improve them by the areas – i.e., what strategies can be implemented, for example, to increase risk awareness or increase preparedness?
- One interesting finding is that most end-users found that completing this exercise itself was interesting and useful as it helped them to reflect on what they already used to assess the resilience of their community albeit in a much less structured and systematic way.

The engagement of end-users led to a refinement of the definition, indicators and proxies of the social dimension to make them more relevant, useful and important to local communities. Key changes to the initial draft of the social dimension included:

- Removing 'community profile' as an indicator as while it provides useful information in the assessment of resilience of a community, it does not meet the criterion of being able to be assessed on a qualitative or quantitative scale as increasing or reducing resilience in a clear way (e.g. the age profile of a community, while relevant, is not explicitly linked with either increased or reduced levels of resilience in a straight forward way for different types of hazards)
- Changing the terminology for some of the indicators, to refer to 'Social connectedness' (rather than support), Trust in authority (rather than just 'Trust' to distinguish between other types of trust – e.g. in other citizens), to use the term 'Community competence' rather than 'Disaster efficacy' (which was often not understood by end-users), and 'Adaptive behaviour' rather than 'Disaster preparedness' (to make a clear link with the steps taken by citizen to protect themselves and their property from the negative impacts of disasters.

The last step was to present the results of the end-user engagement process to other partners in the form of a short internal report (June 2021). Comments received from partners were used to further refine the dimension and indicators and proxies.

## 6.3 Development of the Economic dimension

### 6.3.1 Implemented Methodology

The identification and selection of indicators and related proxies for the Economic dimension, benefits from existing research studies and experience on causal effects ecosystems factors. The contribution to this deliverable is the result of a critical review of the set of eco-factors proposed in the existing literature, identifying which indicators and proxies are appropriate for the purposes of the RESILOC project.

During this process the following steps were taken:

- review of the existing frameworks and literature on Economic ecosystems;
- definition of Economic dimension;
- developing a list of the most relevant indicators according to the frameworks and literature reviewed;
- assigning a description to each indicator, providing a clear link with the Economic dimension and offering a clear rationale;
- operationalisation of the indicators' selection;
- review of the dimension definition and indicators - final discussion and validation.

### 6.3.2 Definition of Economic Dimension

This dimension represents the economic factors that influence the ability to prepare for and recover from a natural hazard. It relates to the level, variability, and diversity of income sources and access to other financial resources that contribute to the wealth or financial sustainability

of the community. It includes, for example, the range and types of businesses locally, available physical structures and industrial assets needed to generate wealth, etc. It should also include an assessment of the existing wealth of the community relating to levels of savings and debit/credit, type and cost of housing, the existing income generating skills-base of members of the community and groups of citizens particularly vulnerable to economic shocks. It also should consider the factors affecting business continuity following a disaster, including e.g., the dependence of the community on local jobs for income generation or the extent to which local citizens are able to carry out their jobs remotely wherever they are based.

### 6.3.3 Selection of Economic Indicators

In order to realise a preliminary list of relevant indicators for Economic dimension, the work started from the reviewing of the existing literature. The focus was mostly on indicators framed into entrepreneurial ecosystem, consisting of the so called “eco-factors” required for a successful ecosystem (Khoja et al, 2020). The indicators selection started from the framework proposed in Nicotra et al. 2017, exploring indicators and related data sources towards their utilisation in assessing the economic resilience of a community.

Some indicators were retrieved from different popular holistic dataset that focus on country level of analysis and consider many countries, like World Economic Forum, International Monetary Fund (IMF), UNESCO, EUROSTAT Database, EU Regional Competitiveness Index, Global Competitiveness Report, Global Entrepreneurship Monitor (GEM), Global Entrepreneurship and Development Index (GEDI); hence variables and related data sources here listed has been translated into Indicators and operationalised providing insight into the drivers of productivity and prosperity at local economic level. Such secondary data are also gathered by the World Bank and collected in the World Development Index[4], in details, indicators include estimates that are related to general economic factors, compiled from officially-recognized national, regional, and global sources.

At the end of this process, a first consolidated list of indicators for the Economic dimension was drafted, ready to be revised together with the other partners of the RESILOC Consortium.

The development of a consolidated list of indicators was achieved by rating them considering their applicability scale (NUTs) and evaluation criteria (preferring quantitative over qualitative). The interaction with the RESILOC consortium allowed to identify the potential indicators needed, this allowed to do an assessment work on the relevance and appropriateness of the identified indicators; at the same time identifying those that are deemed necessary, those that are judged interesting, those that should be discarded and possible gaps to bridge.

### 6.3.4 Definition of Indicators' Description and Rationale

Once a first consolidated draft list of indicators has been created, it was provided a short description for each of them, conveying the clear link with the overarching dimension. The description was extracted by secondary data sources and eventually depicted in such a way that indicators may be assessed on a qualitative (e.g., from high to low) or quantitative/numerical scale (e.g., from 1 to 5).

Likewise, a clear rationale on the reason why each indicator has been included as a key property or attribute of economic dimension was sketched. It considers the variability of weights

[4] www.data.worldbank.org/data-catalog/world-development-indicators

that can be assigned to the different indicators, producing a ranking to obtain a comparison among community and groups of citizens particularly vulnerable to economic ecosystems.

In line with the exercise conducted for the development of the indicators list, some meetings were organised to review the description identified; the aim was to verify that the description provided are clear and ensuring that they fit the indicators selected to assess the economic dimension. This activity was done by presenting the descriptions elaborated by IES, reviewing them with the users and gathering feedback on what need to be improved. The users were also involved in the co-production of the rationale for each of the indicators identified and in their later revision.

### 6.3.5 Operationalisation of Indicators

The list of secondary data, once cut down to a suitable number of indicators and confirmed, was subjected to an operationalisation process. Some examples of proxies that could be used to measure or assess each indicator was provided. These has been drawn using accurate, robust and reliable proxies identified from assessment frameworks previously reviewed and existing lists already developed by secondary data sources as indicated above.

### 6.3.6 Final Discussion and Validation

Validation of the indicators was implemented using the methodology outlined in Section 5 above. This entailed an initial review of the indicators set against relevant literature, followed by feedback workshops with users.

## 6.4 Development of the Infrastructure Dimension

### 6.4.1 Implemented Methodology

The infrastructure dimension relates to the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a community, both in routine circumstances and in the extreme circumstances of an emergency (see: UNISDR, 2009). These include transport structures such as train stations, major roads, and air and seaports, electricity, gas, water and communications systems, food distribution chains, hospitals and health clinics, and centres for fire, police and public administration services. This dimension also considers the extent to which any failure or disruption to such structures, facilities or systems will impact on a community before, during or after an emergency.

Below we explain how the infrastructure dimension is approached so as to define the RESILOC resilience indicators in it - an approach that resonates with other indicator-based approaches in the field (Jovanovic, Øien, & Choudhary, 2018; Prior, 2014; Petrović, Stranjik, & Peternel, 2018). The work in this section enriches the indicators and proxies available to the research community, which according to an extensive literature review done by Beccari (Beccari, 2016[5]) constitutes roughly 10% of the composite indicators present in academic and grey literature in the field of *"risk, vulnerability and resilience composite indicator methodologies"*. After, we

[5] Beccari, B. (2016, March 14). Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators. PLOS Currents Disasters. doi:doi: 10.1371/currents.dis.453df025e34b682e9737f95070f9b970

rationalize the choice to include the given indicators in it and we present their operationalization with example proxies.

### 6.4.2 Definition of Infrastructure Dimension

The identification and selection of relevant indicators and proxies in the domain of infrastructure partially builds upon the work done for T2.1 and T2.2 within RESILOC. It also sources from the vast infrastructure resilience literature. This section describes the process of unpacking each dimension into its constituent variables – or 'indicators' – in a systematic and methodologically robust way. Doing this involves the following steps:

1. Literature review on infrastructure assets of the community that affect its resilience to natural hazards.
2. Expert consultation on resilience indicators and proxies.
3. Operational definition of infrastructure dimension. [T3.1]
4. Selection of the most relevant indicators and proxies according to the previous steps. [T3.1]
5. Final operationalization of the dimension definition and selection of indicators and proxies. [T3.1]
6.

### 6.4.3 Selection of Infrastructure Indicators

The indicators that are chosen are of high importance to the communities' normal functioning, but are critical in the occurrence of a disaster. Most indicators are chosen to address multiple hazards, or rather be hazard insensitive, so that they can be used in different scenarios.

There are several infrastructure types (e.g., RESILENS, 2015; Poulin & Kane, 2021). Those employed in the present work are based on the taxonomy found in (Poulin & Kane, 2021). The infrastructure types (i.e., groups) include:

- Energy
- Transportation
- Water
- Financial
- Information
- Healthcare
- Supply chains
- Coupled systems
- Others

Here, the coupled systems item is not viewed as an infrastructure type on its own, but is rather spread in the other types, where applicable, through indicators reflecting interdependencies between infrastructure systems (Zeniewski, Brancucci, & Pearson, 2013).

This taxonomy views the infrastructure dimension from a higher-level perspective compared to, for example, the infrastructure categories employed in the Report Card for America's Infrastructure (American Society of Civil Engineers, 2021). This approach positions the infrastructure dimension in a balanced way to the rest of the dimensions in the RESILOC

framework (i.e., does not put too much weight on the dimension, while it keeps the variability of the infrastructure types visible).

The infrastructure dimension in the RESILOC resilience indicators is a multifaceted dimension. It not only encompasses several infrastructure types that have their own specificities, but at the same time one needs to be mindful that local communities often have challenges in influencing this dimension, as its management is usually outsourced to the central government and / or private service providers. As an answer to this, the approach for infrastructure undertaken by RESILOC is to seek the level of access of community population to a given infrastructure type.

On one hand, this people-centered approach (Mehvar et al., 2021) is applied in order to ensure that human needs are taken into account. In such a way, the critical infrastructure needs to continuously consider them in cases of emergency and to improve its capacity to “respond” and “recover” considering the human experience of disasters.

On the other hand, using the “who has access” approach used to define the proxies in the infrastructure dimension resonates with (Khazai, Cardona, Carreño Tibaduiza, & Barbat, 2015) and a priori implies the infrastructure’s availability to the people in the community. So in the cases in which access is suboptimal or lacking altogether, communities undergoing an assessment of the infrastructure dimension will be nudged to explore the infrastructure availability as well. The management of infrastructures is not included among the indicators, because: (a) if people have access to given infrastructure, this means that the infrastructure is manager properly and (b) the management responsibility as well as capacity for some types of infrastructure spans outside of the community assessing its own resilience, which would make management indicators uninformative for the communities using the RESILOC tools.

### 6.4.4 Operationalisation of Indicators

As in the other dimensions, indicators allow to be quantitative and qualitative; their proxies can be expressed in absolute or relative terms, or be binary (Poulin & Kane, 2021). In this dimension, the relative ones are preferred as the relative expression makes their assessment insensitive to community size and allow for temporal and spatial comparisons. Moreover, the indicators are chosen to be outcome, rather than process, indicators.

### 6.4.5 Final Discussion and Validation

The discussion and validation step involved the active participation of a representative of a RESILOC local community on 21st December 2021. Part of the proxies were co-created with the representatives of this community.

## 6.5 Development of the DRR Dimension

### 6.5.1 Implemented Methodology

The process of identification and selection of indicators and related proxies deemed relevant for the "Disaster Risk Reduction" (DRR) dimension, partly benefits from the experience gained during the execution of T2.3 - Analysis of the exposed value; which has been useful as preliminary work for the definition of indicators and resilience matrix (T3.1).

For this process of unpacking DRR dimension into its constituent "indicators", the following steps were taken:

- review of the existing frameworks and literature on DRR;
- definition of DRR dimension;
- developing a list of the most relevant indicators according to the frameworks and literature reviewed;
- assigning a description to each indicator, providing a clear link with the DRR dimension and offering a clear rationale;
- operationalisation of the indicators' selection;
- review of the dimension definition and indicators - final discussion and validation.

### 6.5.2 Definition of DRR Dimension

In the RESILOC Resilience framework a "dimension" represents standard areas through which a community is deconstructed for analysis in terms of resilience (i.e., functional areas inherent to a standard community). The framework simplifies the complexity of a community by deconstructing it in 6 dimensions. In this conceptualisation of dimensions, the DRR dimension "*describes the features of the community in terms of frameworks, process and resources dedicated/allocated to risk reduction and the management of emergency situations. Physical resources include, for example, emergency management equipment, temporary housing, rescue equipment, ladders, etc. Organisational resources include both statutory and voluntary organisations"*.

### 6.5.3 Selection of DRR Indicators

In order to realise a preliminary list of relevant indicators for DRR dimension, the work started from the reviewing of the RESILOC Resilience matrix database. The focus was mostly on indicators framed into "DRR & Emergency Management" dimension, consisting in 8 indicators and 127 proxies, drawing from a consistent set of literature.

Some indicators were retrieved from previous work done by IES and Municipality of Catania ("Provisional Indicators for Resilience in RESILOC"), in which indicators and proxies for all the 6 dimensions were listed, including the DRR dimension, and categorised according to hazard specific scenario (e.g., earthquake and flood).

The indicator selection process moved on with an extensive review of approaches developed to measuring and evaluating resilience. This review included similar initiatives world-wide such as the "UNDRR - Disaster Resilience Scorecard for Cities" and "Indicators Bank database" developed for New Zealand Resilience Index (NZRI), from which some indicators were identified and adopted to draw up a preliminary list for the validation process.

At the end of this process, a first consolidated list of indicators for the DRR dimension was drafted, ready to be revised and validated together with community representatives/experts.

The development of a consolidated list of indicators was achieved by user engagement (Catania LRT coordinators). The interaction with users allowed to identify the potential indicators they need, representing the key properties or attributes of the DRR dimension on the basis of their knowledge and experience. These were then compared against indicators available from the literature and previously identified by IES. The comparison allowed to do an

assessment work on the relevance and appropriateness of the identified indicators; at the same time identifying those that were deemed necessary, those that they apparently did not think of but found in the literature and judged interesting, those that should be discarded and possible gaps to bridge.

### 6.5.4 Definition of Indicators' Description and Rationale

Once a first consolidated draft list of indicators has been created, it was provided a short description for each of them, conveying the clear link with the overarching dimension. The description was depicted in such a way that indicators may be assessed on a qualitative (e.g., from high to low) or quantitative/numerical scale (e.g., from 1 to 5).

Likewise, a clear rationale on the reason why each indicator has been included as a key property or attribute of DRR dimension was sketched.

In line with the exercise conducted for the development of the indicators list, some meetings were organised with the users to review the description identified; the aim was to verify that the description provided are clear and ensuring that they fit the indicators selected to assess the DRR dimension. This activity was done by presenting the descriptions elaborated by IES, reviewing them with the users and gathering feedback on what need to be improved. The users were also involved in the co-production of the rationale for each of the indicators identified and in their later revision.

### 6.5.5 Operationalisation of Indicators

The list, once cut down to a suitable number of indicators and confirmed, was subjected to an operationalisation process. Some examples of proxies that could be used to measure or assess each indicator was provided. These has been drawn using proxies identified from assessment frameworks previously reviewed and existing lists already developed by the RESILOC project to date.

### 6.5.6 Final Discussion and Validation

The analysis of what has been produced was finally validated in a dedicated meeting with the Catania Civil Protection PO and the LRT coordinators; they confirmed that the list developed includes what they need to capture of the community from DRR perspective, assuming that may suit in general all RESILOC users.

## 6.6 Development of the Environmental Dimension

At first the definition of the environment dimension was developed. It was based on a review of the literature and our own experience of assessing resilience in environment contexts. This dimension refers to the natural environment and ecosystem assets of the community that affect its resilience to natural hazards. It includes the assessment of two core resilience features. On the one hand, hazard and exposure mapping of the local ecosystem, including local topography, geography, geology, vegetation and biodiversity, to natural hazards. On the other, the supervision of the community's natural capital and ecosystem assets that provide adaptive capacity to community members, support their work and livelihoods and/or protect them from

natural hazards. This includes a recognition that environmental characteristics[6] in one area can affect neighbouring communities and that the weakening of natural capital assets (such as marsh lands, natural fire breaks or floodplains) can lead to communities becoming more exposed to the effects of natural hazards[7]. It is worth noting that the definition was devised both to operationalise the concept of community resilience and to the final list of indicators incorporated in this dimension.

### 6.6.1 Implemented Methodology

The identification and selection of relevant indicators and proxies in the domain of natural environment partially builds upon the work done for T2.1 and T2.2 and our own experience of assessing resilience in natural environment contexts.

This section describes the process of unpacking each dimension into its constituent variables – or 'indicators' – in a systematic and methodologically robust way. Doing this involves the following steps:

- Literature review on natural environment and ecosystem assets of the community that affect its resilience to natural hazards.
- Expert consultation on resilience indicators and proxies.
- Operational definition of environment dimension. [T3.1]
- Selection of the most relevant indicators and proxies according to the previous steps and splitting indicators into "provisioning" indicators and "exposure" indicators. [T3.1]
- Final operationalisation of the dimension definition and selection of indicators and proxies. [T3.1]
- Final Discussion and Validation. [T3.1]

### 6.6.2 Definition of Environmental Dimension

Indicators are frequently used to measure contribution towards accomplishing a desired goal (performance measure). Developed indicators are likely to be clearly understood as decision makers are likely to be conversant with them. In order to make indicators consistent and comparable, we have separated them into "provisioning" indicators and "exposure" indicators.

The environment dimension includes the following list of indicators which together aim to capture the key properties of a community that can affect its resilience to different types of disasters:

*Natural capital sensitivity, maintenance, and preservation:*

- State of forests
- Local food provision
- Drinking water quality/quantity
- Natural resource availability and health

[6] Scherzer, S., Lujala, P., and Rød, J. K. (2019): A Community Resilience Index for Norway: An Adaptation of the Baseline Resilience Indicators for Communities (BRIC). International Journal of Disaster Risk Reduction, 36, p. 101107.
[7] Cutter, S. L., Ash, K. D., and Emrich, C. T. (2014): The geographies of community disaster resilience. Global Environmental Change, 29, pp. 65–77.

- Marshes and wetlands
- Ecosystem fragmentation
- Area of green infrastructure within urban areas
- Air quality

*Hazard exposure:*

- Exposure to flooding and area of operational floodplain
- Exposure to landslides and avalanches
- Exposure to storm surges
- Exposure to strong wind
- Exposure to coastal erosion
- Exposure to forest fire
- Exposure to pollution
- Exposure to heat
- Land use change

Indicators ought to measure how resilient the environment is to hazard by measuring the extent to which the characteristics identified are present or are being achieved. The first stage in identifying indicators is a review of current indicator sets to detect those which have the potential to measure the characteristics (e.g., a natural environment which is diverse, a natural environment can deliver ecosystem services). Though, there is a need to ensure that where current indicators are employed, they are fit for purpose and comply with the evaluation criteria. Moreover, where there are no fitting prevailing indicators, there will be a need to propose and evaluate new or revised ones. Especially for resilience indicators, it is not possible to set quantified targets of how much is enough due to the uncertainty linked with the impacts of hazard/climate change and the response of the natural environment. Hence the proposed indicators are not complemented by any targets. For some indicators, a clue of how to interpret change in the context of resilience is given, for instance, whether an increase in the indicator represents an increase or decrease in resilience. These interpretations will have to be evaluated on a regular basis as the hazard and uncertainty over what constitutes a resilient natural environment is reduced.

### 6.6.3 Selection of Environmental Indicators

After defining each indicator and assessing the relevance and quality of those indicators, the next step elaborates clear rationales for each indicator included, where possible based on existing literature, on the reason for why this indicator has been incorporated as a key property or attribute of this dimension. Preferably, it is based on evidence from earlier studies relating those indicators with higher or lower levels of resilience of a community. This needs to be concise by making a clear link with how any change in that indicator is expected to impact on the resilience of the community.

### 6.6.4 Operationalisation of Indicators

An approach to confirm that the indicators selected to meet the criteria of relevance and validity is to provide some instances of the kinds of proxies that could be used to assess this indicator. Here, we are not looking at a comprehensive list, but instead some examples to illustrate you

have thought through the process of operationalising the dimension and indicator – and that each indicator is measurable, via either quantitative or qualitative measures or proxies.

### 6.6.5 Final Discussion and Validation

The set of indicators and proxies defined following the above presented steps has been the object of an expert consultation process involving the Norwegian Centre on Sustainable Climate Change Adaptation (NORADAPT):

- 8 NORADAPT members, in a face-to-face meeting held by WNRI on 30th November 2021.
- NORADAPT researcher, in an online meeting held by WNRI on 9th December 2021.
- NORADAPT researcher, in an online meeting held by WNRI on 5th January 2022.

The participants clearly assessed the proposed environmental indicators and proxies.

[8] The Norwegian Centre on Sustainable Climate Change Adaptation (Noradapt)

# 7 Results: the RESILOC Indicators Matrix

This section presents the results of the work described in Section 6 above – providing an overview of the current status of the six dimensions that form the current draft of the RESILOC Resilience Indicator Matrix.

## 7.1 Governance

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Multi-stakeholder collaboration | Level of engagement of stakeholders at local level in planning, preparation and response to natural hazards, including local authority, emergency services, community organisations and citizens. | Co-design and planning involving all key stakeholders encourages trust and shared ownership of strategies and solutions to increase resilience to natural hazards. | Is there a multi-agency/sectoral mechanism with appropriate authority and resources to address DRR?[9] |
| | | | Resilience community organization meeting frequency and attendance[10] |
| | | | % of community neighbourhoods with regular DRR meetings[11] |
| | | | How frequently are emergency exercises conducted?[12] |
| Accountability, transparency and ethical conduct | Level of transparency of processes, outputs and outcomes of emergency governance processes and degree of responsibility and accountability of institutions. | Transparency and accountability, as well as the absence of conflicts of interest, are key in delivering effective emergency plans. | Does the local institution have a robust process as set out in its legal framework, to remedy against maladministration and against actions of local authorities which infringe civil rights, in accordance with rules, regulations and best practice?[13] |
| | | | Do local institutions prepare regular public reports (at least annually) to |

[9] UNDRR, 2017
[10] UNDRR, 2017
[11] UNDRR, 2017
[12] UNDRR, 2017
[13] Council of Europe, 2008

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | account for the decisions they have taken?[14] |
| | | | Is there a process for appealing against decisions which is widely available and understood?[15] |
| Citizens' participation | Level of promotion of citizen participation through information, consultation, dialogue and partnership activities, at all levels and stages of DRR policy making process. | Citizens' participation allows for the sharing of relevant knowledge, the active involvement of local population in self-protection activities and contributes for the lowering of social conflicts. | % voter participation in the last election[16] |
| | | | Community Engagement Score[17] |
| | | | % of individuals from minority, disenfranchised, and non-mainstream groups involved in community-planning and leadership[18] |
| Building regulations and licences | Presence and quality of regulative tools which allow for the control of the built environment, both in terms of quantity and quality of the buildings. | Building regulations and licences incorporate many features which are relevant in terms of territorial resilience, i.e., building quality, localisation choices, land use provisions. | Building inspection establishments per 1,000 persons[19] |
| | | | Are zoning rules, building codes and standards widely applied, properly enforced and verified?[20] |

[14] Council of Europe, 2008
[15] Council of Europe, 2008
[16] Cutter & Emrich,2010, Council of Europe, 2020
[17] Parsons et al., 2020
[18] Magis, 2010
[19] Brody et al., 2010
[20] UNDRR, 2017

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | Are sustainable building design standards such as REDi, LEED, GreenStar and BREEAM implemented so to improve resilience?[21] |
| Risk awareness and financing | Presence of provisional and financial tools to protect human properties from disasters' effects. | An adequate definition of provisional and financial covering instruments would allow for better adaptation and mitigation strategies. | Infrastructure and housing insurance as a % of GDP[22] |
| | | | % of households covered by insurance[23] |
| | | | Are hazards maps available?[24] |
| Responsiveness, efficiency and effectiveness | Degree of adaptation of objectives, rules, structures, and procedures to the legitimate expectations and needs of citizens and to the foreseen objectives, taking in account the amount and typology of available resources. | Responsiveness, efficiency and effectiveness constantly improved in a community constitute relevant resources in times of crisis too. | Does an organisation of emergency response, with coordination authority, exist?[25] |
| | | | Are changes in policy and service delivery informed by research, reports, consultations, complaints and other methods of input? Are such changes adequately publicised?[26] |
| | | | Are all major services and functions regularly reviewed at appropriate |

[21] UNDRR, 2017
[22] Cardona, 2005
[23] UNDRR, 2017
[24] Eidsvig et al., 2011
[25] Eidsvig et al., 2011
[26] Council of Europe, 2008

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | intervals, so to evaluate their performance and impact?[27] |
| Competence, capacity, innovation | Degree of embeddedness of methods and procedures to transform skills into capacity and to produce better results. Degree of experimentation aimed at producing new and efficient solutions, in a climate favourable to change. | The capability of a community to adapt itself to new and partly unexpected scenario, as a result of new combination of resources stemming from ongoing and structured solutions constitutes a strategic feature when facing a natural hazard. | Is there a local institutions workforce training plan, implemented and monitored to ensure that training needs are fully met, in action?[28] |
| | | | Are land use and zoning regulations appropriate?[29] |
| | | | Is the city strategic plan reviewed on a regular basis?[30] |
| | | | Do local institutions identify the skills needed to deliver its services effectively, also through skills audit to identify any gaps?[31] |
| | | | Do local institutions take action to identify and implement examples of good practice and new solutions?[32] |

[27] Council of Europe, 2008
[28] Council of Europe, 2008
[29] City Resilience Index, 2015
[30] UNDRR, 2017
[31] Council of Europe, 2008
[32] Council of Europe, 2008

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | Do local institutions have a structured approach to innovation, research and development?[33] |
| Sustainability and long-term orientation | Level of sustainability of the community, also through time, i.e., taking into account the needs of future generations. Presence of a broad and long-term perspective at the basis of all decisions, especially from a financial management point of view. | Multi-dimensional sustainability is a key factor in building community preparedness against natural hazards. The possibility to access to saved and/or renewable resources in time of crisis may help to activate different coping strategies. | Do local institutions take part in an inter-municipality organisation in order to improve its performances and its services to the citizens?[34] |
| | | | % of Governmental and external funds available per community member[35] |
| | | | Do local institutions grasp all sources of funding as well as available routes to attract external funding?[36] |
| | | | Does a capital financing plan exist, that ensures the long-term viability of the infrastructure and assets of the community?[37] |
| | | | Do local institutions have a structured approach to long term development?[38] |

[33] Council of Europe, 2008
[34] Council of Europe, 2008
[35] Moore et al., 2013
[36] UNDRR, 2017
[37] Council of Europe, 2008
[38] Council of Europe, 2008

## 7.2 Social

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Community engagement | Level of engagement of the local population in the community, including volunteering and attending community groups and events. | Civic engagement facilitates collective action for mutual benefit and helps citizens to adaptively learn and transform in the face of threats or hazards. | % of population who vote in local elections<br>Number of NGOs per 1000 population for pre and post-disaster response<br>% of population undertaking voluntary work<br>% of population actively engaged in such NGOs |
| Social connectedness | The extent to which the local population feel connected and are willing to provide support to each other and in particular to more vulnerable members of the community. | Communities that feel connected and support each other are better at recovering from disasters and also more able to ensure that the most vulnerable are supported and protected during or after a crisis. | % of population willing to lend to and borrow from others<br>% of population who have a friend or relative they can rely on for help if they have a serious problem<br>% of population willing to help each other in everyday situations<br>% of population willing to help each other in times of crisis |
| Trust in authority | The level of trust citizens have in their local authority representatives and emergency services. | High level of trust is associated with citizens being more likely to follow guidelines and instructions before, during or after an emergency to keep themselves and others safe. | % of population aware of and believing in the effectiveness of NGOs in their community or area<br>% of population who trust and believe in information shared by their authority |
| Place attachment | This describes the extent to which citizens in the community feel a sense of belonging to where they | Place attachment encourages citizens to invest time and energy to improve | % of population with close relationships with others, such as family, friends, neighbours |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | live and have strong links with their neighbours and neighbourhood they live in. | resilience of their community … e.g. by engaging in resilience activities, etc. | The extent to which there is a strong community-wide identity and culture<br><br>% residents in same residence for greater than 5 years<br><br>% of population living in the area for 10+ years |
| Community competence | This describes the extent to which citizens have relevant skills or competences to protect themselves and others before, during or after an emergency. | Citizens with high levels of disaster relevant skills or competences are more likely to be able to take steps to protect themselves and others before or during a disaster. | % of households have received education or acquired skills relating to coping with local disasters<br><br>% of population who feel confident in their ability to self-organise in the event of a natural disaster.<br><br>% of population who feel responsible for their own safety in the event of a natural disaster.<br><br>% of population who trust their own ability to protect themselves during a natural disaster. |
| Adaptive behaviour | This describes the extent to which citizens have taken active steps to protect themselves and their property from the negative impacts of disasters. | Higher levels of adaptive behaviour in communities are associated with increased resilience in communities in the face of natural hazards. | % of population who actively participate in a local organisation that aims to prepare for disasters.<br><br>% of population who have insurance cover to protect them from the negative effects of disasters. |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | % who have taken steps to prepare themselves in case of a disaster affecting their home.<br><br>Count of preparation activities (CPR training, first aid training, created a personal plan to be used in case of emergency, prepared an emergency kit for natural disasters, discussed how to prepare for a disaster with someone else, attended meetings to learn how to prepare for a disaster) |
| Risk awareness | This describes the extent to which citizens are aware of different potential hazards and their likelihood and know what to do to mitigate the effects of such hazards. | A community's engagement with, and awareness of, the hazards it faces will enable them to plan and act to reduce the harmful impact of a hazard on their livelihoods and well-being. | % of population that expect to experience a natural disaster over the next 3 years that will put them in danger<br><br>% of population that are afraid that they or someone close to them will be directly affected by a disaster<br><br>Level of awareness of most likely risks to community among population |

## 7.3 Economic

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Macro-economic diversity | The diversity of productive sectors and industries in a given community. | A regional economy reliant on a small number of sectors, industries, or businesses is more likely to be heavily impacted by the collapse of one or more of those sectors following a disaster. | % of economic output attributed to different sectors. |
| | | | % of SME businesses relative to total number of businesses. |
| | | | % distributions of manufacturing, resource extraction, and service businesses in the community. |
| Community Economic Capital | The economic capital of the community, including factors such as employment, wealth and income. | A community with high levels of capital is more likely to be resilient in the face of disaster, owing to the higher levels of capital resources and household economic security so as to withstand and recover from the economic shocks of disaster. | Economic Diversity Index |
| | | | % of employment in largest single employment sector |
| | | | Ratio of large to small businesses |
| | | | Employment concentration |
| | | | % of the workforce in informal employment |
| Disaster Risk Financing | Accessibility and strength of household and non-domestic insurance in the community for damage and losses suffered as a result of natural disasters. This also refers to the provision of resilience incentives for business owners, community organisations, and citizens. | High levels of insurance cover and resilience incentives cover means that a community is more likely to recover from a disaster more quickly. Insurance can help withstand the immediate shock of disaster, while resilience incentivisation can help ensure | % of domestic properties with insurance coverage for high-risk hazards |
| | | | % of business properties with insurance coverage for high-risk hazards |
| | | | Infrastructure and housing insurance as a % of GDP |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | that businesses/households are fiscally prepared. | |
| Household access to savings and credit | The accessibility of and strength of household savings and credit lines in a given community. | A community that has strong, rapidly accessible reserves of funds or credit lines is more likely to withstand the immediate and long-term economic disruption that may arise from a disaster. | % of population with rapidly accessible deposit account<br>% of population with rapidly accessible credit lines |
| Division of labour | Articulation of the labour market according to different criteria (gender, economic sector, level of specialisation) | Division of labour has direct and indirect effects on the resilience of economic systems, in terms of modularity and redundancy of available resources (including labour force as a resource). | % of population dependent on the land for primary source of income<br>% of population employed in SMEs (small and micro) as share of total employed force |
| Easy of doing business | Numerous countries promote firm's development because they create jobs, reducing unemployment, and they generate innovation, explore new markets, and define the way to provision of jobs in the future; they are also a way of commercializing new ideas and technologies.<br>Entrepreneurial ecosystems require sophisticated financial | One of the significant economic contributions made by start-ups is job creation; the average number of new employees varies (as one might expect) according to the stage of development of the start-ups.<br>Financial capital related to funds provided by lenders (and investors) is necessary for entrepreneurship in a territory. | % of population with accessible entrepreneurship education and/ or capacity building programmes (public or private)<br>% of population with accessible public fund to new venture creation<br>% of population with accessible pre-seed and/or seed capital<br>% of start-up with accessible funds provided by investors |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | markets that can provide access to capital for private sector investment from the banking sector, well-regulated securities exchanges, venture capital, and other financial products. | The presence and quality of programs directly assisting SMEs at all levels of government (national, regional, municipal) is relevant to capacity building. | % of early-stage companies with accessible financial capital to growth |
| Labour market efficiency | The industrial district approach emphasizes the local division of a pool of competent labour in an ecosystem. Knowledge capital reflects the activity of sharing specific mindsets and skills associated with entrepreneurship as well as education and training programs that seek to stimulate entrepreneurship. | As a local economy develops, factors related to a more skilled labour force and a more efficient labour market come into play. Young workers, such as university graduates, are often willing to take risks. Additionally, they have the capacity to acquire entrepreneurial skills. Hence, a younger labour force can be positively associated with new firm creation | Employment rate (excluding agriculture) - Persons employed aged 15-64 (excl. agriculture) as % of population same age cohort |
| | | | Unemployment rate - % of active population |
| | | | Labour productivity - GDP (ml euro pps) / hours worked (thousand) - EU28=100 |
| | | | % of population aged 15-24 not in education, employment or training |
| | | | Involuntary part-time /temporary employment - Share of population aged 20-64 in involuntary part-time or temporary job |
| Market size | Market size, a part from contributing to financial capital, is an important contributor of knowledge capital since it can be a driver for innovation. Large markets can generate greater technological spillovers and knowledge exchange among heterogeneous entrepreneurs and workers and from better | Market size drives the accumulation of institutional capital, and also of knowledge capital and social capital. These support structures offer professional service network and quality connections to universities and/or competence centers | Disposable income per capita - Net adjusted disposable household income in PPCS per capita (index EU28=100) |
| | | | Potential market size expressed in GDP: index GDP (pps) EU28=100 - EU28 average computed as population weighted average of the NUTS2 values |
| | | | Potential market size expressed in population - index population EU28=100 |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | matching in labour market pooling. | improving also the quality of the human capital. | |
| Entrepreneurship | Defined as the process of starting and running a new business.<br><br>There is a broad consensus that the likelihood of becoming an entrepreneur is not only influenced by individual characteristics but also by context. However, context factors are not stable per se; they tend to vary over time, particularly with regard to economic cycles.<br><br>Successful entrepreneurs can act as role models in their communities and can provide advice or act in a variety of stakeholder roles.<br><br>Entrepreneurial role models (knowing entrepreneurs) in the same region strongly influence the adults' decision to start a business, as well as reducing the adults' fear of failure. In these challenging times, the analysis of role models is critical in understanding entrepreneurial behaviours and actions. | Entrepreneurial activity is of primary importance to drive economic recovery: individuals that are currently making the decision to start and/or to grow a business are ultimately creating jobs and incomes, adding value to society and strengthening economies in the post-crisis recovery period.<br><br>Evidence has shown that uncertain economic cycles influence the type and number of new entrepreneurs who are motive-related (either opportunity-driven or necessity-driven). It is reasonable to assume that the human nature of the crisis situations will be embedded in the startup's motivation. | Level of Total early-stage Entrepreneurial Activity (TEA): % of adults population (aged 18-64) actively engaged in starting or running a new business.<br><br>% of adults population (aged 18-64) Total early-stage Entrepreneurial Activity (TEA) precepting how easy it is to start a business.<br><br>% of adults population (aged 18-64) Total early-stage Entrepreneurial Activity (TEA) showing the intentions to create new businesses driven by crisis.<br><br>% of adults (aged 18-64) which perceive that "there are good opportunities to start a business in the area where I live". |

## 7.4 Infrastructure

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Energy grid access for individuals[39] | This indicator shows how well the energy grid covers the population living in a given community, irrespective of community and energy grid specificities. | It is crucial to understand how well the population is connected to the energy grid, as this has an effect on the steepness of the resilience curve during a disaster. | % of houses connected to the gas grid |
| | | | % of houses connected to the electricity grid |
| | | | Number of gas stations per 1000 inhabitants |
| | | | % of houses with alternative electric sources |
| Energy grid access for the business and public institutions[40] | This indicator shows how well the energy grid covers the business and public institutions in a given community, irrespective of community and energy grid specificities. The indicator is | It is crucial to understand how well businesses and public institutions are connected to the energy grid, as this has an effect on the steepness of the resilience curve during a disaster. | % of businesses connected to the gas grid |
| | | | % of public institutions connected to the gas grid |
| | | | % of businesses connected to the electricity grid |

[39] Based on D2.3; United Nations, 2021; Kumar, Ghosh, & Chopra, 2020; International Energy Agency, 2020:
International Energy Agency. (2020, October 13). *Defining energy access: 2020 methodology.* Retrieved from International Energy Agency: https://www.iea.org/articles/defining-energy-access-2020-methodology
Kumar, N. M., Ghosh, A., & Chopra, S. S. (2020, April). Power resilience enhancement of a residential electricity user using photovoltaics and a battery energy storage system under uncertainty conditions. *Energies, 13*(16). doi:10.3390/en13164193
United Nations. (2021). *Theme report on energy access: towards the achievement of SDG 7 and net-zero emissions.* Retrieved from UN: https://www.un.org/ohrlls/sites/www.un.org.ohrlls/files/technical_working_group_1_energy_access_report_2021.pdf

[40] Based on D2.3 and International Energy Agency, 2020.

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | measured as a ratio. It is differentiated from the access to individuals as businesses and public institutions need more complex access compared to individuals. | | % of public institutions connected to the electricity grid |
| | | | % of public institutions with alternative electric sources |
| Interdependence between infrastructure systems[41] | The indicator shows whether different infrastructure systems are coupled with each other. | The more the energy grid is coupled with other infrastructure systems, the less resilient it is. | % of annual downtime of electricity grid (in days) that is due to downtime of another infrastructure system |
| | | | % of annual downtime of gas grid (in days) that is due to downtime of another infrastructure system |
| | | | % of annual downtime of oil grid (in days) that is due to downtime of another infrastructure system |
| | | The more the water infrastructure system is coupled with other infrastructure systems, the less resilient it is. | % of annual downtime of water supply system (in days) that is due to downtime of another infrastructure system |

[41] Based on Cutter, et al., 2008 and UNDRR, 2017:
Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008, October). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change, 18*(4), 598-606. doi:https://doi.org/10.1016/j.gloenvcha.2008.07.013

UNDRR. (2017, May). *Disaster resilience scorecards for cities.* Retrieved from UNDRR: https://mcr2030.undrr.org/sites/default/files/2021-08/UNDRR_Disaster%20resilience%20scorecard%20for%20cities_Detailed_English_Jan2021.pdf

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | The more the financial infrastructure is coupled with other infrastructure systems, the less resilient it is. | % of annual downtime of cash withdrawal system (in days) that is due to downtime of another infrastructure system |
| | | Internet is, for example, dependent on electricity supply. In case of electricity outage, internet connection may also suffer temporary outages in case the electricity grid has been damaged by a hazardous event. This would diminish its redundancy use and the possibility of people to communicate with others, especially upon failure of the other communication means. | % of annual downtime of internet connection (in hours) that is due to downtime of another infrastructure system |
| | | Mobile communication is dependent, for example, on the electricity supply. It may suffer temporary outages in case the electricity grid has been damaged by a hazardous event. This may lead to disruption to the ability to alarm authorities about a hazard, as well as to disruption of coordination of rescue activities during and after a hazardous event. | % of annual downtime of mobile connection system (in hours) that is due to downtime of another infrastructure system |
| | | Healthcare is dependent on, for example, electricity supply, oil supply, transport routes and their redundancy and means of transport. There might be temporary | % of annual downtime of vital medical equipment (in days) that is due to downtime of another infrastructure system |

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | limited access to point of care in case of disaster. In the case of a hazardous event, the percentage of people with access to point of care may decrease or even be =0, which is important when setting targets in the anticipation and preparedness phases. | % of people with no access to medical services |
| | | Supply chains depend on the electricity supply, oil supply, routes and their redundancy, and means of transport. There might be temporary limited (interrupted) supply of vital products and medicines due to outage of those systems. It is important for the community to plan for a certain stock of vital products and supplies. | % of annual interruptions of vital products supply (in days) that is due to downtime of another infrastructure system |
| | | | % of annual interruptions of vital medicines supply (in days) that is due to downtime of another infrastructure system |
| Transport routes redundancy[42] | Transport route redundancy is defined as access to alternative transport environments in a reasonable amount of time. | It would be the main means of communication in case of a hazardous event, including coordination of rescue activities. | % of people with access to alternative transport routes |
| | | | N. of land transport routes to enter / exit the community |
| | | | N. of water transport routes to enter / exit the community |

[42] Based on Zurich Flood Resilience Alliance, 2019 and Arup, 2015:
Arup. (2015, December). City Resilience Framework. Retrieved from Rockefeller Foundation: https://www.rockefellerfoundation.org/wp-content/uploads/City-Resilience-Framework-2015.pdf
Zurich Flood Resilience Alliance. (2019). The Flood Resilience Measurement for Communities (FRMC). Retrieved from Zurich Flood Resilience Alliance: http://repo.floodalliance.net/jspui/bitstream/44111/2981/7/1027-PA-ZFRP-AdHoc-UK-V2a-WEB.pdf

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | N. of air transport routes to enter / exit the community |
| Transport means access[43] | This indicator measures the level of access of individuals to means that can be used on the different routes available in the community. | Even if there are routes accessible to the individuals in the community, it also matters to what extent individuals can make use of those routes. Lack of access to transport means negatively affects the access to timely healthcare, education, and the participation in economic life in general. | % of people in the community who have their own means of transport |
| | | | % of people who have access to public transport |
| | | | % of people who can use private means of transport (not their own) |
| Water access[44] | This indicator shows how well the water infrastructure system covers the population living in a given community, irrespective of community and energy grid specificities. The indicator includes access to public potable water (incl. purified water), private potable water and sewage. | A community with higher access to water and sanitation is more resilient during hazardous events and faster in the recovery phase. | % of people in the community who have access to public potable water sources |
| | | | % of people in the community who have own potable water sources (tanks, wells, etc.) |
| | | | % of people in the community who have access to public sewage |

[43] Based on United Nations. (2021). *Sustainable transport, sustainable development: Interagency report, Second Global Sustainable Transport Summit*. Retrieved from SDGs UN: https://sdgs.un.org/sites/default/files/2021-10/Transportation%20Report%202021_FullReport_Digital.pdf

[44] Based on Jovanović, et al., 2016 and Yu, et al., 2021:

Jovanović, A., Klimek, P., Choudhary, A., Schmid, N., Linkov, I., Øien, K., Lieberz, D. (2016). Analysis of existing assessment resilience approaches, indicators and data sources: Usability and limitations of existing indicators for assessing, predicting and monitoring critical infrastructure resilience. In IRGC, Resource Guide on Resilience. Lausanne: EPFL International Risk Governance Center.

Yu, W., Rex, W., McCartney, M., Uhlenbrook, S., von Gnechten, R., & Delli Priscoli, J. (2021, February). Storing water: A new integrated approach for resilient development. Retrieved from GWP: https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/perspectives-paper-on-water-storage.pdf

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| | | | % of people in the community who have access to private sewage |
| | | | Community water storage volume (cubic metres) |
| Access to cash[45] | This indicator shows how well the infrastructure enables individuals in their cash positions. | The access to cash forms is at the basis of financial infrastructure and largely determines access to other infrastructures in times of disaster. | % of people with access to cash withdrawal (ATM) |
| | | | % of people with access to human service cash withdrawal |
| Disaster risk financing[46] | This indicator shows the level of coverage of disaster risk financing in a community. | The indicator provides the basis for making an analysis as to how well the community will build back better. | % of people using private insurance |
| | | | % of public infrastructure that is insured |
| Internet connection access[47] | Internet connection is one of the modes of communication with the rest of the world and an important service to the population. | It is a redundant mean of communication in case of outage of other means. | % of people in the community who have internet connection access |
| | | | % of people in the community who have broadband internet connection access |

[45] Based on Jacobsen, K., Marshak, A., & Griffith, M. (2009, December). *Increasing the Financial Resilience of Disaster-affected Populations.* Retrieved from ALNAP: https://www.alnap.org/system/files/content/resource/files/main/increasing-financial-resilience-2009.pdf
[46] Based on D2.2 and Wolfrom, L., & Yokoi-Arai, M. (2015). Financial instruments for managing disaster risks related to climate change. *OECD Journal: Financial Market Trends, 2015*(1). Retrieved from OECD: https://read.oecd-ilibrary.org/finance-and-investment/financial-instruments-for-managing-disaster-risks-related-to-climate-change_fmt-2015-5jrqdkpxk5d5#page1
[47] Based on The Resilience Index. (2021). The Composite resilience index: A modelling tool to measure the resilience of local communities to climate extremes. Retrieved from The Resilience Index: https://theresilienceindex.weebly.com/our-solution.html

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Mobile connection access[48] | Mobile connection is one of the modes of communication with the rest of the world and a vital service to the population. | It would be the main means of communication in case of a hazardous event, including coordination of rescue activities. | % of people in the community who have mobile connection access |
| | | | % of people in the community who have mobile internet connection access |
| Radio communication[49] | Radio connection is means of communication with the rest of the world in areas where there is no coverage by any other means. Radio waves travel much farther than an LTE broadcast and thus it can reach as many people as possible. | It is a redundant (often last resort) means of communication in case of outage of all other means in very large-scale hazards, like fire. | % of people in the community with access to radio broadcasting device |
| | | | % of people in the community with access to radio transmitting device |
| Early Warning Systems (EWS) access[50] | The EWS are an important element of disaster anticipation and preparedness, in particular at minimizing loss and damage. | The EWS are important for the anticipation and preparedness, as well as for limiting the damages from disasters. | % of people in the community reached by EWS |
| | | | % of people in the community who have passed a drill on emergency evacuation in the past 3 years |

[48] Based on Tariq, H., Pathirage, C., & Fernando, T. (2021). Measuring community disaster resilience at local levels: An adaptable resilience framework. International Journal of Disaster Risk Reduction, 62, 102358. Retrieved from https://www.sciencedirect.com/science/article/pii/S2212420921003241
[49] Based on Coile, R. C. (1997). The role of amateur radio in providing emergency electronic communication for disaster management. Disaster Prevention and Management: An International Journal, 6(3), 176–185. https://doi.org/10.1108/09653569710172946
[50] Based on United Nations Office for Disaster Risk Reduction. (2015, June 3). Implementing the Sendai Framework. Retrieved December 8, 2021, from United Nations Office for Disaster Risk Reduction: http://www.preventionweb.net/files/resolutions/N1516716.pdf

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Medical capacity[51] | Medical capacity is the ability of the healthcare system to care for all people in need. | Disasters may lead to a lot of injured people seeking health and a sudden shortage of capacity. It is important to make sure (anticipation and preparedness) that all potentially injured people will have timely have access to emergency and usual medical care. | Number of medical staff per 1000 inhabitants in the community |
| | | | Number of ambulances per 1000 inhabitants in the community |
| | | | Number of hospital beds per 1000 inhabitants in the community |
| | | | % of people with access to medical services |
| | | | Time to arrive at a point of care (minutes) |
| | | | % of people with immediate access to first aid |
| Vital products and medicines supply chains redundancy[52] | These include food, drinks and staple goods supply (vital products) and medicines. | Food and water are indispensable for survival.<br>Disaster may cause a shortage of vital product supplies.<br>Some people may take medicines due to chronic illness. Disaster may cause an increased need of medicines. | % of people with uninterrupted access to vital products |
| | | | % of people with uninterrupted access to medicines |
| | The presence and quality of protective infrastructures designed to mitigate the | | % of population protected by structural disaster risk measures for flood |

[51] Based on The Resilience Index 2021.
[52] Based on Zurich Flood Resilience Alliance, 2019.

| Indicators | Description | Why is this important? | Example proxies |
|---|---|---|---|
| Structural disaster risk measures[53] | impact of natural disasters such as sea walls, flood plains. | Protective infrastructures provide more time for evacuation in case of disaster and thus mitigate the impact. | % of population protected by structural disaster risk measures for snow storm |
| | | | % of population protected by structural disaster risk measures for landslide |
| | | | % of population protected by structural disaster risk measures for wildfires |
| Shelter capacity[54] | Shelter is a protective infrastructure that can accommodate people in case of large-scale damage of the buildings (private homes) or if their own homes do not provide sufficient protection from the disaster. | It is important to know the capacity, in order to know how many people can be protected in case of disaster threatening the entire community. This can be used as a target for anticipation and preparedness measures. | % of population that can be accommodated by public shelters |
| | | | % of population that can be accommodated by private shelters |
| | | | N. of days public shelters can operate at 100% capacity taken |
| | | | N. of days private shelters can operate at 100% capacity taken |

[53] Based on UNDRR. (2017, May). Disaster resilience scorecards for cities. Retrieved from UNDRR: https://mcr2030.undrr.org/sites/default/files/2021-08/UNDRR_Disaster%20resilience%20scorecard%20for%20cities_Detailed_English_Jan2021.pdf
[54] Based on The Resilience Index 2021 and UNDRR, 2017.

## 7.5 Disaster Risk Reduction (DRR)

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| Infrastructure Resilience | Identifies the capacity to restore community infrastructure service for key critical assets (water, electricity, gas, transportation services). | Useful for the assessment of the community's capacity to recover the full operability of critical services, in response to the service interruption caused by different reasons. | "Electricity critical asset (ECA) loss factor". If: a = estimated # of days to restore regular service area-wide and b = % of critical assets affected… then ECA loss factor = a x b |
| | | | "Gas loss factor". If: a = estimated # of days to restore regular service area-wide and b = % of user accounts affected… then gas loss factor = a x b. |
| | | | "Water/sanitation loss factor". If: a = estimated # of days to restore regular service area- wide and b = % of user accounts affected… then water/sanitation loss factor = a x b. |
| | | | Airport loss factor. If: a = estimated # of flights in and out per day possible after the disaster and b = max # of flights per day in normal operations and c = # of days estimated before restoration of full capacity…then airport loss factor = (a/b) x c as a %. |
| | | | Estimated # of days' disruption to critical administration services under "most probable" and "most severe" scenarios, given availability of redundant facilities, support staff etc. |
| | | | Rail loss factor (for rail, use tons; for metro, use passengers). If: a = carrying capacity (tons or passengers per day) of affected rail lines to the city and b = # of days estimated before reopening and c = carrying capacity (tons per day per hour) of all rail |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| | | | links to the city…then RCA loss factor = (a/c) x b as a. |
| | | | River/seaport loss factor. If: a = estimated # of dockings per day possible after the disaster and b = max # of dockings per day in normal operations and c = # of days estimated before restoration of full capacity… then River/seaport loss factor = (a/b) x c as a %. |
| | | | Road loss factor – If: a = miles of major road network for city and surrounding area at risk of becoming impassable to any type of vehicle after event and b = likely number of days estimated before reopening and c = total of major roads in the city and surrounding area lost for one day…then road loss factor = (a/c) x b as a %. |
| Mitigation plan | identification of the local population coverage by regulations to safeguard and mitigation against both natural and human-related hazards. | to improve the protection and safeguarding of the population and to protect the main economic and cultural assets of the community | % of population covered by building codes. |
| | | | % of population covered by comprehensive plans |
| | | | % of population covered by government approved mitigation plans |
| | | | % of population covered by zoning regulations per 1000 persons |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| Planning and preparation | Assessment of the community's preparedness level against expected hazards, understood in terms of land and services covered by plans to monitor existing hazards and manage associated risks, as well as facilitate/foster continuity of existing services in response to a disaster - a better preparedness level typically indicates a higher level of resilience. | The availability of updated plans, especially those identifying the existing hazards and managing potential associated risks, is an important factor in terms of preparedness against specific events. It allows access to organised information, useful to understand potential events and improve the efficiency of emergency management by all stakeholders. In addition, the presence of essential services covered by continuity plans, helps to preserve these services in case of disaster, facilitating the recovery phase. | Calculated as the area of the city covered by publicly available hazard maps in square kilometres divided by the total city area in square kilometres then multiply by 100. |
| | | | Calculated as the total number of city-wide disaster-management plan updates that occurred in the previous 5 years divided by five. |
| | | | Calculated as the total number of essential service providers that have a documented business continuity plan divided by the total number of essential service providers then multiply by 100. |
| | | | Calculated as the total number of essential services that are covered by a documented continuity plan divided by the total number of essential services provided in the city by government entities then multiply by 100. |
| | | | Calculated as the volume of city electronic data with secure and remote back-up storage divided by the total volume of electronic city data then multiply by 100. |
| Population awareness and skills | Assessment of the population's level of awareness about the tools and resources available to cope with disasters; as well as the knowledge, skills, and abilities acquired to protect against, cope | A population's ability to adopt self-protective behaviours, measures, and strategies is an important driver of risk reduction. This capacity comes from the acknowledgement of the tools and | % of households aware of and believing in disaster management plans by the government |
| | | | % of households having received education or acquired skills relating to local risks, preparation and protection |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| | with, and recover from local hazards. | the acquisition of information on how to protect against and recover from local risks, developing a greater awareness towards possible disasters (also learning from previous disaster experiences) and promoting an increase of resilience. | % of households having received education or acquired skills relating to recovery procedures from disasters |
| | | | % of population aware of the availability of disaster information, such as early warning systems |
| | | | % of population having learned from previous disaster experiences and taking action against future crises |
| Efficiency and Effectiveness | Evaluation of the community's level of effectiveness and efficiency, measured through the implementation of practices aimed at monitoring performance and interchange of best practices. These performed in order to improve the effectiveness of their strategies and the definition and implementation of future public policies. | The efficiency and effectiveness evaluation of a community, is a useful factor for the overall improvement of a community's vulnerability; understood in terms of willingness to constantly review and evaluate services provided and establishment of policies to improve performance by implementing new practices. | All major services and functions are regularly reviewed at appropriate intervals, to evaluate their performance and impact.<br><br>(qualitatively expressed as:<br>0 - no reviewing scheduled;<br>0.25 – reviews are carried out irregularly;<br>0.50 – reviews are planned and carried out on some services and functions;<br>0.75 - reviews are planned and carried out on major services and functions performances and with no impact assessment;<br>1 - reviews are planned and carried out on major services and functions performances and impact assessment) |
| | | | The municipality exchanges good practises with other municipalities and uses this information to improve its own efficiency and effectiveness.<br><br>(qualitatively expressed as:<br>0 - no exchange of good practises; |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| | | | 0.25 – exchange of good practises is not systematic;<br>0.50 – exchange of good practises are carried out without impacting on the services provided;<br>0.75 - exchange of good practises are carried out with impacts on the services provided;<br>1 - exchange of good practises are carried out and increased efficiency and effectiveness are assessed) |
| | | | The municipality takes into account the results of its evaluations on order to implement its future public policies.<br><br>(qualitatively expressed as:<br>0 - no evaluations are carried out;<br>0.25 – evaluations are not followed by action plans;<br>0.50 – evaluations are taken into account for updating operational procedures;<br>0.75 - evaluations are taken into account for updating plans and budgets ;<br>1 - evaluations are taken into account for future policies) |
| Building regulation and standards | Enforcement level of building regulations designed to mitigate natural risks and aimed at reducing impacts on the environment and urban structure. | The availability of zoning and land use regulations, as well as the existence of building standards, is potentially an important parameter in addressing natural hazards and reducing impacts on the environment and urban structure. However, the extent to which these rules and codes are | Are zoning rules, building codes and standards widely applied, properly enforced and verified? (qualitatively expressed as:<br><br>0 - no zoning rules;<br>0.25 - existing zoning rules and building codes;<br>0.50 - existing and applied;<br>0.75 - existing, applied and enforced;<br>1 - existing, applied, enforced and verified) |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| | | enforced is equally relevant, as their non-application or limited application could result in a failure or partial achievement of the purposes behind them. | Extent to which land use zoning is enforced (expressed as quintiles). |
| | | | Guidelines in place for all constructions and land-use activities to ensure minimal risk to exposed population (expressed as quintiles). |
| | | | Implementation of building codes on relevant structures (expressed as quintiles). |
| Protective infrastructure | Level of territorial protection in the form of infrastructures designed to reduce potential damage to people and goods from natural and man-made hazards. | The existence of adequate, effective and well-maintained protective infrastructures designed to protect against specific or multiple hazards, reduces the vulnerability of exposed value (people and assets). | Structural mitigation measures in place and operational to protect against hydrological related hazard threats (e.g., embankments, flood diversion channels, water harvesting tanks, etc.). |
| | | | Structural mitigation measures in place and operational to protect against hydrogeological hazard threats (e.g., consolidation structures, crib walls, reinforced concrete walls, etc.). |
| | | | Structural mitigation measures in place and operational to protect against fire-related hazard threats (e.g., firebreaks). |
| Environmental management practices for sustainability/disaster or climate resilience/ mitigation | Level of investment in environmental management practices and policies designed to promote sustainability and development that emphasize the capacity of the natural environment to absorb, mitigate, and facilitate recovery from various hazards. | Investing in the community's public environmental resources by projecting improvements in their management and effectiveness in mitigating impacts from natural hazards, fosters the community's ability to absorb, mitigate and recover from possible impacts. | Level of local/regional government spending on environmental maintenance/regeneration with hazard resilience co-benefits projects per capita |
| | | | Proportion of high hazard areas that are undeveloped public lands, such as parks, forests or preserves. |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| DRR and emergency knowledge/ training/preparedness | Level of knowledge, preparedness and skills of community members about local hazards, emergency preparedness and mitigation strategies (emergency plans) and disaster response; derived from awareness campaigns, training activities and/or personal experience. | The knowledge and experience that people in a community possess in emergency preparedness (derived from previous disaster experiences as well), constitutes relevant factors towards the development of appropriate behaviour and beneficial for mitigation of local hazards and related risks. | % of people who have experience with disasters (estimated based on the duration of residence of a specific household in a hazard-exposed area) |
| | | | % of community members informed about publicly available disaster plans (0% - if disaster plans are not available). |
| | | | % of community members that are trained in disaster response/search & rescue and first aid and CPR and are willing to help in emergency situations. |
| | | | % of community members who know about facilities/services/skills available pre-, during and post-emergency, and how to access these. |
| | | | % of community members have emergency supplies at home, work and in their cars. |
| | | | % of community members can recognize warning signal(s) (e.g., emergency sirens) and know what to do. |
| Early warning and DRR communication /information dissemination | Degree of population interception via early warning systems and other communication and information dissemination systems for risk reduction and response. | To reduce the impact of possible hazards on the population of a community, the use and efficiency of early warning systems (population covered and effective understanding by the public) and other forms of communication and information dissemination are important factors to assess. | % of population covered by awareness raising and preparedness programs facilitated by first responder organisation. |
| | | | % of community members reached by EWS (via radio, TV, telephone and other communications technologies). |
| | | | % of community members not reached by EWS and reached via community EW mechanism only (such as volunteer networks). |
| | | | % of community members who trust in official communication during a disaster. |

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| Access to information/communication services | Level of community members' accessibility to relevant information on any potential hazards before, during and after a disaster event via different communication services. | Missing information and/or communication on hazards/disasters before, during and after events, due to people's inability to access dissemination services, may lead to potential negative impacts. | N. of weekly community messages to keep people informed before/after events (for example, via television, radio, newspaper, internet, phone, neighbours) about issues that are relevant to them. |
| | | | N. of daily community messages to keep people informed during an event (for example, via television, radio, newspaper, internet, phone, neighbours) about issues that are relevant to them. |
| | | | % of household with internet/broadband coverage, mobile phone coverage |
| Health services/ medical care capacity | Availability level of health care facilities, medical professionals, and funding to health services and research. | Lack of health resources in terms of people, equipment, facilities and funding, contributes to reducing the ability of a community's health system to meet the emergency needs. | Number of hospitals per 1.000 people by TA. |
| | | | Medical doctors/1.000 |
| | | | Expenditure on research and development |
| Institutional character - preparedness, professionalism, resilience of emergency services/emergency managers | Availability level of community resources and services competent in emergency management and DRR. | Lack of adequately trained resources and services, capable of effectively dealing with disaster-related risks, limits a community's ability to cope with the consequences of a disaster. | N. of local fire and police departments. |
| | | | N. of search & rescue regularly practices disaster/emergency drills. |
| | | | N. of staffed and trained ambulance service or medical response team. |
| | | | N. of local health care providers (e.g., family physicians, nurses) who have disaster training. |

## 7.6 Environmental

| Indicators | Description | Why is this important? | Examples proxies |
|---|---|---|---|
| State of forests | The extent to which forests are managed to avoid erosion and fires | Poor forestry practices increase landslide risk from erosion during intense precipitation. Poor management can also increase forest fire risks. | Forest management practices |
| | | | Percentage of land area that consists of windbreaks and environmental plantings |
| | | | Natural buffer (Percentage of land area) |
| Local food provision | Mechanisms to maintain and enhance aspects of the ecosystem that benefit community members' work and livelihoods, e.g., farming, tourism, fishing. | Natural hazards can damage assets of ecosystems relevant to livelihoods (e.g., farming, fishing, or the provision of relevant products and services (water, energy, fuel, natural materials) | Percentage of local population with an ecosystem-based livelihood |
| | | | Percentage of arable land that is cultivated |
| | | | Number of agriculture farms / 10,000 sq. km coastal area |
| | | | Degree of modernization in the agriculture sector |
| | | | Access of farmers to inputs to buffer against climate variability and change |
| Drinking water quality/quantity | Quality and availability of drinking water to population | Water quality and/or quantity is a crucial ecosystem service and poor water quality, or quantity can lead to health issues in humans | Percentage of access to safe (bacteriologically compliant) drinking water |
| | | | Proportion of population that has access to a sustainable safe water |

| | | | |
|---|---|---|---|
| | | | supply and hygienic sanitation in the household |
| | | | Percentage of financial resources dedicated to IWRM in relation to other water resource management functions |
| | | | Percentage of countries that have an IWRM policy framework and legislation, which specifically reflects public health concerns; |
| | | | Ratio of water supply from renewable resources and withdrawals to meet current or projected needs |
| | | | Precipitation amount in mm |
| Natural resource availability and health | The availability and health (sustainability, amount of degradation, quality) of natural resources including air, soil, biodiversity, vegetation levels, and other relevant environmental/natural resources | A greater number of natural resource availability achieving good ecological status indicates a reduction in anthropogenic pressures on the natural environment thus an increase in this indicator | Percentage of terrestrial zone set aside as reserves |
| | | | Millions of litres of hydrocarbons used /10,000 sq. km land area / year (average over last 5 years) |
| | | | Composite of conditions that affect human health |
| Marshes and wetlands | The indicator aims to measure marsh's capacity to buffer against flood and storm surge damage. Specifically, how marsh management affects buffering capacity, and the | It is crucial to understand how marsh buffers communities from flood risks and storm surges and how to ensure which marches that are at risk from being drained for various development purposes. | Percentage of land area not in an inundation zone (100/500-year flood and storm surge combined) |
| | | | Percentage of land area with no wetland decline |

| | | | |
|---|---|---|---|
| | economic values associated with the marsh's buffer role | | Percentage of marsh below mean high water |
| | | | Percentage of marsh in lowest third of plant distribution |
| | | | Elevation change rate (mmyr−1) |
| Ecosystem fragmentation | This indicator aims to measure the extent to which community's areas of semi-natural habitat are fragmented. Highly fragmented ecosystems are unlikely to be able to adapt to the impacts of disasters and climate change. Therefore, an increase in this indicator should be interpreted as a decrease in resilience | A resilient natural environment should have habitats and ecosystems which are connected, allowing species to move in response to the impacts of disasters and climate change. Ecosystem connectivity can increase the adaptive capacity of the natural environment | Percentage of the area covered by habitat networks (Measures a number of characteristics – diversity, ecosystem functioning, anthropogenic pressures) |
| | | | Degree of human intrusion into the natural landscape |
| | | | Nitrogen/phosphorus loading of ecosystems and stresses from pollution |
| | | | Total amount of semi-natural habitats in the vicinity of the focal site. |
| Area of green infrastructure within urban areas | An increase in the area or urban greenspace indicates an increase in the delivery of ecosystem services. Therefore, an increase in this indicator should be interpreted as an increase in resilience | Urban greenspace performs a number of services including providing a space for recreation, flood alleviation, local climate regulation and contributing to improved urban air quality | Percentage of area of green infrastructure in the community |
| | | | Access of population to basic services to buffer against climate variability and change |
| | | | Number of parks in the community |
| | | | Number of green roofs (hybrid green-gray infrastructure that integrate urban ecosystem components into the built form of the city) |

| | | | |
|---|---|---|---|
| Air quality | This indicator aims to measure the level of anthropogenic pressures acting on the natural environment and the provision of ecosystem services. A decline in this indicator should be interpreted as an increase in resilience of the natural environment | Air quality is a vital ecosystem service and poor air quality can lead to health problems in humans | Average number of days on which pollution levels were above National Air Quality Standards. |
| | | | Number of actual hot spots for potential air pollutant distribution. |
| Exposure to flooding and area of operational floodplain | Awareness of the exposure and vulnerability to past and present hazards based on up-to-date data.<br>The area of operational floodplain is a good indicator for several resilience characteristics. It is an indicator of ecosystem structure and function. A growth in this indicator should be interpreted as a rise in resilience. | This can raise awareness of the risks of depleting natural capital assets in own and neighbouring communities can have on community resilience.<br>A functioning floodplain is important for regulating flood risk, but it also contributes to other services such as silt deposition, soil formation and providing a diverse ecosystem structure e. | Percentage of land area does not prone to liquefaction |
| | | | Percentage of flooded area, magnitude of a 100-year event flood |
| | | | Mean water depth [in m] of flooded area, magnitude of a 100-year event flood |
| | | | Flood duration (month) |
| | | | Population density within areas (%) |
| Exposure to landslides and avalanches | Landslides and avalanches are external geologic processes called “mass wasting.” Major causes of mass wasting are the downslope movement of rock under the force of gravity, slope angle, weakness in the structure and composition of rock (weathering), storms or heavy rain for periods of time, snow melting, and human activities on slope | Landslides not only kill people but also have an extremely serious impact in terms of hindering rescue operations and the supply of aid and can cause long-term damage to communication and electricity networks | Percentage of population in areas that are at risk from land slides |
| | | | Percentage of not slide area |

| | | | |
|---|---|---|---|
| Exposure to storm surges | Normally resilience to disasters caused by storm surges is best represented by a multi-dimensional scale that combines measures of household infrastructure, economic capital, self-organization and learning, and social safety nets | Impacts of storm surge include extensive property loss, erosion of beaches, damage to coastal habitats, and undermining the foundations of infrastructure such as roads, railroads, bridges, buildings, and pipelines. Storm surges also pose a serious threat of death by drowning | Percentage of population in areas that are at risk from storm surges/ % of land area < 20m above sea level |
| | | | Percentage of land in wetlands |
| | | | Mean elevation of the community (meter) |
| | | | Percentage of urban area |
| Exposure to strong wind | The degree to which the population or natural environment is exposed to the negative effects of strong wind and high wide events, including downed trees and power lines, flying debris, and building collapses | Strong wind events cause significant damage to structures and property | Percentage of population in areas that are at risk from strong wind |
| Exposure to coastal erosion | This indicator is the process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast | Sea level rise threatens communities and natural ecosystems by increasing impacts from coastal hazards leading to increasing loss of land and ecosystem services, and damage to the built environment. Sea level rise results in accelerating shoreline erosion, increasing chronic and event-based flooding along the shoreline and in low lying areas, impeded stormwater drainage, and in some locations permanent submergence of land | Percentage of coastal land area composed of unconsolidated sediments |
| | | | Erosion/accretion rates |
| | | | Decadal loss of shoreline, permanent inundation areas |
| Exposure to forest fire | The degree to which the natural environment is exposed to the negative effects of forest fires or wildfire events. Forest resilience | Forest fire seasons are becoming more and more frequent worldwide, and large wildfires are having unusual impacts on people and property, in spite of several | Percentage forested land cover |
| | | | Greatest number of consecutive days per year with daily precipitation < 1 mm |

| | | | |
|---|---|---|---|
| | mechanisms are difficult to quantify because forests consist of long-lived species,<br>span huge geographical extents, and are affected by disturbances at a broad range of spatial scales | investments to support social–ecological resilience to wildfires | Mean of daily mean summer temperature (June, July, August) |
| | | | Summer precipitation (June, July, August) |
| Exposure to pollution | Presence, quantity, typology and localisation of waste and pollution sources. | The presence of waste and pollution sources may threaten the environment quality in case of a natural disaster. | Percentage of land area affected by waste disposals (industrial and household disposals) |
| | | | Percentage of population is exposed to unhealthy air |
| | | | Soil erosion ton per year per person |
| Exposure to heat | The degree to which the population and natural environment is exposed to the negative effects of heat wave events and heat-related health impacts. | The strong increases of heat stress in central and partly northern Europe and, on a lower level, in eastern Europe as well (Lung, Lavalle, Hiederer, Dosio, and Bouwer, 2013) | Number of summer days with max temperature is greater than 25°C in summer period (June, July, August) |
| | | | Number of tropical nights with min temperature is greater 20°C in summer period (June, July, August) |
| Land use change | The amount or proportion of an area that has changed from one type of land use, land cover, or land classification type to another in a given period of time | Usually used to indicate loss of natural environments that provide buffering capacity to populations | Percentage of change in "natural" land usage |
| | | | Percentage of reconstructed in months |

# 8 Conclusions and Implications

## 8.1 Summary of Key Results

This Deliverable has presented the results of the initial Task implemented in work package 3 of the project (Task 3.1: Definition of resilience indicators and matrix). The work carried out in Task 3.1 to produce this deliverable involved the following activities: developing an approach and methodology to produce the Resilience Indicators Matrix; validating the approach and methodology through a review of the literature on resilience assessment and working with users to pilot one of the dimensions of the Resilience Indicators Matrix; applying the validated approach and methodology to collect data to populate the Resilience Indicators Matrix; and integrating the results of the data collection to produce a first consolidated draft of the RESILOC Resilience Indicators review of the literature on resilience Matrix.

The conceptual framework that underpins the approach and methodology used to develop the RESILOC Resilience Indicators matrix draws on theory and practice in 'operationalisation' - the process through which abstract (fuzzy) concepts are translated into measurable variables and indicators. Initial validation of the overall approach and methodology within the resilience context, using a literature review, was implemented across three themes: a review of conceptual frameworks and approaches aimed at modelling resilience at the community level; a review of disaster resilience measurement frameworks; a review of how these frameworks are implemented in practice through resilience assessment. A key conclusion of the 'grounding' literature review – reported in Section 4 above – is that assessment approaches based solely on 'indices' – which struggle to model the contextual variety of different local communities – or approaches based solely on 'scorecards' – which struggle to work effectively in strategic planning scenarios – will not support the RESILOC vision and its objectives. RESILOC's direction of travel should therefore adopt a 'flexible toolkit' approach to community resilience assessment.

Starting with the six 'dimensions of resilience' identified through WP2 of RESILOC, a set of indicators and proxies were developed for each dimension using this methodology. These six dimensions were then validated against available evidence from the literature to make an assessment of the relevance and appropriateness of the indicators and proxies developed for each dimension. A set of Measurement Quality Criteria for the indicators was developed and applied to further assess relevance and appropriateness. Taken together, the initial literature review carried out to validate the overall methodology, plus the specific literature reviews subsequently carried out to validate each of the six dimensions in the RESILOC indicators matrix, entailed review of 155 items of literature in total.

Validation of the overarching methodology and the indicators developed for the six resilience dimensions through desk research – the literature reviews - was supported by a user-focused validation methodology. This entailed 'co-design' work with user communities to elicit feedback on the relevance, usefulness and importance of the indicators developed in the RESILOC Resilience Indicators matrix. Users were also asked to provide feedback on the extent to which the indicators would likely contribute to the resilience of the end-user's community in a recent disaster; any indicators that were missing; the relevance and availability of the proxy measures associated with the indicators, and the extent to which the indicators accurately and meaningfully reflect 'causal explanations'. This methodology was initially pilot-tested with the 'social dimension' with 11 users from four communities, representing a range of community agencies including municipality governance and administration, civil protection services and volunteer organisations. The indicators and proxies developed for the remaining five resilience dimensions – Disaster Risk Reduction (DRR), Economic, Environmental, Governance and

Infrastructure – were subsequently validated using the piloted literature review/user-focused co-design hybrid approach.

Implementation of the methodology has resulted in the development of the RESILOC Resilience Indicators matrix. This contains a total of 70 indicators and 260 associated proxy measures in 6 dimensions, as follows. DRR: 13 indicators, 55 proxies; Economic: 9 indicators, 32 proxies; Environmental: 17 indicators, 58 proxies; Governance: 8 indicators, 30 proxies; Infrastructure: 16 indicators, 60 proxies; Social: 7 indicators, 25 proxies.

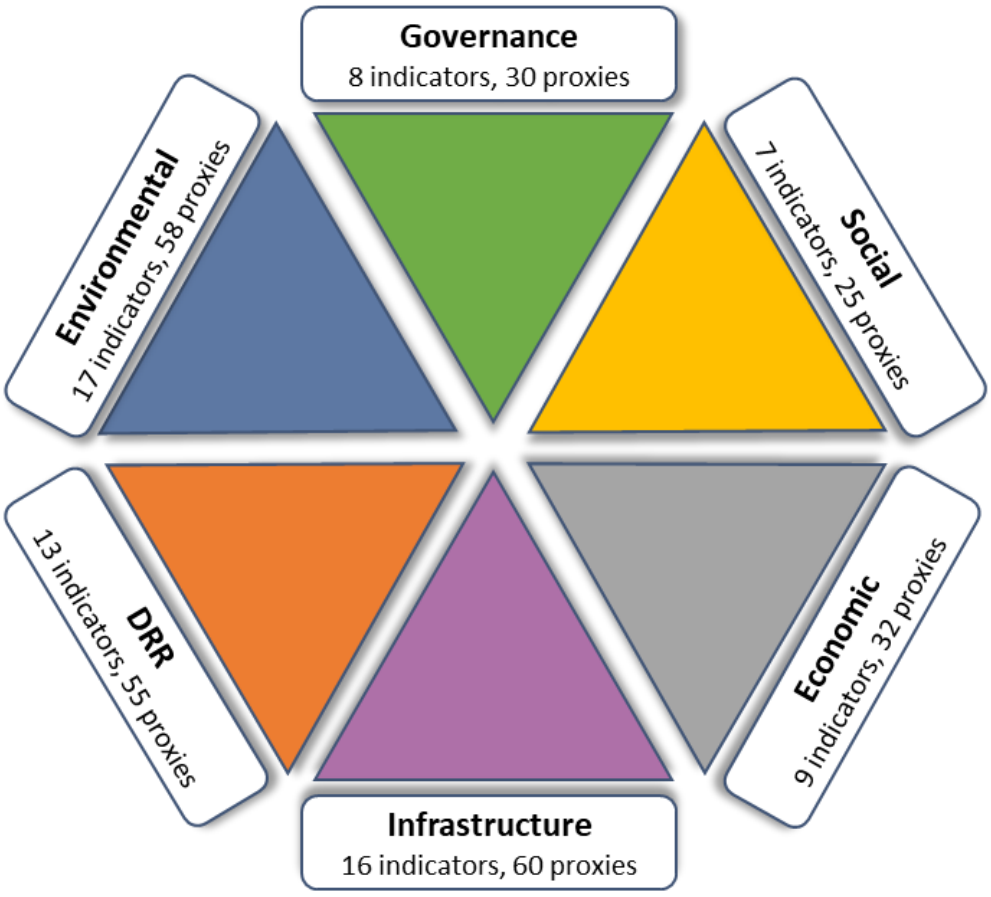



*Figure 7 RESILOC dimensions, indicators and proxies for resilience assessment*

## 8.2 Next Steps

The next steps in the ongoing evolution and application of the matrix entail further validation of the matrix in RESILOC Task 3.2 – Definition of new strategies for improving resilience. Task 3.2 will also involve working with users in 'co-design' mode to explore how the matrix can be used to apply the tool in co-design activities to identify new strategies to improve community resilience. Further piloting and validation of the matrix will also be implemented through the field trials in work package 5.

This will include both exploring the importance, usefulness and relevance of the different indicators for each dimension to different communities and disaster scenarios, but also to explore the suggested list of 'proxies'. We know from our conversations with communities in developing the dimension but also through our exploration of the social dimension (see Section 5.2) with communities that some of the proxies can be derived from Eurostat, others might rely on more detailed local statistics, while others can only de derived from a dedicated survey or

other form of data collection or assessment. Further iterations of the RESILOC resilience indicators matrix, derived from these validation exercises, will therefore also include information on the availability of the data required to be collected for included proxies and on the data collection methods likely to be needed.

Once the list of proxies is shared with the LRTs in the communities during the trials, the list will be “assessed” in terms of relevance (Is the information provided by this proxy potentially interesting/useful to us?), second in terms of “data availability” (Is it possible to find this information either from existing data sources or collecting it now in one way or the other?), and third in terms of “usability”/“attributing meaning” (Now that I have this information, how can I include it in the analysis and what do we make out of it within the scope of one or more indicators?).

This is an important step in developing the matrix, particularly in the perspective of reusing and upscaling the tools to other communities, as we need to explore not only the relevance of the indicators and proxies, but also the extent to which this should rely on easily collectible and quantifiable proxies, or instead on those most relevant to the assessment of resilience and development of new strategies in different settings and for different scenarios. This will be the task for the trials and Task 3.2.

# VII. Appendix A: RESILOC Ethics Self-Assessment Sheet

## RESILOC ethics self-assessment sheet

This document is a self-assessment sheet that must be filled out by owners of RESILOC deliverables. This is to ensure that research and/or development activities related to each project deliverable comply with requirements of RESILOC Guidelines on Ethics and Data Protection (GDPR).

This RESILOC ethics self-assessment sheet must be used as part of each project deliverable that involves humans either in an active (e.g. data subjects) or passive (e.g. affected by tools) manner. Project reports (e.g. management or financial reports) are not required to undergo this ethics assessment.

This document is an important exercise part of the RESILOC Ethics Framework as it allows the owner of each RESILOC deliverable to reflect on ethical consideration and data protection requirements in a structured and approved manner before submitting the document to the Commission for review.

The document shall be used in line with the RESILOC Ethics Framework including the guidelines and procedures under deliverables D9.1 to D9.12 (all documents are made available on the RESILOC Own Cloud). The ethics self-assessment sheet must be included as the 1st Appendix A of the each RESILOC deliverable. In addition to filling out the sheet, authors must provide explanations of the answers given on the main table. Such explanations must be provided in the methodology section of the deliverable using the headline "Ethics Considerations and Data Protection". The ethics self-assessment sheets of private deliverables must be assessed through the responsible position within the issuing organisation. However, for public deliverables, the ethics self-assessment sheet must be approved by the RESILOC Internal Ethics Board. For that, please send this document to the Internal Ethics Board.

| **For Information or assistance contact:** | | helena.marruecos@iml.fraunhofer.de | |
|---|---|---|---|
| The self-assessment was conducted by: | | The self-assessment was approved by: | |
| Name | Rajendra | Name | Helena |
| Surname | Akerkar | Surname | Marruecos |
| Institution | WNRI | Institution | Fraunhofer IML |
| Date | 19.01.2022 | Date | 21.01.2022 |

| | | yes | no | n/a |
|---|---|---|---|---|
| **G** | **GENERAL** | | | |
| a | Did the research for this deliverable involve the collection of personal data? | x | | |
| b | Does this deliverable, and the activities that have fed into it, comply with Regulation (EU) 2016/679 known as GDPR and 2002/58/EC Directive on privacy and electronic communications? | x | | |
| c | Does this deliverable, and the activities that have fed into it, comply with the relevant national data protection and privacy laws, codes of practice and guidelines? | x | | |
| d | Are there any ethics risk identified related to your work under this deliverable? | x | | |
| **1** | **Human Participation/ Informed Consent** | | | |
| 1.1 | **Procedures and criteria that will be used to identify/recruit research participants** (D9.1) | | | |
| a | Did the research for this deliverable involve the recruitment of research participants? *(this includes surveys and interviews)* | x | | |
| b | Did you identify selection, inclusion, & exclusion criteria? | x | | |
| 1.2 | **Recruitment of respondents via social media** (D9.4) | | | **x** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| b | Were special measures taken to ensure that the participants are adults? | | | | | | |
| c | Did the research for this deliverable involve data collection using social media? | | | | | | |
| d | Were measures taken to use only public profiles for the collection of data? | | | | | | |
| | | yes | no | | yes | no | n/a |
| 1.3 | **Use of the informed consent forms and Info sheets to recruit research participants** (D9.2) | | | | | | |
| a | Consent Form was issued | x | | | x | | |
| b | Information sheet was issued | x | | Issued in local language | x | | |
| c | Combined sheet was issued | | | | | | |
| 1.4 | **Use of the informed consent forms and information sheets on data processing** (D9.9) | | | | | | |
| a | Consent Form was issued | x | | | x | | |
| b | Information sheet was issued | x | | Issued in local language | x | | |
| c | Combined sheet was issued | | | | | | |
| **2** | **Organizational measures** | | | | | | |
| 2.1 | **Data Protection Officer or contact person** (D9.5) | | | | | | |
| a | Do you have a Data Protection Officer or contact person for participants? | | | | x | | |
| b | Was this contact mentioned on the Informed Consent Forms? | | | | x | | |
| **3** | **Technical measures** | | | | | | |
| 3.1 | **Technical safeguard mechanisms for handling of personal data (PD) and special categories of personal data (SCOPD)** (D9.6 / D9.8) (SCOPD include information such as ethnic origin, political opinions, data concerning health, etc. For more details see Article 9(1) GDPR). | | | | | | |
| a | Did the research for this deliverable involve the collection of SCOPD? (D9.6) | | | | | x | |
| b | Which mechanisms were used to safeguard the personal data collected? | | | | | | |
| | pseudonymisation | x | | anonymization | | | |
| | encryption | | | other *(specify in the line below)* | | | |
| | access restriction | x | | | | | |
| 3.2 | **Data minimisation** (D9.7) | | | | | | |
| a | Has as little as possible data been collected throughout the research process? | | | | x | | |
| b | If more data was collected than initially needed, did you ensure the data was deleted? | | | | | | |
| 3.3 | **Data profiling** (D9.10) | | | | | | **x** |
| a | Was or will the data collected in the deliverable be used for data profiling? | | | | | | |
| b | Were all data subjects informed of the profiling and its possible consequences?<br>(as part of the Inform Consent Form and the Information Sheet) | | | | | | |
| c | Were sufficient measures in place to safeguard their fundamental rights? | | | | | | |
| 3.4 | **Processing of previously collected personal data** (D9.11) | | | | | | **x** |
| a | Did you obtain consent to use personal data from previously executed research? | | | | | | |
| b | Are technical/organisational measures required to safeguard the rights and freedoms of the data subject according to EU and national legislation in place in your organisation? | | | | | | |
| **4** | **Other Issues of ethical concern** | | | | | | |
| a | Were there any other ethical considerations detected during the work of this deliverable that are not covered by the list above? | | | | x | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| b | If yes, please list the concerns below and elaborate on the related counter measures in the methodology section of this document | | | | | | | |
| B cont. | There are two elements that should be noted regarding other issues of ethical concern:<br>• Representation of reality: the translation of reality into proxies, or in other words, the impossibility of translating reality into quantitative and/or qualitative assessments. This matter falls under the level of Research Ethics and can be classified as Level 3 and Level 4 of the RESILOC Ethics framework. For additional information see Deliverable 9.13 and the RESILOC Ethics How-to-guide.<br>• Risk of political misuse of the tool: this risk was identified in the RESILOC Ethics Risk Registry. It is connected to the ethical principle of integrity. For additional information see the RESILOC Ethics Risk Register. | | | | | | | |
| **5** | **Opinions/approvals provided by ethics committees and other experts** | | | | | | | |
| 5.1 | **Following documents received opinions/approvals provided by ethics committees and other experts for the research conducted for this deliverable.** | | | | | | | |
| | | | yes | no | | yes | no | n/a |
| a | Informed Consent Forms and Information sheet | IEB | x | | EEA | | x | |
| | | DPO | | x | LEB | | x | |
| b | Questionnaires / Surveys | IEB | x | | EEA | | | |
| | | DPO | | | LEB | | | |
| c | Design /Methodology of research activity | IEB | | x | EEA | | | |
| | | DPO | | | LEB | | | |

# VIII. Appendix B: Literature Review

## 8.1. Methodological Approach

This section describes in detail how we identify relevant and credible literature addressing resilience at the community level. In the following sections, common themes are determined and summarised to generate insights into community resilience. The interest of this review is to find and evaluate studies, projects, and tools that draw upon new solutions for communities to model, measure, and visualise resilience.

### a. Research Questions

There is a need for a more transparent analytical overview and a selection of the studies, projects, and tools most relevant to what we can focus on in more detail. The results of this review will summarise and discuss the following research questions. Generally, different communities could benefit from this literature review's much more comprehensive overview of:

1. What resilience studies, projects, and tools at community level already exist??
2. What types of threats, hazards, shocks, disasters, etc. do they face?
3. What and how many resilience components do they define?
4. How do they measure community resilience—i.e., using more qualitative evidence, quantitative indicators, or a combination of the two?
5. What are the appropriate visualisation techniques to express community resilience information?

We conduct this review study to fulfil the information required by communities in both static and dynamic phases. In the static phase, our target is to define what we have and what we suffer from. On the other hand, we aim at understanding whether those variables represent objects or contexts that we can work towards in the dynamic phase.

### b. Search Strategy

We started this work by searching the published articles on Google Scholar, Scopus, Web of Science, and ScienceDirect, which are not limited to particular disciplines, using text strings "community resilience", "resilience assessment", and "resilience visualisation" and their combinations. Meanwhile, the systematic search of relevant projects and tools is conducted on Google search engine. We also check the reference lists of the selected articles to discover additional related work. Supplementary data sources involve our pre-existing knowledge of the literature.

### c. Eligibility Criteria and Selection Process

To be included in this review, the inclusion criteria established that the literature must adhere to the following rules. No restrictions are imposed with regards to the time or country of publication.

- Focusing on modelling, measuring, or visualising community resilience.
- Having full-text publications or descriptions.
- Publishing in the English language.

On the contrary, we define the exclusion criteria used to filter literature that is not relevant for this study as follows.

- The literature is a letter, thesis, dissertation, or conference abstract.
- The literature is not related to defined research questions.

After screening the data, full-text documents are collected to extract necessary study-specific parameters (e.g., type of resilience at the community level, number of resilience components, methodologies to assess resilience, and techniques for representing resilience information) for further analysis. Upon our search using the search strategy and inclusion criteria devised, we identify 40 studies, projects, and tools in the last 20 years, from 2000 to 2020, for inclusion in this literature review, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

*Table 11 Resilience studies, projects, and tools at community level (M: Modelling, A: Assessment, V: Visualisation).*

| Study/Project/Tool | Focus | M | A | V |
|---|---|---|---|---|
| Analysis of Resilience of Communities to Disasters (ARC-D) Toolkit (Clark-Ginsberg et al., 2020) | Disasters | x | | x |
| Australian Natural Disaster Resilience Index (Parsons et al., 2016) | Hot-spots of high or low disasters | x | | x |
| Baseline Resilience Indicators for Communities (BRIC) (Cutter, Ash, and Emrich, 2014) | Disasters | x | | x |
| Bay Localize Community Resilience Toolkit (Bay Localize, 2009) | Community assets | x | x | |
| Chandra et al. (Chandra et al., 2011) | National health security | x | x | |
| Climate-related Disaster Community Resilience Framework (CDCRF) (Joerin, Shaw, Takeuchi, and Krishnamurthy, 2012) | Climate-related disasters | x | | |
| Community Advancing Resilience Toolkit (CART) (Pfefferbaum et al., 2013) | All-hazards environment | x | x | |
| Community And Regional Resilience Initiative (CARRI) Research Report (Cutter et al., 2008b) | Natural and human-made disasters | | x | |
| Community Based Resilience Analysis (CoBRA) (United Nations Development Programme (UNDP), 2012) | Crises and disasters | | | x |
| Community Disaster Resilience Index (CDRI) (Peacock et al., 2010; Yoon, Kang, and Brody, 2016) | Disasters | x | x | x |
| Community Disaster Resilience Toolkit (Arbon, 2014) | Disasters | x | x | |
| Community Resilience Framework (CRDSA) (Alshehri, Rezgui, and Li, 2015a, 2015b) | Disasters | x | x | |
| Community Resilience Index (Scherzer, Lujala, and Rød, 2019) | Natural hazards | | | x |
| Community Resilience System (CRS) (Community and Regional Resilience Institute (CARRI), 2013) | Man-made and natural disasters | x | x | |
| Community Self-Assessment (Sempier, Swann, Emmer, Sempier, and Schneider, 2010) | Disasters | x | x | |

| | | | | |
|---|---|---|---|---|
| Conjoint Community Resilience Assessment Measurement (CCRAM) (Cohen, Leykin, Lahad, Goldberg, and Aharonson-Daniel, 2013) | Emergencies | x | | |
| Costs, Opportunities, Benefits, and Risks Analysis (COBRA) Framework (Osman et al., 2014) | E-government services | x | | |
| Disaster Resilience of Place (DROP) Model (Cutter et al., 2008a) | Natural disasters | x | | |
| Flood Resilience Measurement for Communities (FRMC) (Zurich Flood Resilience Alliance (ZFRA), 2019) | Flood | x | | |
| Framework for Community Resilience (FCR) (International Federation of Red Cross and Red Crescent Societies (IFRC), 2013) | Disasters, crises, shocks, and stresses | x | | |
| IMPROVER Project (IMPROVER Project, 2020) | Critical infrastructure | x | | |
| Jordan and Javernick-Will (Jordan and Javernick-Will, 2013) | Disasters | x | x | |
| Localized Disaster-Resilience Index (Orencio and Fujii, 2013) | Disasters | x | x | |
| Moreno et al. (Moreno, Lara, and Torres, 2019) | Tsunami | | x | |
| Natural Hazard Resilience Screening Index (NaHRSI) (Summers, Harwell, Smith, and Buck, 2018) | Natural hazard events | | | x |
| Pilquimán-Vera et al. (Pilquimán-Vera, Cabrera-Campos, and Tenorio-Pangui, 2020) | Community based tourism | x | x | |
| PEOPLES Resilience Framework (Cimellaro, Renschler, Reinhorn, and Arendt, 2016) | Extreme events or disasters | x | | |
| POP-ALERT Project (POP-ALERT Project, 2014) | Crises and cross-border disasters | | x | |
| Rabinovich et al. (Rabinovich et al., 2019) | Soil erosion | x | x | x |
| Rahman and Kausel (Rahman and Kausel, 2013) | Tsunami | x | x | x |
| RELi Resilience Action List & Credit Catalog (C3 Living Design Project, 2019) | Next generation community | x | | |
| Resilience Matrix (RM) (Fox-Lent, Bates, and Linkov, 2015) | Disruptive events in coastal areas | | x | |
| Resilience Modelling Tool (The Resilience Index, 2015) | Natural hazards | x | x | x |
| School-Community Collaborative Network (SCCN) Conceptual Model (Oktari, Shiwaku, Munadi, Shaw, and others, 2015) | Disaster education | | x | |
| Sherrieb et al. (Sherrieb, Norris, and Galea, 2010) | Economic development and social capital | x | x | x |
| Shesh Kanta Kafle (Kafle, 2012) | Disasters | | x | |

| | | | | |
|---|---|---|---|---|
| Tool for Health and Resilience in Vulnerable Environments (THRIVE) (Prevention Institute, 2013) | Health, safety, and health equity | x | x | |
| Uddin et al. (Uddin, Haque, Walker, and others, 2020) | Cyclone and storm surge disasters | x | | x |

## 8.2. Modelling Community Resilience

Determining and defining community resilience's components and properties is an essential step for further developing clear strategies and undertaking practical activities to attain resilience in our community. This section presents different studies that have been conducted to achieve a better understanding and clarification of the community resilience through modelling step.

Although the importance of modelling resilience is widely recognised and researched, proposing an appropriate number of resilience components is still a significant challenge. Researchers find out that short-term human memory works best when we have fewer elements to remember. People are usually good at remembering no more than seven different components (Simon, 1974). The community resilience, therefore, almost encompasses from three to seven components. Noting that in most studies, the order of components does not reflect their importance.

Table 12 presents different studies, projects, and tools arranged by the number of components, their focuses, and years of publication. We use the year of publication instead of the year of study as it is relatively more accessible.

*Table 12. Summary of community resilience components.*

| Number of Components | Focus | Year | Reference | Components |
|---|---|---|---|---|
| Three | Climate-related disasters | 2012 | (Joerin et al., 2012) | Physical, social, economic |
| | Community based tourism | 2020 | (Pilquimán-Vera et al., 2020) | Cultural, social, organisational |
| | Economic development and social capital | 2010 | (Sherrieb et al., 2010) | Economic, social, community |
| | Health, safety, and health equity | 2004 | (Prevention Institute, 2013) | Social-cultural, physical/built, economic/educational |
| | Man-made and natural disasters | 2013 | (Community and Regional Resilience Institute (CARRI), 2013) | Economic, environmental, and social. |
| Four | All-hazards environment | 2013 | (Pfefferbaum et al., 2013) | Connection and caring, resource, potential, management |

| | | | | |
|---|---|---|---|---|
| | Disasters | 2010 | (Peacock et al., 2010) | Social, economic, physical, human |
| | | 2013 | (Jordan and Javernick-Will, 2013) | Social, economic, environmental, infrastructural |
| | | 2014 | (Arbon, 2014) | Community, risk and vulnerability, planning and procedures, resource |
| | Natural hazards | 2015 | (The Resilience Index, 2015) | Social, built, natural, economic |
| | Next generation community | 2014 | (C3 Living Design Project, 2019) | CV (community cohesion, social, and economic vitality), PH (productivity, health, and diversity), EW (energy, water, and food), MA (material and artefact) |
| Five | Flood | 2019 | (Zurich Flood Resilience Alliance (ZFRA), 2019) | Human, social, physical, natural, financial |
| | Soil erosion | 2019 | (Rabinovich et al., 2019) | Economic, social, cultural, governance, environmental |
| Six | Community assets | 2009 | (Bay Localize, 2009) | Food, water, energy, transportation and housing, job and economy, civic service |
| | Critical infrastructure | 2018 | (IMPROVER Project, 2020) | Physical, social, human, natural, economic, and institutional |
| | Disasters | 2014 | (Cutter et al., 2014) | Social, economic, housing and infrastructure, institutional, community, environmental |
| | | 2015 | (Alshehri et al., 2015a, 2015b) | Social, economic, physical and environmental, governance, health and well-being, information and communication |
| | | 2016 | (Yoon et al., 2016) | Human, social, economic, institutional, physical, environmental |
| | Disasters, crises, shocks, and stresses | 2014 | (International Federation of Red Cross and Red Crescent Societies (IFRC), 2013) | Knowledge and health, social, infrastructure and service, economy, natural asset, connectedness |
| | Emergencies | 2013 | (Cohen et al., 2013) | Leadership, collective efficacy, preparedness, place attachment, social trust, social relationship |

| | | | | |
|---|---|---|---|---|
| | Natural disasters | 2008 | (Cutter et al., 2008a) | Ecological, social, economic, institutional, infrastructure, community competence |
| Seven | Disasters | 2010 | (Sempier et al., 2010) | Infrastructure, facility, transportation, community, mitigation measure, business, social system |
| | | 2013 | (Orencio and Fujii, 2013) | Environmental and natural resource, health and well-being, sustainable livelihood, social protection, financial instrument, physical protection, planning regime |
| | Extreme events or disasters | 2016 | (Cimellaro et al., 2016) | Population and demographics, environmental and ecosystem, organized governmental services, physical infrastructures, lifestyle and community competence, economic development, and social-cultural capital |
| More than seven | Cyclone and storm surge disasters | 2020 | (Uddin et al., 2020) | People and place, institution, knowledge, social network, value and belief, economy, outlook, embracing difference, resource, learning, governance, organization |
| | Disasters | 2020 | (Clark-Ginsberg et al., 2020) | Participatory risk assessment, scientific risk assessment, etc. |
| | Hot spots of high or low disasters | 2016 | (Parsons et al., 2016) | Social, economic, infrastructure, emergency service, community, information and engagement, governance, policy and leadership |
| | National health security | 2011 | (Chandra et al., 2011) | Wellness, access, education, engagement, self-sufficiency, partnership, quality, efficiency |
| | Tsunami | 2013 | (Rahman and Kausel, 2013) | Governance, society and economy, resource management, land use and structural design, risk knowledge, warning and evacuation, emergency response and disaster recovery |

a. Less than Five Components

In (Sherrieb et al., 2010), the authors build and verify the correlations of indicators through using the Mississippi county data. The combination of the refined indicators belongs to three community resilience components, which are economic development, social capital, and an additive index of community resilience. Meanwhile, the THRIVE tool of the Prevention Institute (Prevention Institute, 2013) represents community resilience with three interconnected clusters, which are (i) social-cultural environment (people), (ii) physical/built environment (place), and (iii) economic/educational environment (equitable opportunity). This tool guarantees community resilience by increasing the quality of life and handling the biased distribution of health-related resources.

Instead of using three components, the Community Disaster Resilience Framework (CDRF) addresses four different capital assets of a community comprising social, economic, physical, and human capital (Peacock et al., 2010). Similarly, Jordan and Javernick-Will proposed four recovery indicators that are categorised as social, economic, environmental, and infrastructural (Jordan and Javernick-Will, 2013). In (C3 Living Design Project, 2019), the project proposes a comprehensive action list, which can guide actions for a resilience present and future of communities, buildings, homes, and infrastructure, consisting of CV (community cohesion, social, and economic vitality), PH (productivity, health, and diversity), EW (energy, water, and food), and MA (material and artefact).

Apart from that, the authors refer to community capacity and competence-based studies in social psychology and public health to develop the Communities Advancing Resilience Toolkit (CART) (Pfefferbaum et al., 2013). The CART describes four overlapping and interrelated domains of community resilience including (i) connection and caring, (ii) resource, (iii) transformative potential, and (iv) disaster management. A community with higher capability in these four defined domains can be more successful in reducing the harmful effects of disasters and other related difficulties. In addition to the studies mentioned above, the author models the community resilience with community connectedness, risk and vulnerability, available resources, and planning and procedures, which are logically overlapping and able to interact with each other (Arbon, 2014). This demonstrates the equivalence among domains in constructing community resilience towards multiple disasters.

b. From Five to Seven Components

By applying a five-components approach, the Zurich Flood Resilience Alliance (ZFRA) models community resilience with five capitals comprising human, social, physical, financial, and natural (Zurich Flood Resilience Alliance (ZFRA), 2019). These five capitals can assist people in their development as well as enhance the ability to cope with and make a response to various flood-related shocks. The studies in (Cutter et al., 2014) are similar; however, the authors extend their model by supplementing one more index that is the environmental capacity.

The similar idea can be found in (International Federation of Red Cross and Red Crescent Societies (IFRC), 2013) in which the International Federation of Red Cross and Red Crescent Societies (IFRC) describes six resilience indicators to fortifying community resilience including knowledge and health, society, infrastructure and service, economy, natural asset, and connectivity. These indicators are designed to effectively and efficiently support three critical constituents of the Framework for Community Resilience (FCR) that are (i) assisting communities towards risks promptly and proposing solutions to portray underlying vulnerabilities comprehensively, (ii) placing people and their demands in the centre, and (iii) being retrievable by people at anytime and anywhere. According to (IMPROVER Project, 2020), The IMPROVER project provides physical, social, human, natural, economic, and institutional capitals as six crucial components along with the IMPROVER Societal Resilience

Analysis (ISRA) (for qualitative measuring indicators) to self-assess and guarantee community resilience. In (Bay Localize, 2009), the Bay Localize constructs the community resilience toolkit concentrating on six key components being composed of food, water, energy, transportation and housing, jobs and economy, and civic services. This toolkit is beneficial in helping communities facing risks and hazards in the area of climate change and peak oil. Following Alshehri et al., the authors discuss social, economic, physical and environmental, governance, health and well-being, and information and communication dimensions (Alshehri et al., 2015a, 2015b). The featured contribution of these two studies is that the authors discovered the correlation between the six identified dimensions and 62 criteria (i.e., from seven to fourteen criteria connect to every dimension). Yoon et al. build a set of indicators to measure community disaster resilience index utilising human, social, economic, institutional, physical, and environmental factors that are related to vulnerability and capacity aspects of South Korea (Yoon et al., 2016).

Concerning seven dimensions depicting community functionality, the PEOPLES framework is constructed to represent population and demographic, environmental and ecosystem, organised governmental services, physical infrastructure, lifestyle and community competence, economic development, and social-cultural capital (Cimellaro et al., 2016). This framework can promote the empowerment of local planners, decision-makers, and stakeholders to evaluate and improve their community resilience in different temporal-spatial contexts.

c. More than Seven Components

There are not many studies which are conducted in terms of using more than seven components. The authors leverage the top-down approach to put forward eight different indices for consideration, which are clustered into (i) coping capacity (i.e., social character, economic capital, infrastructure and planning, emergency services, community capital, and information and engagement) and (ii) adaptive capacity (i.e., governance, policy and leadership and community and social engagement) (Parsons et al., 2016). Along with each index is a set of measurable indicators. Hence, we can use either one number or sets of numbers to represent a resilience index in this study.

## 8.3. Measuring Community Resilience

After modelling community resilience, it is indispensable to select appropriate methodologies for aggregating and assessing identified components to come up with comprehensive frameworks. To measure community resilience, we can apply either qualitative, quantitative, or combine these two methodologies as a hybrid one. Qualitative approaches, which are suitable for processes required professional experience of experts, are used to evaluate community resilience without providing a particular numerical descriptor. Apart from that, quantitative methods leverage numerical data along with statistical models to measure community resilience. From a practical perspective, both qualitative and quantitative approaches have proved beneficial and useful in measuring complex community resilience. Several appropriate methods for use include, for example, observation (Clark-Ginsberg et al., 2020) and survey (Osman et al., 2014). Table 13 shows the summary of qualitative, quantitative, and hybrid approaches to measure community resilience.

*Table 13. Summary of qualitative, quantitative, and hybrid approaches to measure community resilience.*

| Approach | Focus | Outcome | Reference |
|---|---|---|---|
| Qualitative | All-hazards environment | 4-stage process for identifying issues, solving problems, and planning activities | (Pfefferbaum et al., 2013) |
| | Community based tourism | Relationship between tourism experiences with community resilience processes | (Pilquimán-Vera et al., 2020) |
| | Man-made and natural disasters | 6-stage process with detailed guidance, tools, and resources identified for each module | (Community and Regional Resilience Institute (CARRI), 2013) |
| | National health security | Roadmap used as a starting point to develop local community resilience strategy | (Chandra et al., 2011) |
| | Soil erosion | Impacts on soil erosion based on social, psychological, and cultural parameters | (Rabinovich et al., 2019) |
| | Tsunami | Strength and weakness of tsunami preparedness based on eight resilience elements | (Rahman and Kausel, 2013) |
| | | Analysis of resilience capacities and resources activated to cope with disaster | (Moreno et al., 2019) |
| Quantitative | Disasters | Disaster resilience score ranging between 22 and 110 | (Arbon, 2014) |
| | | Community disaster resilience index for 4 capital indices across 4 management phases | (Peacock et al., 2010) |
| | | A single, scalar measure combined from six multidimensional components | (Yoon et al., 2016) |
| | | Resilience index based on the percentage of check marks and the number of Yes answers | (Sempier et al., 2010) |
| | | Disaster-resilience index score based on process- and outcome-indicator scores | (Orencio and Fujii, 2013) |
| | Economic development and social capital | Composite scores of economic development, social capital, and community resilience | (Sherrieb et al., 2010) |
| | Health, safety, and health equity | Top three priorities to increase health and safety and reduce health inequities | (Prevention Institute, 2013) |
| | Natural hazards | Composite resilience index ranging between 0 and 100 | (The Resilience Index, 2015) |
| Hybrid | Community assets | Toolkit for specific resources and action ideas in six key sectors | (Bay Localize, 2009) |

| | | | |
|---|---|---|---|
| | Disasters | 19 indicators of recovery along with rating of the importance of each indicator | (Jordan and Javernick-Will, 2013) |
| | | Resilience framework involving 7 to 14 criteria in each of six defined dimensions | [13] |
| | Disaster education | Conceptual model for collaborative network and knowledge management | (Oktari et al., 2015) |
| | Disruptive events in coastal areas | Resilience Matrix (RM) framework with performance score for each cell ranging from 0 to 1 | (Fox-Lent et al., 2015) |
| | Natural and human-made disasters | Resilience baseline and its schematic representation based on GIS methodology | (Cutter et al., 2008b) |

a. Qualitative Approaches

The Community Resilience System (CRS) offers six stages (i.e., engagement, assessment, visioning, planning, implementing, and monitoring and maintaining) to support communities in understanding resilience, defining goals, creating strategies, deciding on tools and processes, and evaluating resilience (Community and Regional Resilience Institute (CARRI), 2013). To derive robust consequences, the authors describe appropriate steps for each stage in which each stage involves specific actions (together with related and supporting resources) required to accomplish. In another approach, the CART (Pfefferbaum et al., 2013) proposes a process, which encompasses assessment, feedback, planning, and action, to engage stakeholders in addressing community problems through field-tested surveys, key informant interviews, community conversations, and supplemental instruments. This toolkit contributes to empowering communities in leveraging their assets and strengths for overcoming multiple disasters.

The RAND Corporation aims at providing a roadmap to represent an essential step forward for determining the critical elements of community resilience. Based on eight levers, five core components and their interactions, the literature review, focus groups, and SME meetings are conducted for comprehending and strengthening community resilience (Chandra et al., 2011). This proposed framework is suitable for various communities in reinforcing resilience concerning health security.

According to (Rabinovich et al., 2019), the authors first derive experiences from agro-pastoralist stakeholders through semi-structured interviews. In the following step, the theoretical thematic analysis, which is based on community resilience and social dilemmas frameworks, is applied for strengthening community resilience with respect to the soil erosion reduction concerning five different domains (i.e., economic domain, social domain, cultural domain, governance, and environmental domain). By leveraging in-depth interviews, adding field observation and reading documents, Rahman and Kausel determine planning capacity and social capacity of a community towards a tsunami based on eight essential resilience elements that are governance, society and economy, resource management, land use and structural design, risk knowledge, warning and evacuation, emergency response, and disaster recovery (Rahman and Kausel, 2013).

Referring to (Moreno et al., 2019), this study spends six months to discover relevant and available capacities and resources of a community during a disaster through various resources that are semi-structured interviews, observation, informal conversations, and documentary and social media review. This qualitative research demonstrates the paramount importance of

resilience capacities (i.e., local knowledge, sense of community, cooperation, organisation, social capital, and trust) in terms of responding to emergencies.

b. Quantitative Approaches

Quantitative approaches aim at measuring community resilience in recognisable ways to reduce the whims and opinions of analysts, experts, or other populations of the study. They can evaluate community resilience through the use of ordinal, interval, and ratio data obtained from surveys, observations, or secondary data. Towards qualitative approaches, the values of resilience components and their relationships need to be validated by discernible outcomes (Kafle, 2012). Based on components determined in the modelling step, a direct approach is to apply the composite index formula (The Resilience Index, 2015) as follows.

$$CR = \sum_{j=1}^{|C|} \sum_{k=1}^{|I_{C_j}|} i_k \times w_k, \forall j,k \in \mathbb{N}, j > 0, k > 0 \quad (1)$$

where $CR$ represents community resilience, $C$ is the set of resilience components, $I_{C_j}$ is the set of indicators of component $C_j$, and $i_k$, $w_k$ denote for $k^{th}$ indicator and its weight, respectively. As stated in (Arbon, 2014), the authors identify a score range from 1 (low degree of resilience, it means the red zone) to 5 (high degree of resilience, it means the green zone) for every question in the scorecards. We obtain the final score by summing all the individual scores. If the overall score is above 99, our community is very resilient to disasters; if it is below 33, we are under the risk of preventing and recovering from disasters. We should especially put the greatest attention to a particular element in case its scores are significantly smaller than the others.

Instead of using an adding function, we can use standardised z-scores (due to the diversity of indicators' values) (Peacock et al., 2010; Sherrieb et al., 2010) on entire indicators. As alternatives to explicit numbers, we can also use a priority rating (low/medium/high) (Prevention Institute, 2013; Sempier et al., 2010), an effectiveness score range (A–F) (Prevention Institute, 2013), a vulnerability/capacity category (V/C), or an effect value (positive/negative) (Yoon et al., 2016) for quantitative approaches.

On the other hand, the Analytic Hierarchy Process (AHP) is put to use in (Orencio and Fujii, 2013) to determine disaster-resilient indicators at the local level. The outcome-indicator score is further calculated based on criterion score and their weights. Besides, a six-point scale, which is extended from (Twigg, 2007), is used to rank indicators for measuring process-indicator score. Level 0 represents the "absence of a clear and coherent activity/activities in an overall disaster risk reduction program", while level 5 refers to "a culture of safety exists among all stakeholders". Subsequently, the authors propose the weighted linear average (WLC) to measure composite indices based on these two evaluated scores.

c. Hybrid Approaches

The measurement of community resilience in a variety of situations requires both qualitative and quantitative approaches to capture perceptions, vulnerabilities, exposed values, and other resilience-related factors. A hybrid approach is one where both tangible and intangible elements are applicable for enhancing analytical accuracy and deepening the understanding

of community resilience. Both qualitative (i.e., literature review, group interview, and discussions) and quantitative (i.e., scales and surveys) data are usable (Oktari et al., 2015). Nevertheless, we should keep in mind that hybrid approaches may require much effort and may be time-consuming in the data collection process.

The flexible combination of quantitative and qualitative approaches has been demonstrated in different studies. By mixing both methods, we can generally aggregate opinions of experts along multiple dimensions, indicators, and proxies. Cutter et al. combine the qualitative GIS (Geographic Information System) map and quantitative indicators to generate social vulnerability, built environment/infrastructure, hazard exposure, and hazards mitigation layers (Cutter et al., 2008b). The overlaying of these four layers provides a schematic representation of resilience baseline for communities. In a similar approach, the Bay Localize Community Resilience Toolkit (Bay Localize, 2009) applies a scale from 0–4 to measure community-based resilience indicators. In consonance with rated values, the authors utilise the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, which is an extremely helpful planning and problem-solving technique, to determine and define community's capabilities for overcoming challenges. Strengths and weaknesses are typically internal factors aiming at representing the conditions within our community. On the other hand, opportunities and threats are able to put our community in a clear picture of external influences. In contrast, we can apply a quantitative measurement based on both quantitative and qualitative targets to come up with specific resilience indices. Following this methodology, the following matrix

$$\begin{array}{c} \\ Physical \\ Information \\ Cognitive \\ Social \end{array} \begin{array}{c} \begin{array}{cccc} Prepare & Absorb & Recover & Adapt \end{array} \\ \begin{bmatrix} P-P & Ab-P & R-P & Ad-P \\ P-I & Ab-I & R-I & Ad-I \\ P-C & Ab-C & R-C & Ad-C \\ P-S & Ab-S & R-S & Ad-S \end{bmatrix} \end{array}$$

utilises both qualitative and quantitative data in which qualitative values (obtained through personal communications with stakeholders) are placed at Prepare-Information ($P-I$), Prepare-Social ($P-S$), Recover-Information ($R-I$), and Adapt-Physical ($Ad-P$) positions (Fox-Lent et al., 2015).

According to (Jordan and Javernick-Will, 2013), the authors make use of a three-round Delphi method to determine necessary resilience indicators. The first round begins with a comprehensive literature review to understand and derive a good set of indicators. Experts further evaluate each dimension in the second round in consideration of a five-point Likert type scale that is anchored with 1 (not applicable) and 5 (very important). Besides, the experts are also encouraged to provide their insights into other elements that are crucial for a community to be resilient to change and cope with disasters. All following rounds will continue until we acquire a general agreement of all panel members.

## 8.4. Visualising Community Resilience

This section explores different visualisation techniques to deal with various scales and units of analysis to enhance community resilience. In emergency circumstances, a mass amount of resilience-related information can be generated from diverse data sources. Hence, utilising multiple visualisation techniques to understand and illustrate this information is essential for a more detailed and complete resilience comprehension, community-based resilience planning, and decision-making processes. Besides, employing utilisation technologies can bring us valuable and actionable insights at the application level. Table 14 summarises different visualisation techniques to represent community resilience.

*Table 14. Summary of community resilience visualisation techniques.*

| Type of Visualisation | Technique | Focus | Reference |
|---|---|---|---|
| Geospatial information | Density map | Disasters | (Cutter et al., 2014; Yoon et al., 2016) |
| | | Economic development and social capital | (Sherrieb et al., 2010) |
| | | Hot spots of high or low disasters | (Parsons et al., 2016) |
| | | Natural hazards | (Scherzer et al., 2019; The Resilience Index, 2015) |
| Multidimensional information | Stacked bar chart | Crises and disasters | (United Nations Development Programme (UNDP), 2012) |
| | Spider chart | Crises and disasters | (United Nations Development Programme (UNDP), 2012) |
| | | Disasters | (Clark-Ginsberg et al., 2020) |
| | | Soil erosion | (Rabinovich et al., 2019) |
| | | Tsunami | (Rahman and Kausel, 2013) |
| | Radial stacked bar chart | Natural hazard events | (Summers et al., 2018) |
| | Co-occurrence network | Cyclone and storm surge disasters | (Uddin et al., 2020) |

a. Geospatial Information Visualisation

In case geospatial information of community resilience is available, we can use a density map to highlight and demarcate critical locations (Parsons et al., 2016) through different colour codes in which dark and cold colours usually indicate high resilience. In contrast, light and warm colours stand for low resilience. To show colours in a map, we are able to use either qualitative, sequential, or diverging scheme. The density map is advantageous in case many data points (or data lines) exist in a small geographic area.

In a similar approach, the authors visualise disaster resilience as well as six components based on a diverging scheme, from low (standard deviation < -1.5) to high resilience (standard deviation > 1.5) (Cutter et al., 2014). Furthermore, leveraging standard deviations (Scherzer et al., 2019), other studies create the density map to represent community resilience indices of Mississippi counties (Sherrieb et al., 2010), disaster resilience indices of 11 local government areas (e.g., Greater Brisbane Area, Sunshine Coast, and others) (The Resilience Index, 2015), and community disaster resilience indices of 229 local municipalities in South Korea (Yoon et al., 2016). Despite the ability to present a holistic perspective of the resilience of a community and its neighbours, the density map shows the disadvantage if we want to represent all dimensions because each dimension will require a separate diagram.

b. Multidimensional Information Visualisation

Stacked bar charts, spider charts (which is also known as radar charts), and radial stacked bar charts are beneficial for displaying multiple dimensions of community resilience. Among these three types, stacked bar charts are designed to concurrently compare the overall resilience between communities and recognise essential dimensions within a community. In (United Nations Development Programme (UNDP), 2012), stacked bar charts are used to indicate top-ranking resilience dimensions by gender/age group, livelihood group, and level of intervention. Despite that, one major disadvantage of a stacked bar chart is that we find it hard to compare a particular dimension of a community with others since they are not aligned with a common baseline.

On the other hand, spider charts help us to compare (i) resilience dimensions of a community over time or between communities by placing multiple polygons over or upon each other in a single diagram (Rahman and Kausel, 2013) and (ii) resilience dimensions with a defined standard (Clark-Ginsberg et al., 2020). Generally, spider charts can enable a better understanding of the strengths and weaknesses of resilience dimensions (Rabinovich et al., 2019) and therefore very useful for high-level presentation of assessments. The CoBRA framework describes community attainment of resilience by illustrating five sustainable livelihood framework categories that are financial, human, natural, physical, and social by the current and crisis years (United Nations Development Programme (UNDP), 2012). If measuring scales of axes are different, it would not seem helpful to compare resilience dimension across these axes. Besides, we should avoid concentrating too much on the polygons because the area and the shape of polygons can change depending on how we organise the axes. We may use parallel coordinate charts as an alternative to spider charts. By extending the radial stacked bar chart, the authors express multiple indicators associated with defined dimensions required for a resilient community dexterously (Summers et al., 2018).

# IX. Appendix C: Resilience Framework End User Feedback

Reporting Template

## 9.1. Purpose of the Template

End-users were asked to provide feedback on the proposed Resilience Framework developed in Task 3.1 for the 'Social' dimension of the framework, and in particular the indicators proposed to capture the 'social' dimension of resilience, via a 'feedback topic guide'. This document provides a template to record the responses from end-users to this topic guide.

The Reporting Template is intended to be completed by the person responsible for carrying out the end-user interview, drawing on end-user responses to the topic guide.

For each section below, please summarise these responses using the Tables and instructions provided.

## 9.2. Details of Interview

| | |
|---|---|
| Location of community covered | |
| End-user(s) interviewed | |
| Interview carried out by | |
| Interview Date | |

## 9.3. Section 1: Indicators Relevance, Usefulness and Importance

This Section covers end user responses on the relevance, usefulness and importance of the indicators (key questions a, b, d and e).

*Table 15 Indicators Relevance, usefulness and importance*

| **Indicator** | **A. Relevance (Y/N)** | **B. If used (Y/N)** | **C. Importance (Rank 1-8)** | **D. Why not relevant** | **E. Why Important** |
|---|---|---|---|---|---|
| Community profile | | | | | |
| Civic engagement | | | | | |
| Social support | | | | | |
| Trust | | | | | |
| Place attachment | | | | | |
| Risk awareness | | | | | |
| Disaster efficacy | | | | | |
| Disaster preparedness | | | | | |

In Column A: Specify whether the indicator is viewed by the User as relevant in their assessment of the community's level of resilience when facing a disaster – write 'Y' (for Yes) and 'N' (for No') for each indicator listed

In Column B: Specify whether the indicator is used in practice by the User in their assessment of the community's level of resilience– write 'Y' (for Yes) and 'N' (for No') for each indicator listed

In Column C: Specify how important the User rates each indicator in terms of affected the resilience of their community in a recent disaster by ranking each indicator from 1 (most important) to 8 (least important)

In Column D: For each of the Indicators described as not relevant in Column A, specify the reason(s) why the indicator is seen as not relevant by the User.

In Column E: For the four Indicators described as the most important in Column C (i.e. ranked 1, 2, 3 and 4), specify the reason(s) why the indicator is seen as important.

## 9.4. Section 2: Indicator Contribution to Resilience

This Section captures whether and in what ways the factors reflected by the indicators have contributed to the resilience of the end-user's community in a recent disaster, from the perspective of the end-user.

*Table 16 Contribution to resilience*

| Indicator | B. Impact on community resilience |
|---|---|
| Community profile | |
| Civic engagement | |
| Social support | |
| Trust | |
| Place attachment | |
| Risk awareness | |
| Disaster efficacy | |
| Disaster preparedness | |

In Column A, summarise what contribution if any each indicator in the list made to increasing or reducing the resilience of the community to a disaster, from the perspective of the User (key question c).

## 9.5. Section 3: Missing Indicators

This Section provides information on whether the end-user identified additional indicators they felt are missing from the framework (key question f).

*Table 17 Additional indicators*

| A. Indicator Name | B. Description | C. How this would be measured |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

In Column A, specify any additional indicators suggested by the User.

In Column B, write down a description for each of these additional indicators.

In Column C, specify how the indicator should be measured.

## 9.6. Section 4: Indicator Measures

This Section covers end-user opinions and observations on the measures associated with the indicators (key question g).

*Table 18 Indicator measures*

| Indicator | Measures | A. Ease of collection | B. Similar data available |
|---|---|---|---|
| Community profile | 1. % of population over 75<br>2. % of population <5 years old<br>3. % of female population<br>4. Average household income compared with national median income<br>5. % of population born in community<br>6. % of population with a disability<br>7. % of population who have attended university<br>8. % of population who feel safe in their area<br>9. % of single parent households | | |
| Civic engagement | 1. % of population active in setting creative community engagement strategies<br>2. % of population who vote in local elections<br>3. % of households participating in community activities and events<br>4. % population undertaking voluntary work<br>5. Number of NGOs per 1000 people for pre and post-disaster response | | |
| Social support | 1. % of population willing to lend to and borrow from others<br>2. % of population who have someone they can rely on for help if they have a serious problem<br>3. % of population willing to help each other in everyday situations<br>4. % of population willing to help each other in times of crisis | | |
| Trust | 1. % of population aware of and believing in the effectiveness of NGOs in their community or area<br>2. % of population who trust information shared by their authority<br>3. % of population who participate in solving collective problems | | |
| Place attachment | 1. % of population with close relationships with others, such as family, friends, neighbours<br>2. Level of community-wide identity and culture | | |

| Indicator | Measures | A. Ease of collection | B. Similar data available |
|---|---|---|---|
| | 3. % of population living in the area for 10+ years | | |
| Risk awareness | 1. % of population that expect to experience a natural disaster over the next 3 years that will put them in danger<br>2. % of population that are often afraid that they or someone close to them will be directly affected by a disaster<br>3. Level of awareness of most likely risks to community among population | | |
| Disaster efficacy | 1. % of households with skills relating to coping with local disasters<br>2. % of population who feel confident in their ability to self-organise in the event of a natural disaster<br>3. % of population who trust their own ability to protect themselves during a natural disaster<br>4. % of population who know how to keep safe in the event of most likely hazards | | |
| Disaster preparedness | 1. % who have taken steps to prepare themselves in case of a disaster affecting their home<br>2. % population involved in local disaster resilience groups<br>3. Number of citizens per 1000 who have undertaken one or more type of preparation activities, including: CPR training, first aid training, creating a personal plan to be used in case of emergency, preparing an emergency kit, discussing how to prepare for a disaster with someone else, attending meetings to learn how to prepare for a disaster)<br>4. % of population who have insurance cover to protect them from the negative effects of disasters | | |

In Column A, for each of the numbered measures listed for each indicator, specify how easy it would be for the user to collect the data described using the scale: 1 – Easy 2 – Difficult 3 – Impossible

In Column B, for each of the **indicators** listed, specify whether similar data to that described by the measures is available to the User to collect and what these data are.

## 9.7. Section 5: Descriptions and ‘Mid Range Theories’

This Section covers two aspects. First, end-user observations on the appropriateness of the indicator descriptions. Second, end-user observations on the text used to define why each indicator is important. This reflects what we would call the ‘mid range theory’ behind an indicator – i.e., the assumptions behind why, for example, civic engagement would ‘cause’

increased resilience. A key aim of the user feedback is to collect what kind of these 'causal explanations' are in the minds of end users when they think about resilience and how it can be measured (key question h).

In Column A, specify any changes that need to be made to the indicator descriptions from the user perspective.

In Column B, specify any changes that need to be made to the underlying 'mid range theory' implied by the 'why is it important' description.

*Table 19 Descriptions and 'Mid Range Theories'*

| Indicator | Description | Why is this important? | A. Description changes | B. MRT changes |
|---|---|---|---|---|
| Community profile | This provides a demographic overview of the local population. | Previous research has shown that there is a link between the demographic characteristics of a community and its level of resilience. | | |
| Civic engagement | Level of engagement of the local population in the community, including volunteering and attending community groups and events. | Civic engagement facilitates collective action for mutual benefit and helps citizens to adaptively learn and transform in the face of threats or hazards. | | |
| Social support | The extent to which the local population provide support to each other and in particular to more vulnerable members of the community. | Communities that support each other are better at recovering from disasters and also more able to ensure that the most vulnerable are protected during or after a crisis. | | |
| Trust | The level of trust between citizens and local authority representatives and emergency services. | High level of trust is associated with citizens being more likely to follow guidelines and instructions before, during or after an emergency to keep themselves and others safe. | | |
| Place attachment | The extent to which citizens feel a sense of belonging to where they live and have strong links with their neighbours and neighbourhood. | Place attachment encourages citizens to invest time and energy to improve resilience and engage in mitigation behaviours, including helping others. | | |
| Risk awareness | The extent to which citizens are aware of different | Higher levels of risk awareness are associated with | | |

| Indicator | Description | Why is this important? | A. Description changes | B. MRT changes |
|---|---|---|---|---|
| | potential hazards and their likelihood | increased levels of adaptive behaviour. | | |
| Disaster efficacy | The extent to which citizens have relevant knowledge, skills or competences of how to protect themselves and others before, during or after an emergency. | Citizens with high levels of self-efficacy are more likely to take steps to protect themselves and others before or during a disaster. | | |
| Disaster preparedness | The extent to which citizens have taken/are willing to take steps to protect themselves and their property from the negative impacts of disasters. | Higher levels of preparedness/adaptive behaviour in communities are associated with increased resilience in communities in the face of natural hazards. | | |

## 9.8. Section 6: Overall User Feedback and Recommendations for Improvement

This final section covers end-user perceptions of the proposed framework and recommendations for improvement (key question i).

*Table 20 Overall user feedback and recommendations for improvement*

| A. Overall observations | B. Usefulness | C. Recommendations for Improvement |
|---|---|---|
| | | |

In Column A, write down any other comments, observations made by the end-user that are not recorded elsewhere in the Template.

In Column B, summarise end-user observations and comments about the usefulness of the information in the framework in helping the community prepare for a disaster.

In Column C, specify and suggestions provided by end-users on how the framework and the information it contains could be made more useful.

# X. Appendix D: End User Feedback Topic Guide - Social Dimension

| Indicator | Description | Why is this important? | How can we measure this? (Examples) |
|---|---|---|---|
| Civic engagement | Level of engagement of the local population in the community, including volunteering and attending community groups and events. | Civic engagement facilitates collective action for mutual benefit and helps citizens to adaptively learn and transform in the face of threats or hazards. | % of population active in setting creative community engagement strategies<br>% of households participating in community activities and events<br>% population undertaking voluntary work<br>Number of NGOs per 1000 people for pre and post-disaster response |
| Social support | The extent to which the local population provide support to each other and in particular to more vulnerable members of the community. | Communities that support each other are better at recovering from disasters and also more able to ensure that the most vulnerable are protected during or after a crisis. | % of population willing to lend to and borrow from others<br>% of population who have someone they can rely on for help if they have a serious problem<br>% of population willing to help each other in everyday situations<br>% of population willing to help each other in times of crisis |
| Trust | The level of trust between citizens and local authority representatives and emergency services. | High level of trust is associated with citizens being more likely to follow guidelines and instructions before, during or after an emergency to keep themselves and others safe. | % of population aware of and believing in the effectiveness of NGOs in their community or area<br>% of population who trust information shared by their authority<br>% of population who participate in solving collective problems |
| Place attachment | The extent to which citizens feel a sense of belonging to where they live and have strong links with their neighbours and neighbourhood. | Place attachment encourages citizens to invest time and energy to improve resilience and engage in mitigation behaviours, including helping others. | % of population with close relationships with others, such as family, friends, neighbours<br>Level of community-wide identity and culture<br>% of population living in the area for 10+ years |
| Risk awareness | The extent to which citizens are aware of different potential hazards | Higher levels of risk awareness are associated with increased levels of adaptive behaviour. | % of population that expect to experience a natural disaster over the next 3 years that will put them in danger |

| Indicator | Description | Why is this important? | How can we measure this? (Examples) |
|---|---|---|---|
| | and their likelihood | | % of population that are often afraid that they or someone close to them will be directly affected by a disaster<br>% of population that say that fear of a disaster sometimes influences their behaviour or decisions on a day-to-day basis |
| Disaster efficacy | The extent to which citizens have relevant knowledge, skills or competences of how to protect themselves and others before, during or after an emergency. | Citizens with high levels of self-efficacy are more likely to take steps to protect themselves and others before or during a disaster. | % of households with skills relating to coping with local disasters<br>% of population who feel confident in their ability to self-organise in the event of a natural disaster<br>% of population who trust their own ability to protect themselves during a natural disaster<br>% of population who know how to keep safe in the event of most likely hazards |
| Disaster preparedness | The extent to which citizens have taken/are willing to take steps to protect themselves and their property from the negative impacts of disasters. | Higher levels of preparedness/adaptive behaviour in communities are associated with increased resilience in communities in the face of natural hazards. | % who have taken steps to prepare themselves in case of a disaster affecting their home<br>% population involved in local disaster resilience groups<br>Number of citizens per 1000 who have undertaken one or more type of preparation activities, including: CPR training, first aid training, creating a personal plan to be used in case of emergency, preparing an emergency kit, discussing how to prepare for a disaster with someone else, attending meetings to learn how to prepare for a disaster)<br>% of population who have insurance cover to protect them from the negative effects of disasters |

**Introduction**

The table above provides an overview of our suggested way of assessing the resilience of local communities from a 'social' perspective. In this project, we understand 'resilience' as the capacities of local communities to mitigate, withstand, and recover from the impacts of a

disaster or emergency, as well as to adapt or transform themselves to be less vulnerable to future disasters or emergencies.

We will be assessing other aspects of resilience, but at the moment this table focuses on what we call the 'social dimension' of resilience. This dimension describes the social capacities of a community that help to increase its resilience to different types of disasters. A key focus of this dimension are the social relationships and networks aiding cooperation, solidarity, information sharing and trust at the local level. This includes the extent to which citizens are actively engaged in community organizations and volunteering activities and whether there is a culture of supporting each other in general or in times of crisis. Of particular importance is also the level of trust in the authority and other organizations locally, which informs the extent to which citizens are likely to listen and respond to instructions or advice provided by them to guide behavior in preparation for, and in response to, particular risks and hazards. This dimension also focuses on the extent to which citizens in the community feel a sense of belonging to where they live and have strong links with their neighbors and neighborhood, they live in.

**Key Questions:**

Think about a recent natural disaster – such as a flood, earthquake, fire, or major storm – affecting your community and then consider the following questions:

a) Which of the 'indicators' in the Table are relevant to your assessment of the community's level of resilience when facing a disaster?
b) Do you cover any of the indicator topics when assessing resilience? If so, which ones?
c) Looking at the indicators: to what extent did these things increase or reduce the resilience of your community to the disaster? For example:
    a. Did the level of 'civic engagement' of citizens increase or reduce resilience of your community?
    b. Did the level of 'trust' between citizens and your local authority/emergency service have an impact?
    c. Did citizens' levels of risk awareness prepare them for the disaster in any way?
d) If you were to rank these indicators in order of importance – how would rank them? i.e. Which of these factors was most important in affecting the resilience of your community to this disaster? Why?
e) Were any of these indicators not relevant? Why? Is it related to this particular natural disaster or can you not see them as relevant to your local community in any event?
f) Are any indicators missing?
g) What do you think of the suggested measures for the indicators? How easy/difficult would it be for you to collect such data? Can you think of other similar types of data for these indicators that you have available?
h) Do you have any other comments on the information in the Table – particularly the 'Description' and 'Why is this important?' boxes. Is anything missing?

Overall, how useful would a summary of the information in this table be to help you prepare for disasters? What could make it more helpful?

# XI. Appendix E: Information Sheet and Consent Form

| RESILOC Information Sheet – *'End-user interviews – social dimension'* | |
|---|---|
| Research Project Title | Resilient Europe & Societies by Innovating Local Communities |
| Introduction | You have been invited to take part in activities related to the Resilient Europe and Societies by Innovating Local Communities (RESILOC) project. Please read the following document carefully to make your decision to participate in the relevant activity. If in doubt about individual items of this form, you can contact the responsible person for this activity or the coordinator of the project. |
| Project Background | The RESILOC project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 833671. The project's objective is to increase Europe's resilience to crisis and disasters. Resilience is defined by the United Nations as "the ability to resist, absorb and accommodate to the effects of a hazard, in a timely and efficient manner". Thus, resilient communities are those in which their citizens, environment, businesses, and infrastructures have the capacity to withstand, adapt, and recover in a timely manner from any kind of hazards they face, either planned or unplanned. In recent years efforts have been spent to tackle resilience and there is, still, a long path forward in defining an EU valid and sound approach to the problem. |
| Project Website | https://www.resilocproject.eu/ |
| Invitation | You are being invited to participate in this research project to provide your feedback on the indicators developed as part of the project. The RESILOC research team will use the answers you provide to inform the development of the resilience tool and aims to improve resilience of local communities. |
| Purpose of the research | RESILOC aims at studying and implementing a holistic framework of studies, methods and software instruments that combines the physical with the less tangible aspects associated with human behaviour. |
| Purpose of the specific research activity | The interview will explore your views of one dimension ('the social dimension') and in particular the indicators proposed to capture the 'social' dimension of resilience we have developed over the last few months. This will be done via a series of questions relating to a recent natural disaster experienced in the community, to assess: how useful the indicators are, whether there are any gaps, and how easy or difficulty it will be to collect the suggested information for each of the indicators. |
| Research activity procedures | We want to talk with you over Zoom/Teams/Skype or face-to-face, if safe and possible, for up to 60 minutes – this will be arranged at a date and time convenient to you. We will not contact you again as part of this study unless you specifically agree to be contacted again or to receive results of the research. |
| Voluntary Participation | Your participation in the interviews is completely voluntary, and you can choose to stop participating at any time. If you decide to withdraw, please contact the RESILOC consortium contact point(s) outlined above, and they will explain the best way for you to stop taking part. |
| Risks | We do not foresee any particular risks related to your participation in this study – as detailed below, your answers will be treated in |

| | |
|---|---|
| | confidence. We may use quotes from the interviews in our publications but these will be anonymised and any personal information that could be used to identify you will be removed. |
| Benefits for the participants | There are no direct financial benefits associated with participation in this study, although it is hoped that the study will be of public benefit by contributing to a better understanding of resilience to natural (and other) hazards and help to improve the resilience of local communities. |
| Privacy and Confidentiality | Privacy and confidentiality have been carefully considered in the RESILOC project to meet legal requirements as well as ethical considerations. Data collected throughout the project activities will be used to develop the RESILOC project objective, which is to increase Europe's resilience to crisis and disasters. Only data that is necessary for the development of the project will be collected. In some cases, it might be necessary to collect personal information such as name, an identification number or location (Article 4(1) GDPR). In some other cases "special categories of personal data" also known as SCOPD (Article 9(1) GDPR) could be collected throughout the activities of the project. However, the collection of SCOPD data will be limited and no data will be stored with the purpose of back-tracing individuals.<br><br>Data practices in RESILOC will follow the principles of data minimization and will use anonymization and pseudonymization techniques. In addition, data practices in RESILOC have been designed following legal requirements as well as ethical considerations approved by ethic boards. Only authorised administrators assigned through internal project processes will have access to data. RESILOC will follow the data minimization principle (Article 5 GDPR). This principle consists of collecting only the necessary amount of data and using it to the minimum extent. Therefore, data that is no longer required to develop project activities will be deleted. For this particular research activity, we collect the following personal data: name, organisation and community name, email and phone number (optional), in order to have better understanding of your opinion and perspective. We would also like to make an audio recording of the interview (optional), which will only be used to aid us to improve the analysis of the answers you provide. |
| RESILOC Contact Persons | Local ethics representative:<br>RESILOC Data Protection Officer: resiloc-dpo@fraunhofer.de |

| |
|---|
| **About this form:** Please complete and sign this form to indicate your consent to take part in the end-user interviews as part of the RESILOC research study – an EU research project funded by the European Commission under the Horizon 2020 Programme. Further details about the study and how the data from this interview will be used are provided in the attached information sheet. The information should give you the ability to make an informed decision about participation in this research. You will be provided with a copy of this form and the related information sheet. |
| **Participation requirements:** Adult persons of at least 18 years old only are permitted to participate. In addition, only participants being able to give informed consent themselves shall participate. |
| **Data collection/Study Procedure:** The following data will be collected for an EU research project RESILOC funded by European Commission under the Horizon 2020 Programme. The interview will explore your views of one dimension ('the social dimension') and in particular the indicators proposed to capture the 'social' dimension of resilience we have developed over the last few months. |
| **Location & duration:** The interview will take place over Zoom/Teams/Skype or face-to-face, if safe and possible, for up to 60 minutes – this will be arranged at a date and time convenient to you. |
| **Task description:** The interview will consist of a series of questions relating to a recent natural disaster experienced in your community, to assess: how useful the indicators are, whether there are any gaps, and how easy or difficulty it will be to collect the suggested information for each of the indicators. |
| **Benefits for the participants:** There are no direct financial benefits associated with participation in this study, although it is hoped that the study will be of public benefit by contributing to a better understanding of resilience to natural (and other) hazards and help to improve the resilience of local communities. |
| **Risks of participation:** We do not foresee any particular risks related to your participation in this study – as detailed below, your answers will be treated in confidence. We may use quotes from the interviews in our publications but these will be anonymised and any personal information that could be used to identify you will be removed. |
| **RESILOC Consortium Contact Point(s):** If you have any questions about the research study, please contact Thomas Spielhofer (t.spielhofer@tavinstitute.org) |
| **Data Protection:** The RESILOC ethical board members will monitor procedures for data collection and handling, this includes ethical compliance of deliverables including any kind of data The RESILOC Consortium members who see/access this information will keep it confidential. RESILOC researchers and target groups will have access to anonymized data only. Data collected throughout the project activities will be used to develop the RESILOC project objective, which is to increase Europe's resilience to crisis and disasters. Only data that is necessary for the development of the project will be collected.<br>Only authorised administrators assigned through internal project processes will have access to data. RESILOC will follow pseudonymization and the data minimization principle (Article 5 GDPR). This principle consists of collecting only the necessary amount of data and using it to the minimum extent. Therefore, data that is no longer required to develop project activities will be deleted. In addition, data practices in RESILOC have been designed following legal requirements as well as ethical considerations approved by ethic boards. For this particular research activity, we collect the following personal data: name, organisation and community name, email and phone number (optional), in order to have better understanding of your opinion and perspective. We would also like to make an audio recording of the interview (optional), which will only be used to aid us to improve the analysis of the answers you provide. |
| **Withdrawal Information:** Your participation in the RESILOC project is completely voluntary, and you can choose to stop participating at any time. If you decide to withdraw from the project, please contact the RESILOC consortium contact point outlined above, and they will explain the best way for you to stop taking part.<br><br>You should know that you may be withdrawn from the project for any of the following reasons:<br>• If you don't follow the projects ethical board instructions<br>• If you don't attend the scheduled data collection session<br>• If the whole project is stopped, for reasons not known now |

| Voluntary Participant Data | |
|---|---|
| Name | |
| Organisation | |
| Local community | |
| Email (optional) | |
| Telephone (optional) | |
| Declaration | I have read the terms outlined and understand them.<br>Please, tick the boxes if you agree:<br>□ I am 18 years or older and am competent to provide consent;<br>□ I have been informed about the aims and purposes of the RESILOC project;<br>□ I have read the principles laid out above<br>□ I consent to my data being used for the RESILOC project in line with the principles laid out above<br><br>Also please tick the following box if you agree:<br>□ I agree for the interview to be recorded (you can still take part in the study if you do not agree to be recorded).<br><br>Date, Signature<br><br>_____ |

# XII. List of References

**Adger, W. N. (2000):** Social and ecological resilience: are they related? Progress in Human Geography, 24(3), 347–364.

**Allen, M (2017):** The SAGE Encyclopedia of Communication Research Methods. London: Sage

**Alshehri, S. A., Rezgui, Y., and Li, H. (2015a):** Delphi-Based Consensus Study Into a Framework of Community Resilience to Disaster. Natural Hazards, 75(3), pp. 2221–2245.

**Alshehri, S. A., Rezgui, Y., & Li, H. (2015b):** Disaster community resilience assessment method: a consensus-based Delphi and AHP approach. Natural Hazards, 78(1), 395–416.

**American Society of Civil Engineers. (2021):** *2021 Report Card for America's Infrastructure.* Retrieved from Infrastructure Report Card: https://infrastructurereportcard.org/infrastructure-categories/

**Arbon, P. (2014):** Developing a Model and Tool to Measure Community Disaster Resilience. Australian Journal of Emergency Management, 29(4), pp. 12–16.

**Arbon, P., Steenkamp, M., Cornell, V., Cusack, L., & Gebbie, K. (2016):** Measuring disaster resilience in communities and households. International Journal of Disaster Resilience in the Built Environment, 7(2), 201–215.

**Arup. (2015):** *City Resilience Framework.* Retrieved from Rockefeller Foundation: https://www.rockefellerfoundation.org/wp-content/uploads/City-Resilience-Framework-2015.pdf

**Arup (2017):** City Resilience Index. Downloaded from https://www.arup.com/perspectives/publications/research/section/city-resilience-index

**Asadzadeh, A, Kötter, T, Salehib,and Birkmann, J (2017):** Operationalizing a concept: The systematic review of composite indicator building for measuring community disaster resilience. Int. Jnl. Disaster Risk Reduction, 25, 147-162

**Aslam Sajaa, A.M., Teoa, M., Goonetillekea, A., Ziyatha, A.M. (2018):** An inclusive and adaptive framework for measuring social resilience to disasters. International Journal of Disaster Risk Reduction, 28, 862-873.

**Astbury B and Leeuw F (2010):** Unpacking black boxes: mechanisms and theory building in evaluation. American Journal of Evaluation 31(3): 363–81.

**Bay Localize (2009):** Community Resilience Toolkit: A Workshop Guide for Community Resilience Planning. URL: http://www.baylocalize.org/files/Community_Resilience_Toolkit_v1.0.pdf

**Beccari, B. (2016):** Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators. *PLOS Currents Disasters*. doi:doi: 10.1371/currents.dis.453df025e34b682e9737f95070f9b970

**Brody, D., Seitz William, A., Merrel William, J., Vedlitz, A., Zaharan, S., Harriss Rober, C., & Stickney Robert, R. (2010):** Advancing Resilience of Coastal Localities: Developing, Implementing, and Sustaining the Use of Coastal Resilience Indicators: A Final Report

**Bryman, A (2012):** Social Research Methods. 4th ed. New York: Oxford University Press.

**Buckle, P. (2006):** Assessing social resilience. In D. Paton & D. M. Johnston (Eds.), Disaster resilience: An integrated approach (pp. 88–103). Springfield: Charles C. Thomas.

**Bulmer, M (2001):** Social measurement: what stands in its way. Social Research, 68, 2, 455-480

**Burton, C. G. (2015):** A validation of metrics for community resilience to natural hazards and disasters using the recovery from Hurricane Katrina as a case study. Annals of the Association of American Geographers, 105(1), 67-86.

**C3 Living Design Project (2019):** Resilient Design for a Changing World. URL: http://c3livingdesign.org/?page_id=5110

**Campbell, K (2019):** First insights from the Flood Resilience Measurement Tool: A large-scale community flood resilience analysis International Journal of Disaster Risk Reduction, 40

**Cardona, O.D. (2005):** Indicators of Disaster Risk and Risk Management- Program for Latin America and the Caribbean: Summary Report, Inter-American Development Bank, Department of Sustainable Development, Washington.

**Centre of Expertise for Good Governance (2020):** Civil Participation in Decision-Making Toolkit. https://rm.coe.int/civil-participation-in-decision-making-toolkit-/168075c1a5

**Chandra, A., Acosta, J., Howard, S., Uscher-Pines, L., Williams, M., Yeung, D., Garnett, J., and Meredith, L. S. (2011):** Building Community Resilience to Disasters: A Way Forward to Enhance National Health Security. Santa Monica, CA: RAND Corporation.

**Chen, Y., Huang, Y., Li, K., & Luna-Reyes, L. F. (2019, April):** Dimensions and measurement of city resilience in theory and in practice. In Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance (pp. 270–280).

**Cimellaro, G. P., Renschler, C., Reinhorn, A. M., and Arendt, L. (2016):** PEOPLES: A Framework for Evaluating Resilience. Journal of Structural Engineering, 142(10), p. 4016063.

**City resilience index, the Rockfeller Foundation, & ARUP (2015):** City resilience Framework: Understanding and measuring city resilience

**Clark-Ginsberg, A., McCaul, B., Bremaud, I., Caceres, G., Mpanje, D., Patel, S., and Patel, R. (2020):** Practitioner Approaches to Measuring Community Resilience: The Analysis of the Resilience of Communities to Disasters Toolkit. International Journal of Disaster Risk Reduction, 50, p. 101714.

**Cohen, O., Leykin, D., Lahad, M., Goldberg, A., and Aharonson-Daniel, L. (2013):** The Conjoint Community Resiliency Assessment Measure as a Baseline for Profiling and Predicting Community Resilience for Emergencies. Technological Forecasting and Social Change, 80(9), pp. 1732–1741.

**Coile, R. C. (1997):** The role of amateur radio in providing emergency electronic communication for disaster management. Disaster Prevention and Management: An International Journal, 6(3), 176–185. https://doi.org/10.1108/09653569710172946

**Community and Regional Resilience Institute (CARRI) (2013):** Building Resilience in America's Communities: Observations and Implications of the CRS Pilots Report. URL: http://community.resilienceguild.org/system/files/CRS-Final-Report.pdf

**Corrente, S., Greco, S., Nicotra, M. Romano, M., Schillaci, C. (2019):** Evaluating and comparing entrepreneurial ecosystems using SMAA and SMAA-S. Journal of Technology Transfer, 44, 485-519.

**Council of Europe (2007):** Strategy on Innovation and Good Governance at local level. https://rm.coe.int/1680701699

**Council of Europe (2008):** 12 Principles of Good Governance. https://www.coe.int/en/web/good-governance/12-principles

**Cutter, S. L. (2016):** The landscape of disaster resilience indicators in the USA. Natural Hazards, 80(2), 741–758

**Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010):** Disaster resilience indicators for benchmarking baseline conditions. Journal of Homeland Security and Emergency Management, 7(1), Article 51.

**Cutter, S. L., Ash, K. D., & Emrich, C. T. (2014):** The geographies of community disaster resilience. Global Environmental Change, 29, 65–77.

**Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008a):** A place-based model for understanding community resilience to natural disasters. *Global Environmental Change, 18*(4), 598-606. doi:https://doi.org/10.1016/j.gloenvcha.2008.07.013

**Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., and Webb, J. (2008b):** Community and Regional Resilience: Perspectives From Hazards, Disasters, and Emergency Management. Geography, 1(7), pp. 2301–2306.

**Cutter, S. L., Emrich, C. (2010):** Disaster Resilience Indicators for Benchmarking

**De Vaus, D. (2002):** Surveys in Social Research. 5th Edition, Routledge, London.

**Doran, G. T. (1981):** There's a S.M.A.R.T. way to write management's goals and objectives. Management Review. 70 (11): 35–36.

**Eidsvig, U., McLean, A., Vangelsten, B. V., Kalsnes, B. (2011):** Socio-economic vulnerability to natural hazards – proposal for an indicator-based model. Geotechnical Safety and Risk. ISGSR 2011, pp.141-148.

**FEMA (2016):** Mitigation Framework Leadership Group (MitFLG) Draft Concept Paper Draft Interagency Concept for Community Resilience Indicators and National-Level Measures. https://www.fema.gov/media-library-data/1466085676217-a14e229a461adfa574a5d03041a6297c/FEMA-CRI-Draft-Concept-Paper-508Jun2016.pdf

**Fox-Lent, C., Bates, M. E., and Linkov, I. (2015):** A Matrix Approach to Community Resilience Assessment: An Illustrative Case at Rockaway Peninsula. Environment Systems and Decisions, 35(2), pp. 209–218.

**Gusenbauer, M. (2019):** Google Scholar to Overshadow Them All? Comparing the Sizes of 12 Academic Search Engines and Bibliographic Databases. Scientometrics 118 (1): 177–214. https://doi.org/10.1007/s11192-018-2958-5

**He, J and van de Vijver, F (2012):** Bias and equivalence in cross-cultural research. Online Readings in Psychology and Culture, 2(2), 8

**Hincks S. (2014)** Contextual Indicators. In: Michalos A.C. (eds) Encyclopedia of Quality of Life and Well-Being Research. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0753-5_557

**IMPROVER Project (2020):** Improved Risk Evaluation and Implementation of Resilience Concepts to Critical Infrastructure. URL: http://improverproject.eu

**International Energy Agency. (2020):** *Defining energy access: 2020 methodology.* Retrieved from International Energy Agency: https://www.iea.org/articles/defining-energy-access-2020-methodology

**International Federation of Red Cross and Red Crescent Societies (IFRC) (2013):** IFRC Framework for Community Resilience. URL: https://media.ifrc.org/ifrc/document/ifrc-framework-community-resilience

**ISO (2019):** ISO 37123:2019 Sustainable cities and communities — Indicators for resilient cities. https://www.iso.org/standard/70428.html

**Iyengar, S. S., & Lepper, M. R. (2000**). When choice is demotivating: Can one desire too much of a good thing? *Journal of Personality and Social Psychology, 79*(6), 995–1006

**Jacobsen, K., Marshak, A., & Griffith, M. (2009):** *Increasing the Financial Resilience of Disaster-affected Populations.* Retrieved from ALNAP: https://www.alnap.org/system/files/content/resource/files/main/increasing-financial-resilience-2009.pdf

**Jessop, B. (2001):** Institutional Re(Turns) and the Strategic – Relational Approach. Environment and Planning A: Economy and Space, 33(7), 1213-1235.

**Joerin, J., Shaw, R., Takeuchi, Y., and Krishnamurthy, R. (2012):** Assessing Community Resilience to Climate-Related Disasters in Chennai, India. International Journal of Disaster Risk Reduction, 1, pp. 44–54.

**Joerin, J., Shaw, R., Takeuchi, Y., & Krishnamurthy, R. (2014):** The adoption of a climate disaster resilience index in Chennai, India. Disasters, 38(3), 540–561.

**Jonker J and Pennink B (2010):** The Essence of Research Methodology. Springer

**Jordan, E., and Javernick-Will, A. (2013):** Indicators of Community Recovery: Content Analysis and Delphi Approach. Natural Hazards Review, 14(1), pp. 21–28.

**Jovanović, A., Klimek, P., Choudhary, A., Schmid, N., Linkov, I., Øien, K., Lieberz, D. (2016):** Analysis of existing assessment resilience approaches, indicators and data sources: Usability and limitations of existing indicators for assessing, predicting and monitoring critical infrastructure resilience. In IRGC, *Resource Guide on Resilience.* Lausanne: EPFL International Risk Governance Center.

**Jovanovic, A. S., Øien, K., & Choudhary, A. (2018):** An Indicator-Based Approach to Assessing Resilience of Smart Critical Infrastructures. In A. Fekete, & F. Fiedrich (Eds.), *An Indicator-Based Approach to Assessing Resilience of Smart Critical Infrastructures: Addressing Risks in Societies.* Springer. doi:10.1007/978-3-319-68606-6_17

**Kafle, S. K. (2012):** Measuring Disaster-Resilient Communities: A Case Study of Coastal Communities in Indonesia. Journal of Business Continuity & Emergency Planning, 5(4), pp. 316–326.

**Kahn, M. B. (2005):** The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions. Review of Economics and Statistics, 87(2), 271-284.

**Kaufmann, D. et al. (2010):** The Worldwide Governance Indicators: Methodology and Analytical Issues. http://info.worldbank.org/governance/wgi/Home/Documents

**Khazai, B., Cardona, O. D., Carreño Tibaduiza, M. L., & Barbat, A. H. (2015):** *A Guide to measuring urban risk resilience: Principles, tools and practice of urban indicators.* Retrieved from PreventionWeb: https://www.preventionweb.net/publication/guide-measuring-urban-risk-resilience-principles-tools-and-practice-urban-indicators

**Khoja, L., Schubert, R. & Joerin, J. (2020):** Social Resilience Indicators for Disaster Related Contexts: Literature Review. FRS Working Paper 2

**Kraay, A., Kaufmann, D., & Mastruzzi, M. (2010):** The Worldwide Governance Indicators : Methodology and Analytical Issues. Policy Research Working Papers. The World Bank.

**Kuhlicke, C, Masson, T, Kienzler, S, Sieg, T, Thieken, A and Kreibich, H (2020):** Multiple Flood experiences and Social resilience: Findings from Three Surveys on Households and Companies Exposed to the 213 Flood in Germany. Weather, Climate and Society, 12.

**Kumar, N. M., Ghosh, A., & Chopra, S. S. (2020):** Power resilience enhancement of a residential electricity user using photovoltaics and a battery energy storage system under uncertainty conditions. *Energies, 13*(16). doi:10.3390/en13164193

**Kusumastuti, R. D., Husodo, Z. A., Suardi, L., & Danarsari, D. N. (2014):** Developing a resilience index towards natural disasters in Indonesia. International Journal of Disaster Risk Reduction, 10, 327–340.

**Kwok, A. H., Doyle, E. E., Becker, J., Johnston, D., & Paton, D. (2016):** What is 'social resilience'? Perspectives of disaster researchers, emergency management practitioners, and policymakers in New Zealand. International Journal of Disaster Risk Reduction, 19, 197–211.

**Leggett, A (2011):** Constructs, variables and operationalization, in J.F. Hair, R.P. Bush & D.J. Ortinau (eds.), Marketing Research within a Changing Information Environment, pp. 56–93, McGraw-Hill, Boston, MA.

**Leykin, D., Lahad, M., Cohen, O., Goldberg, A., & Aharonson-Daniel, L. (2013):** Conjoint community resiliency assessment measure-28/10 items (CCRAM28 and CCRAM10): A self-report tool for assessing community resilience. American Journal of Community Psychology, 52(3–4), 313–323.

**Leykin, D., Lahad, M., Cohen, R., Goldberg, A., & Aharonson-Daniel, L. (2016):** The dynamics of community resilience between routine and emergency situations. International Journal of Disaster Risk Reduction, 15(1), 125–131.

**Lung, T., Lavalle, C., Hiederer, R., Dosio, A., and Bouwer, L. M. (2013):** A multi-hazard regional level impact assessment for Europe combining indicators of climatic and non-climatic change. Global Environmental Change, 23(2), pp. 522–536.

**Magis, K. (2010):** Community resilience: An indicator of social sustainability. Society and Natural Resources, 23(5), 401–416.

**Mehvar, S., Wijnberg, K., Borsje, B., Kerle, N., Schraagen, J. M., Kruijf, J. V., … Hulscher, S. (2021):** Review article: Towards resilient vital infrastructure systems – challenges, opportunities, and future research agenda. Natural Hazards and Earth System Sciences, 21, 1383–1407. https://doi.org/10.5194/nhess-21-1383-2021

**Merton R (1967):** On sociological theories of the middle-range, chapter 2 in R Merton, On Theoretical Sociology: Five essays old and new. New York: Free Press

**Moore, M., Chandra, A., & Feeney, K. C. (2013):** Building community resilience: what can the United States learn from experiences in other countries?. Disaster Medicine and Public Health Preparedness, 7(3), 292–301.

**Moreno, J., Lara, A., and Torres, M. (2019):** Community Resilience in Response to the 2010 Tsunami in Chile: The Survival of a Small-Scale Fishing Community. International Journal of Disaster Risk Reduction, 33, pp. 376–384.

**Nardo M, Saisana M, Saltelli A, Tarantola S, Hoffmann A, Giovannini E. (2008):** Handbook on Constructing Composite Indicators: Methodology and User Guide. Paris (France): OECD publishing

**Nicotra, M., Romano, M., Del Giudice, M., Schillaci, C. (2018):** The causal relation between entrepreneurial ecosystem and productive entrepreneurship: a measurement framework. Journal of Technology Transfer, 43, pp. 640-673.

**Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008):** Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. American Journal of Community Psychology, 41(1–2), 127–150.

**OECD (2014):** Recommendation of the council on the governance of critical risks. http://www.oecd.org/gov/risk/Critical-Risks-Recommendation.pdf

**OECD (2018):** Indicators for resilient cities. https://www.oecd-ilibrary.org/docserver/6f1f6065-en.pdf?expires=1595354802&id=id&accname=guest&checksum=4CDE467BBEE0FFCE3E3709F6AF95347E

**Oktari, R. S., Shiwaku, K., Munadi, K., Syamsidik, and Shaw, R. (2015):** A Conceptual Model of a School -- Community Collaborative Network in Enhancing Coastal Community Resilience in Banda Aceh, Indonesia. International Journal of Disaster Risk Reduction, 12, pp. 300–310.

**Orencio, P. M., & Fujii, M. (2013):** A localized disaster-resilience index to assess coastal communities based on an analytic hierarchy process (AHP). International Journal of Disaster Risk Reduction, 3, 62–75.

**Osman, I. H., Anouze, A. L., Irani, Z., Al-Ayoubi, B., Lee, H., Balc, A., Medeni, T. D. and Weerakkody, V. (2014):** COBRA framework to evaluate e-government services: A citizen-centric perspective. Government Information Quarterly, 31(2), pp. 243–256.

**Papathoma-Köhle, M., & Thaler, T. (2018):** Institutional Vulnerability. In Fuchs, S. & Thaler T., Vulnerability and Resilience to Natural Hazards (pp. 98-123). Cambridge: Cambridge University Press.

**Parsons, M., Glavac, S., Hastings, P., Marshall, G., McGregor, J., McNeill, J., Morley, P., Reeve, I. & Stayner, R. (2016):** Top-down assessment of disaster resilience: A conceptual framework using coping and adaptive capacities. International Journal of Disaster Risk Reduction, 19, 1–11.

**Parsons, M., Reeve, I., McGregor, J., Marshall, G., Stayner, R., McNeill, J., Hastings, P., Glavac, S., Morley, P. (2020):** The Australian natural disaster resilience index: conceptual framework and indicator approach.

**Paton, D., Millar, M., & Johnston, D. (2001):** Community resilience to volcanic hazard consequences. Natural Hazards, 24(2), 157–169.

**Parsons, M., Morley, P., Marshall, G., Hastings, P., Glavac, S., Stayner, R., McNeill, J., McGregor, J., and Reeve, I. (2016):** The Australian Natural Disaster Resilience Index: Conceptual Framework and Indicator Approach. URL: https://www.bnhcrc.com.au/publications/biblio/bnh-2585

**Pawson R (2000):** Middle-Range Realism. Archive Européenes de Sociologie, XLI: 283-325

**Peacock, W. G., Brody, S. D., Seitz, W. A., Merrell, W. J., Vedlitz, A., Zahran, S., Harriss R. C., & Stickney, R. (2010):** Advancing resilience of coastal localities: Developing, implementing, and sustaining the use of coastal resilience indicators: A final report. Hazard Reduction and Recovery Center, 1–148. URL: https://hrrc.arch.tamu.edu/_common/documents/10-02R.pdf

**Petrović, N., Stranjik, A., & Peternel, R. (2018):** Generic resilience indicators of critical infrastructures. *Ann. Disaster Risk Sci*, 97-103.

**Pfefferbaum, R. L., Pfefferbaum, B., Van Horn, R. L., Klomp, R. W., Norris, F. H., and Reissman, D. B. (2013):** The Communities Advancing Resilience Toolkit (CART): An Intervention to Build Community Resilience to Disasters. Journal of Public Health Management and Practice, 19(3), pp. 250–258.

**Pilquimán-Vera, M., Cabrera-Campos, G., and Tenorio-Pangui, P. (2020):** Experiences of Resilience and Mapuche Community Based Tourism in the Pre-Cordilleran Territories of Panguipulli, Southern Chile. Sustainability, 12(3), p. 817.

**POP-ALERT Project (2014):** Population Alerting: Linking Emergencies, Resilience and Training. URL: http://www.eos-eu.com/pop-alert

**Poulin, C., & Kane, M. B. (2021):** Infrastructure resilience curves: Performance measures and summary metrics. *Reliability Engineering & System Safety, 216*. doi:https://doi.org/10.1016/j.ress.2021.107926

**Prevention Institute (2013):** THRIVE: Tool for Health & Resilience In Vulnerable Environments. URL: https://www.preventioninstitute.org/tools/thrive-tool-health-resilience-vulnerable-environments

**Prior, T. (2014):** *Measuring Critical Infrastructure Resilience: Possible Indicators, Risk and Resilience Report 9.* ETH Zürich, Center for Security Studies. Zurich: ETH Zürich. Retrieved December 18, 2021

**Qasim, S., Qasim, M., Shrestha, R. P., Khan, A. N., Tun, K., & Ashraf, M. (2016):** Community resilience to flood hazards in Khyber Pukhthunkhwa province of Pakistan. International Journal of Disaster Risk Reduction, 18, 100–106.

**Rabinovich, A., Kelly, C., Wilson, G., Nasseri, M., Ngondya, I., Patrick, A., Blake, W. H., Mtei, K., Munishi, L., and Ndakidemi, P. (2019):** "We Will Change Whether We Want It or Not": Soil Erosion in Maasai Land as a Social Dilemma and a Challenge to Community Resilience. Journal of Environmental Psychology, 66, p. 101365.

**Ragin, C. C. (2014):** The comparative method, moving beyond qualitative and quantitative strategies. Berkeley, CA: University of California Press.

**Rahman, M. S., and Kausel, T. (2013):** Coastal Community Resilience to Tsunami: A Study on Planning Capacity and Social Capacity, Dichato, Chile. IOSR Journal of Humanities and Social Science, 12(6), pp. 55–63.

**RESILENS. (2015):** *Resilience Evaluation and SOTA Summary Report.* Retrieved from RESILENS: http://resilens.eu/wp-content/uploads/2016/08/D1.1-Resilience-Evaluation-and-SOTA-Summary-Report.pdf

**Rubin, C. B., Saperstein, M. D., & Barbee, D. G. (1985):** Community recovery from a major natural disaster.

**Saja, A. A., Teo, M., Goonetilleke, A., & Ziyath, A. M. (2018):** An inclusive and adaptive framework for measuring social resilience to disasters. International Journal of Disaster Risk Reduction, 28, 862–873.

**Sarantakos S. (1998):** The research process. In: Social Research. Palgrave, London

**Scherzer, S., Lujala, P., and Rød, J. K. (2019):** A Community Resilience Index for Norway: An Adaptation of the Baseline Resilience Indicators for Communities (BRIC). International Journal of Disaster Risk Reduction, 36, p. 101107.

**Sempier, T. T., Swann, D. L., Emmer, R., Sempier, S. H., and Schneider, M. (2010):** Coastal Community Resilience Index: A Community Self-Assessment. URL: http://masgc.org/assets/uploads/publications/662/coastal_community_resilience_index.pdf

**Sherman, L W (1997):** Preventing Crime: What Works, What Doesn't, What's Promising. Report to the U.S. Congress. Washington, D.C.: U.S. Dept. of Justice, 655 pp

**Sherrieb, K., Norris, F. H., and Galea, S. (2010):** Measuring Capacities for Community Resilience. Social Indicators Research, 99(2), pp. 227–247.

**Simon, H. A. (1974):** How Big Is a Chunk?: By Combining Data From Several Experiments, a Basic Human Memory Unit Can Be Identified and Measured. Science, 183(4124), pp. 482–488.

**Singh-Peterson, L., Salmon, P., Goode, N., & Gallina, J. (2014):** Translation and evaluation of the baseline resilience indicators for communities on the Sunshine Coast, Queensland Australia. International Journal of Disaster Risk Reduction, 10, 116–126.

**Snyder, H. (2019):** Literature Review as a Research Methodology: An Overview and Guidelines. Journal of Business Research 104 (November): 333–39. https://doi.org/10.1016/j.jbusres.2019.07.039

**Sullivan H and M Stewart (2006):** Who Owns the Theory of Change? Evaluation, Vol. 12, No. 2, 179-199

**Summers, J. K., Harwell, L. C., Smith, L. M., and Buck, K. D. (2018):** Measuring Community Resilience to Natural Hazards: The Natural Hazard Resilience Screening Index (NaHRSI) -- Development and Application to the United States. GeoHealth, 2(12), pp. 372–394.

**Tariq, H., Pathirage, C., & Fernando, T. (2021):** Measuring community disaster resilience at local levels: An adaptable resilience framework. International Journal of Disaster Risk Reduction, 62, 102358. Retrieved from https://www.sciencedirect.com/science/article/pii/S2212420921003241

**The Resilience Index (2015):** The Modelling Tool to Measure and Improve Community

Resilience to Natural Hazards. URL: https://theresilienceindex.weebly.com

**The Resilience Index. (2021):** *The Composite resilience index: A modelling tool to measure the resilience of local communities to climate extremes*. Retrieved from The Resilience Index: https://theresilienceindex.weebly.com/our-solution.html

**The Resilience Indicators Bank and the New Zealand Resilience Index.** URL: https://www.resorgs.org.nz/publications/the-resilience-indicators-bank-and-the-new-zealand-resilience-index/

**Twigg, J. (2007):** Characteristics of a Disaster-Resilient Community: A Guidance Note. DFID Disaster Risk Reduction Interagency Coordination Group.

**Uddin, M. S., Haque, C. E., Walker, D., and Choudhury, Mahed U. I.(2020):** Community Resilience to Cyclone and Storm Surge Disasters: Evidence From Coastal Communities of Bangladesh. Journal of Environmental Management, 264, p. 110457.

**United Nations Development Programme (UNDP) (2012):** Understanding Community Resilience. URL: https://www.undp.org/content/undp/en/home/librarypage/environment-energy/sustainable_land_management/CoBRA/CoBRA_assessment.html

**UNDRR (2017):** Disaster Resilience Scorecard for Cities. Geneva: United Nations Office for Disaster Risk Reduction (https://www.undrr.org/publication/disaster-resilience-scorecard-cities)

**UNDRR. (2017):** *Disaster resilience scorecards for cities.* Retrieved from UNDRR: https://mcr2030.undrr.org/sites/default/files/2021-08/UNDRR_Disaster%20resilience%20scorecard%20for%20cities_Detailed_English_Jan2021.pdf

**United Nations. (2021):** *Sustainable transport, sustainable development: Interagency report, Second Global Sustainable Transport Summit*. Retrieved from SDGs UN: https://sdgs.un.org/sites/default/files/2021-10/Transportation%20Report%202021_FullReport_Digital.pdf

**United Nations. (2021):** *Theme report on energy access: towards the achievement of SDG 7 and net-zero emissions.* Retrieved from UN: https://www.un.org/ohrlls/sites/www.un.org.ohrlls/files/technical_working_group_1_energy_access_report_2021.pdf

**United Nations Office for Disaster Risk Reduction. (2015):** *Implementing the Sendai Framework.* Retrieved December 8, 2021, from United Nations Office for Disaster Risk Reduction: http://www.preventionweb.net/files/resolutions/N1516716.pdf

**Weiss, C (1995):** Nothing as Practical as Good Theory: Exploring Theory-Based Evaluation for Comprehensive Community Initiatives for Children and Families. In New Approaches to Evaluating Community Initiatives: Concepts, Methods, and Contexts, ed. James P. Connell et al. Washington, DC: Aspen Institute.

**Woolf, S., Twigg, J., Parikh, P., Karaoglou, A., & Cheaib, T. (2016):** Towards measurable resilience: A novel framework tool for the assessment of resilience levels in slums. International Journal of Disaster Risk Reduction, 19, 280–302.

**Wolfrom, L., & Yokoi-Arai, M. (2015):** Financial instruments for managing disaster risks related to climate change. *OECD Journal: Financial Market Trends, 2015*(1). Retrieved from OECD: https://read.oecd-ilibrary.org/finance-and-investment/financial-

instruments-for-managing-disaster-risks-related-to-climate-change_fmt-2015-5jrqdkpxk5d5#page1

**Yoon, D. K., Kang, J. E., and Brody, S. D. (2016):** A Measurement of Community Disaster Resilience in Korea. Journal of Environmental Planning and Management, 59(3), pp. 436–460.

**Yu, W., Rex, W., McCartney, M., Uhlenbrook, S., von Gnechten, R., & Delli Priscoli, J. (2021)**: *Storing water: A new integrated approach for resilient development.* Retrieved from GWP: https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/perspectives-paper-on-water-storage.pdf

**Zeniewski, P., Brancucci, C., & Pearson, I. (2013):** International Handbook of Energy Security Part II Chapter 3 : Framing new threats: the internal security of gas and electricity networks in the European Union. In H. Dyer, & J. Trombetta (Eds.), *International Handbook of Energy Security* (pp. 40-69). Cheltenham: Edward Elgar Publishing Limited.

**Zurich Flood Resilience Alliance. (2019):** *The Flood Resilience Measurement for Communities (FRMC)*. Retrieved from Zurich Flood Resilience Alliance: http://repo.floodalliance.net/jspui/bitstream/44111/2981/7/1027-PA-ZFRP-AdHoc-UK-V2a-WEB.pdf