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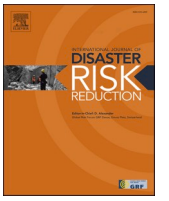

A methodological approach to classify good practices for urban and metropolitan risk management

Veronica Vitiello [a,*], Roberto Castelluccio [a], Anna Maria Zaccaria [b], Antonino Rapicano [b], Mariacarla Fraiese [a], Eva Negri [c], Gloria Terenzi [d]

[a] D.I.C.E.A. - Department of Civil, Building and Environmental Engineering, University of Naples Federico II, Piazzale Vincenzo Tecchio 80, 80125, Naples, Italy
[b] D.S.S. - Department of Social Sciences, University of Naples Federico II, Vico Monte della Pietà 1, 80138, Naples, Italy
[c] D.I.M.E.C. - Department of Medical and Surgical Sciences, University of Bologna, via Palagi 9, 40138, Bologna, Italy
[d] D.I.C.E.A. - Department of Civil and Environmental Engineering, University of Florence, Via Santa Marta 3, 50139, Florence, Italy

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ABSTRACT

The proposed methodology is based on the development of criteria and indicators of Good Practices for Disaster Risk Reduction (DRR) in multi-risk scenarios, derived from a comprehensive review of established practices in scientific literature, carried out with the direct involvement of Stakeholders. The latter, understood as interest bearers but also as actors who receive benefits from the actions in which they are engaged, are usually only involved in some phases of DRR, mainly in those that concern the implementation of decisions that have already been taken. Considering that the meaning of "Good Practice" is highly debated in the literature, and starting from the definition proposed by Olivier Serrat, referred to as "*anything that has been tried and shown to work in some way*", the objective of this work is to engage a variety of societal Stakeholders (experts, local administrators, civil society) in all the phases of DRR, as bearers of knowledge, expertise and competences fundamental to assess the effectiveness of both existing and new DRR practices.

1. Introduction

The proposed study is part of the national project RETURN - multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate, funded by the Extended Partnership composed of Italian Universities, Research Centres, and companies with funds from the National Recovery and Resilience Plan [1] from the European Union – NextGenerationEU, under Mission 4 "Education and Research" – Component 2 "From Research to Business" – Investment 1.3.

Considering the potential increase in the frequency of natural catastrophic events related to climate change, and the severity of their impacts on urban and metropolitan settlements, the partnership aims to achieve a better understanding of complex natural multi-risk dynamics and to develop predictive models applicable at multiple scales, in both the short and long term [2–6].

In detail, this paper presents the first results of research conducted within Spoke TS1: Urban and metropolitan settlements, Work

* Corresponding author.
E-mail addresses: veronica.vitiello@unina.it (V. Vitiello), roberto.castelluccio@unina.it (R. Castelluccio), zaccaria@unina.it (A.M. Zaccaria), antonino.rapicano@unina.it (A. Rapicano), mariacarla.fraiese@unina.it (M. Fraiese), eva.negri@unibo.it (E. Negri), gloria.terenzi@unifi.it (G. Terenzi).

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Package (WP) 2 – Multi-risk-oriented modelling of urban systems, Task 2.4 - Best practices for urban and metropolitan risk management.

The criterion that distinguishes urban and metropolitan settlements from rural ones is essentially related to population density and the presence of physical facilities and infrastructures. Urban settlements are characterised by significant population density (ratio of inhabitants per square kilometre) and the provision of infrastructure and utilities. Metropolitan settlements present the same characteristics but, from a geographical and administrative point of view, they refer to territories linked to one or more central cities by relations of functional interdependence, measured directly or through the identification of homogeneity or proximity areas. Contiguous municipalities that meet an average density in more than 1500 Ihab/km^2 and the total of the area must be more than 250,000 inhabitants tend to be aggregated. These areas are also characterised by a significant flow of economic and social relations.

Suburban areas identify areas on the extreme outskirts of a city, usually residential, or industrial, but in some cases also rural. In rural areas, more than 50 per cent of the population resides in municipalities with a predominantly agricultural economy and a population density of less than 150 inhabitants per km^2. These areas are generally less endowed with physical infrastructure and utilities.

The interest in focusing on urban and metropolitan settlements comes from the evaluation of the high-level of complexity about the risk management in these areas, especially linked to their extension and population density. Damages produced by environmental, natural and anthropogenic events on the physical, functional and social systems are considerable on all the national territory.

Moreover, the safety evaluation and management of the historical and residential heritage, the functionality of the infrastructural network and strategic buildings are a priority of the NRP [1] and it has also been recognised by the 2030 Agenda with five Sustainable Development Goals, specifically on the resilience of infrastructures and communities.

The task aims to build a national and international Repository of Good Practices for multi-risk management in urban and metropolitan settlements, investigating the effectiveness and criticality of practices implemented during a natural catastrophic event and the potential effectiveness of practices that have been designed but not yet applied. The results of the cataloguing work provide fundamental support for identifying Good Practices applicable in multiple contexts and risk scenarios.

To achieve the intended result, the research conducted so far starts from the definition of what is meant by “practice” in multi-risk management in urban and metropolitan settlements, based on bibliographic references. Subsequently, to define criteria for identifying and cataloguing Good Practices, an inductive methodology for the elaboration of indicators of Good Practices, derived from the analysis of international programmes, is designed. The development of this methodology involve several internal Stakeholders in the project who, based on their specific expertise and the semantic analysis of data collected from international programmes, selected, standardised, and clustered a large set of indicators.

One of the main expected outcomes of this work is to develop a participatory, flexible and dynamic methodology aimed at involving different types of Stakeholders. This inclusive approach strengthens the relationship between the academic expertise, represented by the internal knowledge Stakeholders involved in the first elaboration of the Good Practice Indicators, and the technical and political knowledge operating on the territory through the public decision-makers, who represent the external Stakeholders. Even in the first phase of the indicators’ elaboration, the research considers external Stakeholders, anticipating the needs that may be expressed by any context characterised by a multi-risk scenario and identifying the parameters useful to support and improve the Disaster Risk Management (DRM). This aspect can be seen in the methodology for the elaboration of the indicators and relevant variables which, expressed in a question form, will guide the public decision-makers in both a self-assessment and implementation of the practices applied in their context.

Future research developments include validating the Good Practice indicators, which will involve internal and external Stakeholders pertaining to specific application contexts identified in the project.

1.1. State of the art

Introduced in the organisational context of private enterprises, the term “Stakeholder” refers to the necessity for a company to be accountable not only to its Shareholders but also to groups outside the company (Stakeholders), who may nonetheless be affected by its decisions: suppliers and customers, consumers and environmental associations, residents near production facilities, etc. [7]. In this sense, a Stakeholder is defined as any group or individual who can influence or can be influenced by the achievement of the organisation’s objectives [8], who can affect the organisation’s focus, results, and resources, or who is influenced by such results [9]. When applied to the perspective of Public Administrations, the figure of the Stakeholder assumes a broader significance, referring not so much as for companies to the goal of profit-making, but rather to the goal of generating public goods and services for the community [7]. Identifying and involving Stakeholders in decision-making processes enables decision-makers to consider the possible impacts (social, economic, urban, environmental, etc.) of an action, and to identify the actors who can assist in the definition and implementation phases of the process. In this perspective, *Stakeholder engagement* takes on full significance in Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM) practices. The complexity and deep uncertainty that characterise natural disasters, exacerbated by climate change, which generates multi-risk events with increasing frequency, necessitate broadening the decision-making framework to foster active processes of risk governance. Knowledge, skills, values, experiences, memories, and usual practices—whether good or not—are all elements that can be translated into resilience resources in the co-construction of policy actions aimed at reducing disaster damage.

In recent years, scientific literature on best practices for the governance of environmental and anthropogenic risks has grown. The available literature highlights the importance of the role of the *Stakeholders*. A rich empirical literature reports the results of research on specific issues, favouring the case-study approach, and highlighting methodological, conceptual, and applicative implications of

Stakeholders' involvement in DRR practices. Maurizi and Fontana [10] present the case of the risk communication plan development in the Argentine city of Santa Fe, which is particularly exposed to flood risk due to its orographic characteristics and, in recent decades, due to the increased frequency of intense rainfall due to climate change. The Communication Program implemented various strategies and actions with the participation of teachers, students, neighbourhood organizations, the Red Cross, and other local actors. These efforts aimed at increasing the awareness and understanding of flood risk in the city, thereby strengthening the preparedness of each sector to respond effectively.

Boersma et al. [11], present the case of the so-called "Amsterdam Crisis Resilience Living Lab" set up in the financial district of Zuidas, and the one of the Indische Buurt neighbourhoods, with about 55 per cent of immigrant residents. This initiative enables the co-creation of knowledge produced by both formal organizations and local Stakeholders in close collaboration with researchers from the Vrije Universiteit Amsterdam and the Institute for Societal Resilience. The research demonstrates the potential of collaboration among institutional responses, traditional organizations (e.g., firefighters, police), and other local Stakeholders (such as community organizations, citizen groups, and private businesses) to foster a more inclusive and resilient approach to crisis management [12,13]. The Living Lab experience emerges as an effective form of Stakeholder engagement [14].

In this regard, the concept of community engagement in mitigating the consequences of disasters is well-documented in the empirical literature, especially with the recent emphasis on Community-Based Disaster Risk Management (CBDRM) approaches [15,16]. These approaches typically stem from community participation and a mindset of shared responsibility [17]. However, especially in areas with low-income and immigrant populations, the literature highlights the necessity for targeted communication programmes and direct community involvement, such as physically holding meetings in affected neighbourhoods. These strategies, implemented in Living Lab forms as seen in the Amsterdam case and more recently in Huston [17] using a grounded theory methodological approach, have yielded appreciable results.

A novel approach to studying DRR processes adopts the social capital perspective [18–20]. The social capital is understood as the endowment of relational network available within a community [21], that drive information, expertise, emotional sources, economic sources, etc. It constitutes an endowment to which all the community can access to achieve collective objectives. The use of social capital implies the capability of different actors to work in network [22,23].

This approach, empirically applied in our research, allows for identifying the most relevant forms of social capital for enhancing resilience against natural disasters [24]. This perspective holds significant promise for analysing particularly fluid, uncertain, and context-specific dynamics such as those related to crisis management. These studies (and others alike) share two crucial considerations: i) despite their global nature, current crises primarily impact at the local scale, with severe damage on local communities; ii) crisis management is the "*process of how we prepare for, respond to, and learn from the effects of a wide range of major failures that impact upon groups of people, from organizations to local, national and international communities*" [25]. Therefore, it is strategic to create opportunities for local actors to participate actively in the crisis management process, promoting their collaboration. Their grasp of the local context and their integration into local networks have emerged as crucial elements in fostering more inclusive crisis responses. Incorporating a diverse array of perspectives and perceptions regarding risk and vulnerability from multiple Stakeholders is a crucial starting point for developing effective DRR strategies. This approach also re-establishes the relationship of trust between institutions, experts, and citizens, laying the groundwork for consensus that facilitates more effective risk communication by the government.

In general, there is growing evidence that field studies and empirical applications are moving towards a participatory approach that goes beyond traditional stakeholder consultation [26]. This approach is more inclusive, incorporating Stakeholders with factual knowledge and experience at both local and national levels, actively involving them in DRM and proposing operational actions and replicable workflows. For example, in the case study of Santa Fe [10] a set of actions aimed at implementing risk communication for the population is identified; in the case study of Amsterdam [11] a model of actions that develops a set of organisational interactions, to be activated in emergency situations, is proposed; in the case study on Cameron [26] a socio-ecological cut modelling, that prefigures the interactions between populations and hazards, is produced. These analytical approaches are predominantly qualitative, while the aim of our research is to develop a qualitative-quantitative analytical one. The goal is to achieve a holistic understanding of the multi-hazard risk system, which is now inevitable given the increasing challenges posed by climate change and natural disasters. This approach requires a well-articulated methodological framework concerning steps, techniques, and tools to be deployed, particularly focusing on Stakeholder identification and engagement. The literature provides numerous contributions in this direction, developing conceptual models and well-established frameworks that are dynamic and adaptable to different contexts and hazards [27–29]. However, aligning the actions of Stakeholders with formal response structures remains a pressing question that can be best addressed only through collaboration with local actors.

1.2. Tools and indicators for DRM and resilience

To reduce communities' vulnerability to adverse events, DRM strategies aim to provide them with tools to withstand, recover, and "build back better" after disasters [4]. These approaches involve practices, procedures and protocols designed to foster long-term resilience. However, while tools for managing extreme events are increasingly available at national and international levels, detailed information on specific risk scenarios and vulnerabilities are often accessible only at local scales. The gaps between risk governance levels often results in information dispersion, highlighting the need for new tools to align decision-making, enhance understanding of disaster risk and vulnerabilities, evaluate policy effectiveness, and ultimately support the identification of Good management Practices [30]. Cardona [30] and Bretch et al. [31] highlighted indicators' effectiveness in identifying vulnerabilities, enhancing information accessibility, enabling risk scenarios comparisons across space and time, and setting benchmarks to improve effective disaster risk management. In complex multi-risk scenarios, indicators serve as an essential tool in supporting Stakeholders in

defining policies to be implemented and/or monitoring those already in place [32]. The European project Myriad-EU [32] adopts the following definition of an indicator: "*observable and measurable characteristics that can be used to simplify information and facilitate understanding of the state of a concept or phenomenon and/or to monitor it over time to show changes or progress toward achieving a specific change*" [33]. Tracking this progress requires observable and measurable characteristics, which are not always aligned in the literature, as in evolving concepts like "resilient community" [34–36] or resilience more broadly [37–39].

In this context, developing an adaptable set of indicators to monitor the effectiveness of DRM practices, both new and existing, can serve as a Good Practice itself: unlike observable clues that emerge only post-event, indicators allow for proactive assessment of vulnerabilities, identification of exposed elements and potential risk factors [40]. By providing measurable and observable characteristics that simplify complex data, indicators also enable Stakeholders to track progress, guide decision-makings, and support the development and monitoring of DRM practices.

Building on the above consideration, an inductive approach focused on "inescapable practice" has been adopted. Those that consistently emerge across multiple frameworks, programmes, practices etc., presumably bear essential indicators in effective DRM and resilience. To this end, a review of relevant documents regarding these topics was conducted. An initial set of 18 documents was selected by the RETURN project's knowledge Stakeholders, either based on their expertise or chosen from established practices within the relevant scientific literature. Additional documents were subsequently sourced from the Solution Explorer database, an open-access repository of existing Good Practices developed within the ROADMAP project [41]. The inclusion criteria, chosen as filters for querying the database, were aligned with key points of the RETURN project: *practices* implemented in *urban or metropolitan settlements* and applying *multi-risk approaches* to address a wide spectrum of natural and anthropogenic risks, both intensive and extensive [42]. The query yielded 22 results, obtaining a final set of 40 documents, listed in Annex A of the Supplemental Material.

These documents were then analysed in detail considering the following criteria: Stakeholder engagement; participation and cooperation across different sectors and societal levels, both public and private; adoption of a multi-criteria approach (social, economic, cultural, structural etc.). These enabled the selection of practices based on their relevance, replicability, and suitability for deriving DRM and resilience indicators aligned with the overall aims of the proposed study. The review led to the exclusion of 35 documents, mainly due to their lack in generalised approaches with narrow or single-dimension scope; limited or not cross-sectoral stakeholder engagement; and context-related approaches.

In the end, the following 5 core documents were selected: the Sendai Framework for Disaster Risk Reduction 2015–2030 [4], the Disaster Resilience Scorecard for Cities [43], the Australian Disaster Resilience Index [44], the City Resilience Index [45], and the emBRACE framework for Community Disaster Resilience [46].

A description of all five documents is provided in Annex B of the Supplemental Material.

Each document was chosen based on its alignment with the inclusion criteria and was also selected to represent a diversity of viewpoints, ensuring varied perspectives for deriving the indicators. Specifically, the Sendai Framework for Disaster Risk Reduction [4] was chosen as the most recognised framework and, along with its operational tool, the Disaster Resilience Scorecard for Cities [43], were selected as international programmes led by public entities, with a common understanding of resilience. The Australian Disaster Resilience Index [44], also developed by a public entity and generally aligned with Sendai priorities, was chosen for its national focus on the Australian context and its distinct definition of resilience. The emBRACE project [46], an international public-funded initiative, provides a comprehensive and enhanced view of resilience, consistent with the Sendai Framework. Selected from the documents proposed by the knowledge Stakeholders, it was chosen to provide an academic perspective, adding depth to the analysis, and enriching the study's methodology. The City Resilience Index [45], developed by an international private entity, diverge from the Sendai Framework, providing its own operational definition of resilience.

1.3. Operational definition of Good Practice

To develop a methodology for designing Good Practice indicators for multi-risk management in urban and metropolitan settlements, the research began with defining what is meant by "practice". Based on the topics covered and the research team's established expertise, a "practice" was assumed as any action or system of actions implemented by Stakeholders in a given territorial context to cope with a disaster, including actions taken during each phase of both risk assessment (establishing context, risk identification, risk analysis, and risk evaluation [47]) and risk management (mitigation, preparedness, response and recovery [48,49]). The specific application context, therefore, identifies the multiscale of the practice, which may correspond to spatial government instruments, emergency plans, local policies related to one or more phases of risk management, national or international programmes, etc. or the combination of these elements.

Depending on the context and scale of application of the practice, different Stakeholders are identified, including scholars who are experts in the field, technical and political actors within the analysed context, local associations, Third Sector entities, etc. Having established and shared the definition of practice within the relevant scientific community, the study focused on identifying bibliographic references related to the definition of "Good Practice", which was preferred over "best practice" as a conceptual framework [50].

In this article, the definition proposed by Olivier Serrat [51] is accepted: "*A Good Practice is defined as anything that has been tried and shown to work in some way (whether fully or in part but with at least some evidence of effectiveness) and that may have implications for practice at any level elsewhere*". The limitation of this definition lies in the need to first apply a Good Practice to verify its effectiveness, which requires waiting for a catastrophic event to occur. In addition, to benchmark multiple practices, there would have to be a recurrence of the same catastrophic event, which by definition is understood as an event of high intensity and low frequency, in the same reference context. This second assumption is also unlikely since any urban or metropolitan settlement subjected to a catastrophic event would be

altered by it, either through increased vulnerability in the short term due to the damage sustained from the impacts of the external hazard, or increased resilience in the long term because of the restoration and consolidation efforts carried out on the physical, social, and cultural system.

The exemplification of what constitutes Good Practices manifold and documented in technical reports and case study commentaries. Some of the most well-known include the Sendai framework [52], the two Baltimore reports from 2013 to 2018 [53,54], the Santa Fe case study [55], and other recent studies related to climate changes [56,57]. The approach followed to identify Good Practice in these examples can be defined as direct, as these procedures are directly recognised to be those that would have mitigated the damage effects induced by observed disaster events. Departing from this approach, to develop a methodology that can be generalised to any risk situation, it is first necessary to establish an exigency framework that concerns individual Stakeholders and the community. This requires observing how various actors may be involved in a disaster event, identifying detectable criticalities on which the damage to people or property depends, defining the strategies to overcome these critical conditions, and outlining actions that lead to the protection of individuals and urban contexts involved, following a chain of action that depends on the specific urban contexts in which the events occur, and the types of risks and multi-hazard conditions examined. The reference to individual Stakeholders and the community influences whether Good Practice can have implications beyond merely structural aspects, extending to cultural, social, political, and economic dimensions as well.

In light of these considerations, this article proposes an inductive approach to the definition of Good Practices, which begins with the identification of cultural, social, political and economic indicators, generally defined considering various disaster situations, and that can be easily adapted to different urban contexts, as well as specified as optimal requirements for minimising damages related to a given event. Such an approach allows for the development of a flexible and dynamic methodology for the identification and cataloguing of potential Good Practices that, even if not tested in the occurrence of an actual catastrophic event, can be considered "promising" as they meet established criteria and indicators in DDR practices, as well as in the accredited industry literature. In this sense, the proposed methodology also overcomes the limitation of Serrat's [53] definition of Good Practice.

2. Methodology

2.1. Research phases

To identify useful indicators to determine which are the "Good Practices" for urban and metropolitan multi-risk management, an inductive methodology based on bibliographical references is proposed.

The Working Group (WG) engaged in this phase is multidisciplinary and brings together young researchers and scholars who are also professionally involved in concertation with Civil Defence and local authorities in risk management, assuming roles as Knowledge Stakeholders. In the first steps of the methodological approach, a group of 17 Knowledge Stakeholders, pertaining to different scientific fields, was selected from the RETURN project: 1 sociologist expert in Security, risk and vulnerability; 1 sociologist expert in Sociology of the environment and territory; 1 sociologist expert in Urban and rural sociology; 1 sociologist expert in Social vulnerability in urban and metropolitan risk management; 1 construction and civil engineer expert in Engineering for building renovation and technological innovation; 1 construction engineer-architect expert in Diagnosis and recovery of Cultural Heritage; 1 construction engineer-architect

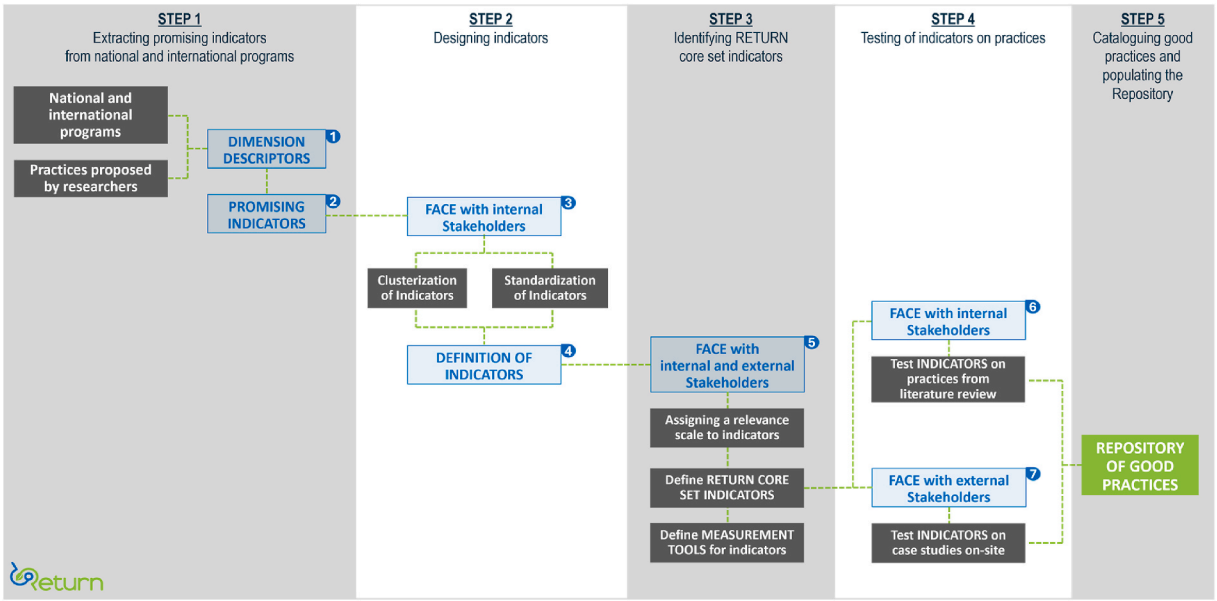

Fig. 1. Workflow for creating the repository of Good Practices for multi-risk management in urban and metropolitan settlements.

experienced in Assessing the impacts of natural and anthropogenic hazards on building envelopes; 1 civil engineer expert in Best management practices in urban drainage systems; 1 civil engineer expert in Structural engineering; 1 construction engineer expert in Diagnosis and treatment of structural instability; 1 civil engineer expert in Structural engineering, geotechnics and seismic risk; 1 civil engineer expert in Advanced seismic protection technologies for new and existing structures; 1 architect expert in Urban, building and public space regeneration to contrast climate impacts; 1 mathematician and medical statistician expert in Epidemiology and biostatistics; 1 physicist expert in Risk and natural hazard assessment, impact forecasting, data mining and processing; 1 physicist expert in Statistical seismology, capacity building and technology transfer; 1 environmental engineer expert in Exposure modelling for multi-hazard analysis.

The methodological approach followed the workflow shown in Fig. 1.

In Step 1, a set of national and international programmes and frameworks addressing the issue of multi-risk management at the urban and metropolitan scale, were analysed.

The analysed programmes were chosen following the approach described in section 1.2. To select the documents, the following inclusion criteria were agreed by all the experts:

- *Practice:* actions, systems of actions, plans, methodological approaches, and regulatory prescriptions implemented to manage multi-risk scenarios in urban and metropolitan settlements.
- *Multi-risk scenario*: a specific scenario typical of a physical and anthropogenic context on which a system of risks simultaneously impacts.
- *Urban and metropolitan settlements*: physical systems in which housing, production and industrial functions take place in a complex characterised by a high level of anthropisation in terms of both population and building density.

To ensure the applicability of the research results to the Italian national context, which the RETURN project addresses, programmes and frameworks developed in high-income countries were chosen.

For each programme, dimension descriptors were extracted, corresponding to the objectives, targets, and priorities outlined in the analysed documents.

For each dimension descriptor, the knowledge Stakeholders developed one or more promising indicators, both qualitative and quantitative. The proposed promising indicators aim at assessing the extent to which the objectives, targets, and priorities of each programme are achieved, indicating the effectiveness of the programme itself.

Following the principle of redundancy of information given by each programme, the extrapolation of promising indicators was focused on the five frameworks described in the introduction.

In Step 2, the promising indicators were examined through a co-occurrence analysis, which resulted in the identification of three different hierarchical clusters for indicator classification.

At this stage, through a comparison between experts composing the WG, the promising indicators were merged, rewritten and standardised in form of variables, expressed as questions that must guide the end user to understand if the specific information is contained in the practice. Variables were classified into clusters resulted from the co-occurrence analysis and grouped into 9 criteria, characterized by homogeneous topics aiming at including all features of risk assessment and management. The considered variables were also classified according to the stages of the Sendai Framework.

The variables were paired with quantitative or qualitative measurable indicators, aimed at collecting the data recorded by the specific analysed practice.

For each cluster, a list of suggestions was included in drop-down menus by the WG. However, in order to maintain the flexibility of the tool, in each drop-down menu there is always also the choice “other”, which allow the compiler to edit a new value in open form. Additionally, for each variable, the suggestion of sources containing necessary information and methods to measure or evaluate them, were identified.

Fig. 2 shows the cataloguing scheme of the 9 criteria and their relevant indicators.

Steps 1 and 2 complete the first part of the methodology, resulting in a set of indicators useful to identify practices for multi-risk management in urban and metropolitan settlements, that is one of the expected outcomes.

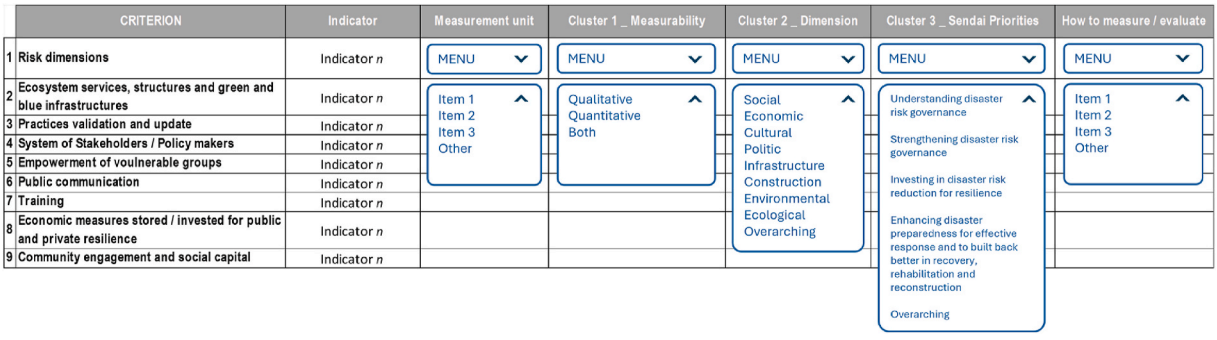

Fig. 2. Methodological scheme for indicators collection.

Next steps aim at determining the *RETURN core-set indicators*, i.e. indicators that a practice must absolutely comply with in order to be defined as "Good".

In these phases internal knowledge Stakeholders and external Stakeholders, representing the social actors of some territories chosen as applicative case studies, will be called upon to assign each indicator a weight, according to their expertise, expressing how relevant the individual indicator is to define an action, or system of actions, as "Good Practice for multi-risk management in urban and metropolitan settlements".

2.2. Methodology for identifying external Stakeholders

The classification proposed by Bobbio [7] distinguishes Stakeholders in three main areas: public institutions (i.e. local territorial authorities, functional agencies, etc.); organised groups (i.e. pressure groups, territorial associations, citizens' committees); and unorganised groups (citizens and collectives, i.e. the totality of citizens comprising the local community). At this stage of the proposed work, external Stakeholders will be identified within public institutions, particularly among the heads of local territorial authorities, and within organised groups, specifically referencing the territorial associations most directly involved in crises management. This exclusive choice is motivated by: a) the need to contain the time required to elaborate the core set of indicators; b) the opportunity to refer to "political" actors who are more directly and consistently involved in decision-making; c) the opportunity to consider at least the associations that are more rooted in the territories and have experience in crisis intervention. Consistent with these motivations, Stakeholders will be identified through a positional approach (actors who occupy top positions in local institutions and organizations) and then, when necessary, through a snowballing and reputational method (accepting indications of subjects reputed to be significant Stakeholders with respect to the analysed practices) [58].

This methodological approach will be applied by identifying external Stakeholders through case studies in specific urban contexts, based on two main criteria: relevance concerning experience/exposure to multi-risk, and a minimum level of familiarity with the WG

Table 1
Dimension descriptors extracted from analysed programmes.

Programmes	Dimension descriptors target/goals/priorities
Sendai Framework for Disaster Risk Reduction 2015–2030 [4]	(Priority 1) – Understanding disaster risk (Priority 2) – Strengthening disaster risk governance to manage disaster risk (Priority 3) – Investing in disaster risk reduction for resilience (Priority 4) – Enhancing disaster preparedness for effective response, and to « Build Back Better» in recovery, rehabilitation and reconstruction
Disaster Resilience Scorecard for Cities, 2021 [43]	(Essential 1) – Organize for Resilience (Essential 5) – Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems (Essential 7) – Understand and Strengthen Societal Capacity for Resilience (Essential 3) – Strengthen Financial Capacity for Resilience (Essential 2) – Identify, Understand and Use Current and Future Risk Scenarios (Essential 4) – Pursue Resilient Urban Development (Essential 6) – Strengthen Institutional Capacity for Resilience (Essential 8) – Increase Infrastructure Resilience (Essential 9) – Ensure Effective Disaster Response (Essential 10) – Expedite Recovery and Build Back Better
Australian Disaster Resilience Index (ADRI), 2020 [44]	1. Social Character 2. Economic capital 3. Emergency services 4. Planning and the built environment 5. Community Capital 6. Information Access 7. Social and community engagement 8. Governance and leadership
City Resilience Index (CRI), 2018 [45]	Infrastructure and Ecosystem 7. Reduced exposure and fragility 8. Effective provision of critical services 9. Reliable Mobility and Communications Leadership and Strategy 10. Effective leadership and management 11. Empowered Stakeholders 12. Integrated development planning
Indicators for a Resilient Community, 2011–2015 [46]	Preparedness Response Recovery Mitigation Social support Resource and Capacities Learning

researchers, which may facilitate accessibility. Contact with Stakeholders will be direct, with flexible involvement methods. Additionally, the possibility of involving members of the city community, when necessary and possible, is not excluded.

3. Results

At present, the research has completed the first two steps.

In Step 1, a total of five international programmes addressing the broad spectrum of DRR [4,43–46] were analysed, extrapolating the relevant dimension descriptors from the programmes' targets and priorities. One or more promising indicators were developed for each dimension descriptor. At this stage, the indicators (or variables) are considered promising, with the understanding that only after the process of clustering and standardisation consistent with the objectives of the RETURN project (Step 2), they will be confirmed or not as Good Practice indicators for multi-risk management in urban and metropolitan settlements.

Table 1 shows the dimension descriptors analysed for each programme, while Table 2 details an example of extrapolation of promising indicators from one of the analysed programmes.

The complete catalogue of the 236 promising indicators is provided in Annex C.

From the co-occurrence analysis performed on the 236 promising indicators, three different hierarchical clusters were derived to classify them:

- Cluster 1 (*measurability*): identifies the degree of measurability of the promising indicators, dividing them into qualitative and quantitative indicators (type, number, percentage, etc.).
- Cluster 2 (*dimension*): identifies the dimension to which the promising indicators refer, broken down into different variables, including social, economic, cultural, political, infrastructure, construction, environmental, and ecological. More than one dimension may be indicated.
- Cluster 3 (*Sendai Framework phases*): identifies the risk management phase to which the indicator refers, concerning those identified in the Sendai framework [4]. This classification aligns with the one already adopted in the ROADMAP project [41], distinguishing the stages of Understanding Disaster Risk; Strengthening Disaster Risk Governance; Investing in Disaster Risk Reduction for Resilience; and Improving Disaster Preparedness for Effective Response and Better Rebuilding in Recovery, Rehabilitation and Reconstruction. More than one phase may be indicated.

Overall, the indicators were organised into 9 criteria according to the methodology described in section 2.1:

- Criterion 1 - *Risk dimensions*: identifies the dimensions and types of risk considered by a practice, taking into account that the RETURN Good Practice Catalogue will apply to the management of multi-risk scenarios in urban and metropolitan settlements.
- Criterion 2 - *Ecosystem services, structures, and green and blue infrastructures*: assesses if the external Stakeholders, who apply the practices, have an in-depth knowledge of the city's infrastructure, including protection infrastructure against prevailing hazards, and if its state of maintenance and operation is regularly monitored and maintained.

Table 2
Elaboration of promising indicators for dimension descriptors extracted from analysed programmes – methodological examples of promising indicators extracted from priorities of Sendai Framework for Disaster Risk Reduction 2015–2030 [4].

Programmes	Dimension descriptor target/goals/priorities	Promising indicators
Sendai Framework for Disaster Risk Reduction 2015–2030 [4]	**(Priority 1) – Understanding disaster risk**	
	Ability to analyse all dimensions of risk	Number and type of risk dimensions analysed
	Ability to assess a pre-disaster condition	Number and type of models or tools used for pre-disaster assessment
	Ability to demonstrate the effectiveness of actions	Actions that the project aims to carry out and capable of being demonstrated by models
	(Priority 2) – Strengthening disaster risk governance to manage disaster risk	
	Ability to involve relevant Stakeholders and partners	Number and type of Stakeholders and Partner involved
	(Priority 3) – Investing in disaster risk reduction for resilience	
	Ability to attract public and private investments	Number and type of Sponsor or Partnership involved
	Ability to create innovation, growth, and job	Number of instruments and tools validated
	(Priority 4) – Enhancing disaster preparedness for effective response, and to « Build Back Better» in recovery, rehabilitation, and reconstruction	
	Ability to strengthen disaster preparedness	Results by qualitative measurement tools
	Ability to empower women and persons with disabilities to publicly lead	Number of women and persons with disabilities empowered
	Ability to promote gender equitable and universally accessible response approaches	Number of public events that involve actors of equal gender representation in the event's organization and planning.
	Ability to strengthen resilient Built Back Better strategies	Results by quantitative measurement tools

- Criterion 3 - *Practices validation and update*: understands if external Stakeholders adopt tools to verify the effectiveness of practices before the occurrence of a catastrophic event and if they periodically update maps and standards describing the most severe risk scenarios.
- Criterion 4 - *System of Stakeholders/Policymakers*: comprehends which and how many Stakeholders and policymakers are involved in the design and implementation of the practices, and if there are structured relationships between the different actors.
- Criterion 5 - *Empowerment of vulnerable groups*: addresses if Stakeholders implementing practices are aware of the presence of vulnerable groups, as well as how these groups are involved in the design of risk management policies.
- Criterion 6 - *Public communication*: determines risk communication strategies practised by Stakeholders, and if tools to evaluate their effectiveness have been developed.
- Criterion 7 - *Training*: understands what training actions are implemented by Stakeholders, and if strategies have been developed to assess their effectiveness.
- Criterion 8 - *Economic measures stored/invested for public and private resilience*: evaluates what economic resources have been dedicated in cities for risk management, if these resources are considered sufficient, and how much they weigh against the overall public budget.
- Criterion 9 - *Community engagement and social capital*: examines whether and to what extent the community is involved in the design and implementation of applied risk management practices.

Fig. 3 shows the synoptic picture of the number of indicators developed for each criterion.

As an example, Table 3 presents all the indicators constructed for Criterion 1 - *Risk dimensions*, following the specified methodology, deferring to Annex D for the comprehensive collection of 132 indicators developed across all 9 criteria.

4. Discussion

On the basis of identified frameworks aimed at proposing or supporting the elaboration of indicators of Good Practices 132 promising indicators have been identified, systematised standardised and then organised into 9 homogeneous criteria. These indicators have also been categorised on the basis of their measurability, dimension and pertinence to the Sendai priorities, providing suggestions on possible ways to measure or evaluate them. The study was conducted focusing on indicators of Good Practices for the multi-risk management in urban and metropolitan settlements in high income countries. Thus, this work provides an innovative and flexible tool that may serve both scholars and public decision-makers to evaluate existing practices and to develop new-ones as well as to create and update a Repository of Good Practices.

Given the diverse sources from which these frameworks derived, and the large number of indicators proposed, an innovative aspect of this approach lies in their selection and combination to avoid redundancies and overlaps, while considering the multidimensional aspects of DRR.

A further innovative aspect is the organisation of variables into homogeneous criteria, that allows to better evaluate each indicator in its specific context, as well as their classification according to different clusters.

Although the focus of the study was on the specific context of multi-risk scenario in urban and metropolitan settlements in high-income countries, the proposed open-ended methodology can be reproduced in other contexts to identify and categorise new indicators following the provided structure.

An important aspect that characterises the proposed methodology for indicators' selection is the restriction to variables that can be measured either quantitatively or qualitatively, resulting in indicators that can be assessed objectively by different experts. The issue of reproducibility has been at the basis of all the developed steps.

The most innovative aspect of this work consists in the involvement of Stakeholders with multidisciplinary backgrounds fostering a

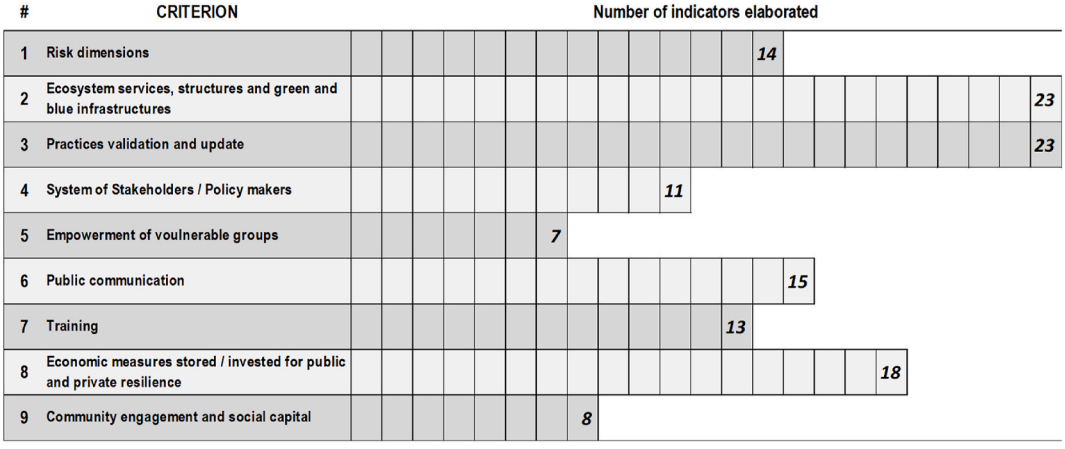

Fig. 3. Synthesis of the number of indicators elaborated for each criterion.

Table 3
Standardisation and clustering of indicators for criterion 1 – Risk dimensions.

CRITERION 1 - RISK DIMENSIONS						
Variables	Indicators	Measurement unit	Cluster 1 Measurability	Cluster 2 Dimension	Cluster 3 Sendai Priorities	How to measure/ evaluate
How many risk dimensions are analysed?	Number of risk dimensions analysed	no.	Quantitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Which types of risk dimensions are analysed?	Types of Risk Dimensions	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Do the city governance measures include and implement disaster risk reduction (DRR) approaches in multi-risk scenarios due to climate change?	Presence of DRR approaches due to climate change in governance measures	y/n	Qualitative	Overarching	Overarching	Number and type of approaches
Does the city have maps to evaluate the consistency of built heritage, updated within the last 5 years?	Presence of maps to evaluate the consistency of built heritage, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of informal settlements, updated within the last 5 years?	Presence of maps to evaluate the consistency of informal settlements, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
If yes, which types of informal settlements have been recorded?	Types of informal settlements recorded	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
What percentage of informal settlements has been recorded?	Percentage of informal settlements recorded	%	Quantitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of green spaces, updated within the last 5 years?	Presence of maps to evaluate the consistency of green spaces, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of open spaces, updated within the last 5 years?	Presence of maps to evaluate the consistency of open spaces, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have lists of skills needed to face the identified risk scenarios?	Presence of lists of skills needed to face the identified risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
If yes, which types of skills have been identified?	Types of skills identified	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
Does the city have maps to evaluate the percentage of high-risk urban areas where development is restricted or prohibited under planning guidelines?	Presence of maps to evaluate the percentage of high-risk urban areas where development is restricted or prohibited under planning guidelines	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
Does the city have a catalogue of past hazard events?	Catalogue of past hazard events	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
If yes, does the catalogue include the impact assessment for the past hazard events?	Presence of impact assessment for past hazard events	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies

comprehensive debate among experts from the start and during the entire process of the proposed methodology.

The number of programmes analysed to derive Good Practice indicators could be considered a potential limitation. However, the five frameworks considered cover different application scales and origins, including technical, political and research dimensions. The detailed analysis of these programmes early on revealed a considerable redundancy among the promising indicators, verifying the comprehensiveness of the collected information.

Experts involved as internal Stakeholders belong to the Italian context. This feature could represent a criticality. However, the Italian territory includes many different risks (volcanic, seismic, bradyseismic, land-slides, floodings, heat-waves, etc.) providing thus

expertise in a variety of multi-risk scenarios. Moreover, many Stakeholders involved in the WG have international experiences in DRR and DRM.

The diversity of internal Stakeholders constitutes an element of strength, providing varied perspectives including semantic gaps, based on which different scholars, in relation to their expertise, evaluate and interpret indicators differently. On the positive side, this fosters opportunities such as the shared understanding of fundamental semantic codes related to risk management issues and the mutual exchange of knowledge and skills.

So far, a useable tool for evaluating Practices in high-income countries has been produced, as well as a methodology that could allow to develop similar tools for other contexts.

The next step will envisage the "validation" phase involving internal and external Stakeholders in the project. This phase aims to achieve two main objectives: i) determine the relative importance of the identified promising indicators, and ii) specify the context in which each indicator is most relevant. Additionally, the aim will be to identify a subset of cross-cutting indicators standing as indicators of Good Practises independent of specific contexts, while acknowledging that others may be more relevant in specific contexts.

At this stage, it will be considered important to involve knowledge Stakeholders to assign a weight of relevance to each indicator. These weights will inherently reflect the role of the Stakeholders and their specific scientific expertise, as well as the types of hazard(s) they primarily study. To address the criticality of varying relevance attributed by knowledge Stakeholders to indicators, due their multidisciplinary perspectives, Multi-Criteria Analysis (MCA) methods may be employed.

5. Conclusions

This paper provides an innovative and flexible tool that will serve both scholars and public decision-makers to assess and eventually improve existing Practices, or design new ones, for multi-risk management in urban and metropolitan settlements.

This work also led to the proposal of an open and dynamic methodology, designed to implement indicators of Good Practices congruent with specific situations and application contexts. Possible future research advancements may focus on developing a Repository of Good Practices through open-science and open-access digital platforms, making it accessible and implementable in real time. This approach sets the stage for developing dynamic Guidelines for drafting Good Practices for multi-risk management, capable of evolving and adapting over time to respond to changing external conditions, potential increase of the impacts of hazards deriving from climate change, and the possible adjustment in land management policies across different context and scales of reference.

CRediT authorship contribution statement

Veronica Vitiello: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Roberto Castelluccio:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization. **Anna Maria Zaccaria:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Antonino Rapicano:** Writing – original draft, Investigation, Formal analysis, Data curation. **Mariacarla Fraiese:** Writing – original draft, Investigation, Formal analysis, Data curation. **Eva Negri:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition. **Gloria Terenzi:** Writing – original draft, Investigation, Funding acquisition.

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2024.105069.

Data availability

Data will be made available on request.

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Supplemental Files - Annex A

Analysed frameworks, programmes and practices presumably bearing essential indicators in effective DRM and resilience.

#	Reference	Organisation/Country	Type of document	Selection method	
				Proposed	Roadmap
1	United Nations Office for Disaster Risk Reduction (UNDRR) (2015) Sendai Framework for Disaster Risk Reduction 2015–2030. Geneva, Switzerland	United Nations of Disaster Risk Reduction	Global policy framework	X	
2	Bushfire and Natural Hazards CRC (2020) Australian Disaster Resilience Index	Australia, Bushfire and Natural Hazards Cooperative Research Centre	Research-based assessment tool	X	
3	United Nations International Strategy for Disaster Reduction (UN/ISDR) (2007) Building disaster resilient communities: Good practices and lessons learned. A publication of the "Global Network of NGOs" for Disaster Risk Reduction. Geneva, Switzerland	United Nations International Strategy for Disaster Reduction (UN/ISDR), Global Network of NGOs for Disaster Risk Reduction	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)	X	
4	Ontario Office of the Fire Marshal and Emergency Management (2012) Hazard Identification and Risk Assessment (HIRA). Ontario, Canada: Ministry of Community Safety and Correctional Services	Office of the Fire Marshal and Emergency Management (OFMEM), Ministry of Community Safety and Correctional Services, Ontario, Canada	Guideline and policy framework	X	
5	Arup International Development, The Rockefeller Foundation (2014) City Resilience Framework	Arup International Development in partnership and The Rockefeller Foundation	Resilience operational framework and guideline	X	
6	emBRACE - Building Resilience Amongst Communities in Europe	University of Northumbria, United Kingdom	Resilience conceptual assessment tool framework	X	
7	Chicago's Façade Ordinance (2020) - Exterior Wall Program Sections 14A-6-603.2/603.4 Chicago Building Code	Chicago, United States	Guideline and Regulations	X	
8	UNDRR (2017) Disaster Resilience Scorecard for Cities. Geneva, Switzerland	United Nations of Disaster Risk Reduction	Assessment tool	X	
9	Oxfam America (2005) Strengthening connections between communities and local government: Building disaster resilience in El Salvador.	Oxfam America and local organisation in El Salvador	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)	X	
10	Maurizi, V. F., Fontana, S. E. (2019) Building capacity through risk communication strategies in Santa Fe city, Argentina	Santa Fe, Argentina	Scientific article	X	
11	United Nations Office for Disaster Risk Reduction (UNDRR) (2023) The Report of the Midterm Review of the Implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030. Geneva, Switzerland	United Nations Office for Disaster Risk Reduction (UNDRR)	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)		X
12	Le Dé, L., Gaillard, J. C., Gampell, A., Loodin, N., Hinchliffe, G. (2021) Fostering Children's Participation in Disaster Risk Reduction Through Play: A Case Study of LEGO and Minecraft. International Journal of Disaster Risk Science, 12(4), 589–602	New Zealand	Scientific Article		X
13	American Red Cross (2005) Disaster Preparedness for People with Disabilities. Washington, D.C.	American Red Cross	Guideline		X
14	United Nations Office for Disaster Risk Reduction (UNDRR) (2021) Nature-based Solutions for Disaster Risk Reduction: Words into Action Guidelines. Geneva, Switzerland	United Nations Office for Disaster Risk Reduction (UNDRR)	Knowledge-sharing and capacity-building guideline		X
15	Swiss Agency for Development and Cooperation (SDC) (2014) Integrated Disaster Risk Management in a Mountainous Area: Cross-border Cooperation in Disaster Risk Management along the Great St Bernard (Italy–Switzerland). Federal Department of Foreign Affairs, Switzerland	Swiss Agency for Development and Cooperation (SDC)	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)		X
16	United Nations Educational, Scientific and Cultural Organization (UNESCO). (2014). Stay Safe and Be Prepared: A Parent's Guide to Disaster Risk Reduction. Paris, France	UNESCO (United Nations Educational, Scientific and Cultural Organization)	Guideline		X
17	European Environment Agency (EEA) (2021) Nature-based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction. Luxembourg: Publications Office of the European Union	European Environment Agency (EEA)	Knowledge-sharing report and guideline		X
18	Izumi, T., Shaw, R., Ishiwatari, M., Djalante, R., & Komino, T. (2019) 30 Innovations for Disaster Risk Reduction	International Research Institute of Disaster Science (IRIDeS), Tohoku University (Japan), Keio University (Japan), University of Tokyo (Japan), United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS)	Research-based knowledge-sharing and capacity-building report		X

		(International), Church World Service (CWS) Japan			
19	Cabinet Secretariat, Government of Japan (2021) Guide to Disaster Management Measures: Japanese Technologies, Know-how, Infrastructure, and Institutions. Tokyo, Japan	Cabinet Secretariat, Disaster Management Bureau, Government of Japan	Knowledge-sharing guideline		**X**
20	United Nations Office for Disaster Risk Reduction (UNISDR) (2014) Guidelines for Communicating Disaster Risk Reduction Information	United Nations Office for Disaster Risk Reduction (UNISDR)	Knowledge-sharing guideline		**X**
21	World Bank (2019) Information and Communication Technology for Disaster Risk Management in Japan: How Digital Solutions are Leveraged to Increase Resilience through Improving Early Warnings and Disaster Information Sharing. Washington, D.C.	World Bank, Japanese institutions and government agencies	National framework and Knowledge-sharing report		**X**
22	European Commission (2021) Disaster Preparedness: A Compendium of Experiences. Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO). Luxembourg	European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)	Knowledge-sharing and capacity-building guideline		**X**
23	Particip GmbH (2022) Evaluation of the European Union's Humanitarian Interventions in Disaster Preparedness: Final Report. Luxembourg.	European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)	Knowledge-sharing report and guideline		**X**
24	Issue-Based Coalition (IBC) on Environment and Climate Change (2021) Review of Good Practices: Integrating Disaster Risk Reduction and Climate Change Adaptation for Risk-Informed and Climate-Smart Development. UN Regional Office for Europe and Central Asia	Issue-Based Coalition (IBC) on Environment and Climate Change and United Nations Office for Disaster Risk Reduction (UNDRR)	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)		**X**
25	Antofie, T. E., Doherty, B., Marin-Ferrer, M. (2018) Mapping of Risk Web-Platforms and Risk Data: Collection of Good Practices. EUR 29086 EN, Publications Office of the European Union, Luxembourg	Joint Research Centre (JRC) of European Commission	Knowledge-sharing report		**X**
26	United Nations Office for Disaster Risk Reduction (UNDRR) (2022) Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk - Transforming Governance for a Resilient Future. Geneva, Switzerland	United Nations Office for Disaster Risk Reduction (UNDRR)	Knowledge-sharing and capacity-building report		**X**
27	United Nations Office for Disaster Risk Reduction (UNDRR) (2023) Words into Action: Guidelines for Multi-Hazard Early Warning Systems. Geneva, Switzerland	United Nations Office for Disaster Risk Reduction (UNDRR)	Knowledge-sharing and capacity-building report		**X**
28	Yore, R., Fearnley, C., Fordham, M., Kelman, I. (2023) Designing Inclusive, Accessible Early Warning Systems: Good Practices and Entry Points. World Bank, Global Facility for Disaster Reduction and Recovery (GFDRR). Washington, D.C.	World Bank Group and Global Facility for Disaster Reduction and Recovery (GFDRR)	Knowledge-sharing and capacity-building guideline		**X**
29	Harari, N., Gavilano, A., Liniger, H. P. (2017) Where People and Their Land Are Safer: A Compendium of Good Practices in Disaster Risk Reduction. Bern and Lucerne, Switzerland	Swiss NGO Disaster Risk Reduction (DRR) Platform, Centre for Development and Environment (CDE), University of Bern	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)		**X**
30	Poljanšek, K., Casajus Valles, A., Marín Ferrer, M., De Jager, A., Dottori, F., Galbusera, L., et al. (2019) Recommendations for National Risk Assessment for Disaster Risk Management in EU: Approaches for Identifying, Analysing, and Evaluating Risks (Version 0). Publications Office of the European Union, Luxembourg	Joint Research Centre (JRC)	Knowledge-sharing report		**X**
31	Landell Mills (2018) Evaluation of Humanitarian Logistics within EU Civil Protection and Humanitarian Action, 2013–2017: Final Report	Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)	Knowledge-sharing and capacity-building report		**X**
32	United Nations International Strategy for Disaster Reduction (UNISDR) (2010) Local Governments and Disaster Risk Reduction: Good Practices and Lessons Learned. Geneva: Switzerland	United Nations International Strategy for Disaster Reduction (UNISDR)	Knowledge-sharing and capacity-building report (case studies on best practices and lessons learned)		**X**
33	Awah, L. S., Bella, J. A., Nyam, Y. S., Orimoloye, I. R. (2024). A participatory systems dynamic modelling approach to understanding flood systems in a coastal community in Cameroon. International Journal of Disaster Risk Reduction, 101, 104236.	Camerun	Research-based knowledge-sharing and capacity-building	**X**	
34	Boersma, K., Bergb, R., Rijbroekc, J., Ardaid, P., Azarhooshe, F., Forozeshe, F., de Kort, S., van Scheepstal, A.J., Bosf, J. (2022). Exploring the potential of local Stakeholders' involvement in crisis management. The living lab approach in a case study from Amsterdam. International Journal of Disaster Risk Reduction, 79, 103179.	Amsterdam	Research-based knowledge-sharing and capacity-building	**X**	
35	Patterson, O., Weil, F., Patel, K. (2010). The role of community in disaster response:	USA	Participatory modelling and	**X**	

	conceptual models, Population Research and Policy Review, 29(2), 127–141.		Stakeholder engagement		
36	LaLone, M. B. (2012). Neighbors helping neighbors: an examination of the social capital mobilization process for community resilience to environmental disasters. Journal of Applied Social Science, 6(2), 209–237.	Appalachi, USA	Participatory modelling and Stakeholder engagement	**X**	
37	Hart, N., Freeman Anderson, K., Rifai, H. (2024). “Not enough”: A qualitative analysis of community perceptions of neighborhood government flood management plans using the case of Houston, Texas. International Journal of Disaster Risk Reduction, 104(2).	Texas, USA	Participatory modelling and Stakeholder engagement	**X**	
38	Nyam, Y. S., Kotir, J. H., Jordaan, A.J., Ogundeji, A.A. (20201). Developing a conceptual model for sustainable water resource management and agricultural development: the case of the Breede River catchment area, South Africa. Environmental Management, 67, 632–647.	Western Cape Province of South Africa	Knowledge-sharing and capacity-building guideline	**X**	
39	Inam, A., Jan, A., Halbe, J., Prasher, S. (2015). Using causal loop diagrams for the initializsation initialisation of Stakeholder engagement in soil salinity management in agricultural watersheds in developing countries: a case study in the Rechna Doab watershed, Pakistan. Journal of Environmental Management, 152, 251–267.	Pakistan	Knowledge-sharing and capacity-building guideline	**X**	
40	Kotir, H., Brown, G., Marshall, N., Johnstone, R. (2017). Systemic feedback modelling for sustainable water resources management and agricultural development: an application of participatory modelling approach in the Volta River Basin. Environmental Modelling & Software, 88, 106–118.	Ghana	Knowledge-sharing and capacity-building guideline	**X**	

Supplemental Files - Annex B

Five documents related to the topics of Disaster Risk Reduction and resilience were selected as the basis for the elaboration of the methodology proposed in this contribution: the Sendai Framework for Disaster Risk Reduction 2015 - 2030 [4], the Disaster Resilience Scorecard for Cities [43], the Australian Disaster Resilience Index [44], the City Resilience Index [45], and the final emBRACE framework for Community Disaster Resilience [46].

The 2021 *Disaster Resilience Scorecard for Cities* [43] from the United Nations Office for Disaster Risk Reduction is a benchmarking tool offered to stakeholders and actors involved in risk management, designed to track the goals of the Sendai Framework 2015-2030 [4]. The objective of the *Sendai Framework* 2015-2030 [4] is to contribute to the resilience of nations and communities against disasters through four priorities: Understanding disaster risk; Strengthening disaster risk governance to manage disaster risk; Investing in disaster risk reduction for resilience; Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction. Resilience, according to the Sendai Framework, is the capacity of a system, community, or society to withstand, adapt to, and recover from hazards, maintaining and restoring its essential functions. In cities, this means addressing both acute and extraordinary shocks (such as floods and earthquakes) and chronic and systemic stresses (such as deforestation and unemployment). The *Ten Essentials for Making Cities Resilient* are the result of a long process that started with the Hyogo Framework 2005-2015 [2] and formed the disaster resilience scorecard. There are two versions of the tool, one for a preliminary analysis consisting of 48 indicators and the second, more detailed one consisting of 117 indicators. Our choice fell on the first set, as it is a recommended evaluation to initiate dialogues with various departments and stakeholders on disaster risk reduction and resilience issues. This preliminary analysis will then be the basis through which policymakers can consider the detailed assessment or focus on several practices and protocols to improve. The first three

essentials cover governance and financial capacity, from the fourth to the eighth essentials the dimensions of disaster planning and preparation are considered, and the last two essentials evaluate disaster response and post-event recovery. This programme was chosen for its historical and institutional character and for its supranational aspiration, which in theory provides a broad base of countries contributing to its implementation. Additionally, the tool was selected for its holistic aspiration: some dimensions that comprise the ten essentials, in addition to monitoring the progress of the Sendai Framework 2015-2030, are also used for the broader project of the Sustainable Development Goals and the Paris Agreement. 790 cities worldwide have applied the tool from 2010 to 2020.

The 2020 *Australian Disaster Resilience Index* [44], unlike the scorecard mentioned above, was selected for its specific regional character, which not only operationalizes resilience differently but is designed for the unique Australian context where the statistically and probabilistically most dangerous risk is represented by bushfires. The *Australian Institute for Disaster Resilience* is the leading institutional body coordinating resilience activities; thus, the priorities of the Sendai Framework 2015-2030 are implemented across Australia starting from this body. Regarding priority 1 (Understanding Disaster Risk), the *Australian Institute for Disaster Resilience* has established the *Australian Disaster Resilience Knowledge Hub*, an agency designed to enhance community engagement through network collaboration with local stakeholders, educational support, and the production and promotion of risk-related knowledge. The *Bushfire and Natural Hazards Cooperative Research Centre*, part of this hub and in collaboration with the University of Melbourne, developed the *Australian Disaster Resilience Index* as a benchmarking tool with primarily top-down analysis that evaluates disaster resilience across the country. In detail, the tool consists of 8 characteristics divided into 35 dimensions, which are further broken down into 77 indicators and has been tested in 2,084 areas across Australia, involving a population of approximately 17.2 million people. Before operationalizing resilience, the tool recognizes the three common characteristics of

various definitions of resilience in the scientific literature: The ability to absorb or withstand the effects of an external disturbance or stressful event; The ability to recover and return to a functional state or persist after an event; The ability to learn, adapt, or transform. Starting from these common characteristics and recognizing resilience as a capacity rather than a state, the degree of ambiguity is further reduced by presenting resilience as the sum of two capacities: Coping Capacity which allows people and organizations to use available resources and skills to deal with adverse consequences; Adaptive Capacity which allows a system to modify or change its characteristics and behaviours to cope with actual or expected stress.

Unlike the programmes previously presented, developed by national and supranational governmental institutions that directly or indirectly refer to the Sendai Framework 2015-2030, the *City Resilience Index* [45] of 2018 is an accredited benchmarking tool for resilience developed by private entities. An initial version of the tool focused on analysing the fundamental functions that an urban context should ensure, with tests conducted in six cities: Cali, Concepción, New Orleans, Cape Town, Surat, and Semarang. The insights gained from studying these urban contexts contributed to providing additional components of resilience (leadership and coordination; urban planning and strategy) as well as highlighting the need to distinguish acute shocks from disasters from those that can be chronic stressors of a social system, such as unemployment or lack of access to essential goods. The final tool is designed to be used in urban and metropolitan contexts by policymakers and local stakeholders, and the operational description of resilience also encompasses dimensions related to socio-economic sustainability as well as intangible aspects such as culture and social networks. Conceptually, and thinking in terms of a desirable future, the seven qualities of a resilient system according to the *City Resilience Index* are as follows: Reflective, Flexible, Integrated, Robust, Resourceful, Redundant, and Inclusive. Operationally, this is translated into four dimensions: Health and Well-being; Economy and society; Economy and

society; Leadership and Strategy. Each of these dimensions is composed of 3 goals, which are achievable through a set of indicators, each of which is measurable through a series of variable items. The complete tool, therefore, consists of 12 goals, 52 indicators, and 156 items. Based on an initial review and adhering to the comparative logic with the previously identified tools, we selected six goals from the dimensions of Infrastructure and Ecosystem and Leadership and Strategy. The Infrastructure and Ecosystem dimension consists of 3 goals, 13 indicators, and 47 items, while the Leadership and Strategy dimension consists of 3 goals, 12 indicators, and 32 items.

The *Embrace* project [46] was an initiative funded by the European Commission under the Seventh Framework Programme of the European Community for research and technological development including demonstration activities. It involved ten research institutes from six European countries, including the Eurac Institute (European Academy of Bolzano), which primarily focused on the development of community resilience indicators. The project's objective was to improve the resilience of European communities to natural disasters, especially considering risk factors stemming from climate change and to better understand the factors that contribute to community resilience. To achieve this goal, the project developed a theoretical concept of resilience focusing particularly on non-structural aspects such as political conditions, governance, institutional cooperation, and communication. Starting from a broader framework that considers community resources and capacities, societal resilience was modelled through simulation experiments and a set of indicators to measure resilience was created. The project, in its general development, built up upon networks, sharing knowledge among a diverse range of stakeholders, and helped tailor communication products and outcomes effectively for multiple actors, Stakeholders, and user groups.

Supplemental Files – Annex C

Dimension descriptors and promising indicators extrapolated from international frameworks.

Table B.1. Data extrapolated from Sendai Framework for Disaster Risk Reduction 2015 – 2030 [4].

Program	Dimension descriptor target/goals/priorities	Promising indicators
Sendai Framework for Disaster Risk Reduction 2015 - 2030	**(Priority 1) – Understanding disaster risk**	
	Ability to analyze all dimensions of risk	Number and type of risk dimensions analysed
	Ability to assess a pre-disaster condition	Number and type of models or tools used for pre-disaster assessment
	Ability to demonstrate the effectiveness of actions	Actions that the project aims to carry out and capable of being demonstrated by models
	(Priority 2) – Strengthening disaster risk governance to manage disaster risk	
	Ability to involve relevant Stakeholders and partners	Number and type of Stakeholders and Partner involved
	(Priority 3) – Investing in disaster risk reduction for resilience	
	Ability to attract public and private investments	Number and type of Sponsor or Partnership involved
	Ability to create innovation, growth, and job	Number of instruments and tools validated
	(Priority 4) – Enhancing disaster preparedness for effective response, and to «Build Back Better» in recovery, rehabilitation, and reconstruction	
	Ability to strengthen disaster preparedness	Results by qualitative measurement tools
	Ability to empower women and persons with disabilities to publicly lead	Number of women and persons with disabilities empowered
	Ability to promote gender equitable and universally accessible response approaches	Number of public events that involve actors of equal gender representation in the event's organization and planning.
	Ability to strengthen resilient Built Back Better strategies	Results by quantitative measurement tools

Table B.2. Data extrapolated from Disaster Resilience Scorecard for Cities, 2021 [43].

Program	Dimension descriptor target/goals/priorities	Promising indicators
Disaster Resilience Scorecard for Cities	**(Essential 1). Organize for Resilience**	
	Plan making	Implementation of DRR approaches in line with the Sendai Framework within the city's practices
	Organization, coordination and participation	Adequacy of lead agency organisation and authorities to act in all phases of DRR
	Integration	Adequacy of integration of resilience principles with other key city functions
	(Essential 5). Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems	
	Awareness and understanding of ecosystem services and functions	Stakeholder understanding and economic valorisation of ecosystem services
	Integration of green and blue infrastructure into city policy and projects	Promotion of green and blue infrastructure in major urban and infrastructure development projects in the city
	Transboundary environmental issues	Awareness of the importance of natural capital and actions taken to protect and manage these assets
	(Essential 7). Understand and Strengthen Societal Capacity for Resilience	
	Community or “grassroots” organizations, networks, and training	Active participation of community organisations in pre-event planning and post-event response
	Social networks “Leave no one behind”	Frequency of organising training programmes
	Private sector/employers	Frequency of updating the business continuity plan
	Citizen engagement techniques	Involvement of the population through multiple media channels (e.g., social, radio, e-mail, newspapers, mobile devices)
	(Essential 3). Strengthen Financial Capacity for Resilience	
	Knowledge of approaches for attracting new investment to the city:	Knowledge and application of strategies to obtain funding for DRR activities
	Financial plan and budget for resilience, including contingency funds	Allocation of dedicated DRR funds in the public budget
	Insurance	Dissemination of insurance products in all sectors/services
	Incentives	Presence of incentives, in all sectors, to increase resilience in relation to known needs
	(Essential 2). Identify, Understand and Use Current and Future Risk Scenarios	
	Hazard assessment	Understanding the main risks, the city faces and their likelihood of occurrence
	Shared understanding of infrastructure risk	Shared understanding of risks between the city and the various service providers
	Knowledge of exposure and vulnerability	Presence of agreed model scenarios defining exposure and vulnerability for each hazard
	Cascading impacts	Collective understanding of potential cascading effects between different city and infrastructure systems under different scenarios
	Presentation and update process for risk information	Presence and regular updating of high-quality hazard maps for most risks
	(Essential 4). Pursue Resilient Urban Development	
	Land use zoning	Presence and regular updating of land use maps related to hazard and risk mapping
	New urban development	Presence of guidelines for a range of professionals (e.g., architects, landscape architects, engineers, etc.)
	Building codes and standards	Presence and regular updating of local regulations addressing all known hazards in the city
	Application of zoning, building codes and standards	Verification of application and compliance with building regulations

(Essential 6). Strengthen Institutional Capacity for Resilience	
Skills and experience	Rapid access to all skills/expertise and resources needed to respond to identified disaster scenarios
Public education and awareness	Presence and reach of information campaigns and programmes on hazards, risks, and disasters
Data Sharing	Presence of a portal (or repository) to bring together/synthesise numerous city datasets, useful for building a picture of the city resilience
Training delivery	Training courses on risk, resilience and disaster response are offered in all sectors of the city, including government, business, NGOs and the community
Languages	Availability of training material in all languages commonly used in the city
Learning from others	Presence of knowledge exchange networks with other cities facing similar challenges
(Essential 8). Increase Infrastructure Resilience	
Critical infrastructure overview	Presence and implementation, in cooperation with other stakeholders, of plans or strategies for the protection of critical infrastructure, utilities, and critical services
Protective infrastructure	Presence of protection infrastructure consistent with best practices for asset design and management, based on relevant risk information
Water - Potable and Sanitation	No loss of service even in the 'most severe' scenario
Energy	No loss of service even in the 'most severe' scenario
Transport	No loss of service even in the 'most severe' scenario
Communications	No loss of service even in the 'most severe' scenario
Health care	Percentage of serious injuries that can be treated in the 'most severe' scenario
Education facilities	No loss of service even in the 'most severe' scenario
First Responder assets	Adequacy of equipment and resources to deal with the “most severe” scenario
(Essential 9). Ensure Effective Disaster Response	
Warning	Percentage of the population reachable by the early warning system
Event management plan	Presence of a disaster management plan outlining the city's mitigation, preparedness, and response strategies for local emergencies
Staffing/responder needs	Implementation of practical exercises to test the ability to cope with emergency conditions in disaster scenarios
Equipment and relief supply needs	Definition of needs, related to disaster scenarios and taking into account the role of volunteers
Food, shelter, staple goods, and fuel supply	Assessment of emergency food and relief supplies assessed according to estimated needs in the 'worst case' scenario
Interoperability and interagency working	Presence of an emergency operations centre designed to address a 'more severe' scenario
Drills	Implementation of annual exercises validated by professionals to be a realistic representation of 'more serious' and 'more likely' scenarios
(Essential 10). Expedite Recovery and Build Back Better	
Lessons learnt / learning loops	Presence of clear and effective strategies to implement the notions derived from previous experiences in the design of reconstruction projects
Post-event recovery planning – pre-event	Understanding of strategies exists by stakeholders

Table B.3. Data extrapolated from Australian Disaster Resilience Index, 2020 [44].

Program	Dimension descriptor target/goals/priorities	Promising indicators
Australian Disaster Resilience Index	**1. Social Character**	
	Language proficiency	Percentage of migrants who speak Italian not well or not at all
	Need for assistance	Percentage of the population in need of assistance
	Family composition	Percentage of single-parent families
		Percentage of households with children
	Household composition	Percentage of lone-person households
		Percentage of group households
	Sex	Sex ratio
	Education	Ratio of certificate/post-grade
	Age	Percentage of population aged over 75
	Employment and occupation	Percentage of force unemployed
		Percentage of those not in the labour force
		Percentage of managers and professionals
	2. Economic capital	
	Homeownership	Percentage of residents owning their house outright
		Percentage of residents owning their house with a mortgage
		Percentage of residents renting their home
		Median weekly rent
		Median monthly mortgage repayment
	Income	Median weekly personal income
		Median weekly family income
		Percentage of families with less than 600 eur income
		Percentage of families with more than 3000 eur income
	Economy	Percentage of in the largest single sector
		Economic diversity index
		Percentage of businesses employing 20 or more people
		Retail and or commercial establishment per 1000 people
		Percentage of population change 2001 and 2011
		Local government grant per capita
	3. Emergency services	
	Health response workforce	Medical practitioners per 1000 inhabitants
		Registered nurses per 1000 inhabitants
		Pysicologist per 1000 inhabitants
		Welfare support workers per 1000 inhabitants
		Available hospital bed per 1000 inhabitants
	Emergency response workforce	Ambulance officers and paramedics per 1000 populations
		Fire and emergency workers per 1000 populations
		Police per 1000 populations
	Emergency response funding	Fire and emergency services organization cost per 1000 population
		Ambulance services organization cost per 1000 population
	Volunteer workforce	Fire services volunteers per 1000 population
		State Emergency Services volunteers per 1000 population
	Remoteness	Distance to medical facilities
		Distance to airport
		Road infrastructures (%)
	4. Planning and the built environment	
	Buildings	Percentage of caravan and improvised dwellings
		Percentage of resident dwellings
		Percentage of commercial and industrial buildings
	Emergency planning	Emergency planning assertment score
	Planning for natural hazards	Full-time equivalent council staff
		Council area per full-time equivalent council staff
		Number of dwellings for full-time equivalent council staff
		New dwelling as a proportion of total dwellings
		New dwellings per week
		Planning assessment score
	5. Community Capital	
	Crimes and safety	Offence against people per 100.000 population
		Offence against property per 100.000 population
		Safe walking Age-standardised rate (18) per 100 population
	Household support	Support in crisis Age-standardised rate (18) per 100 population
		Person age 18+ who can raise 2000 euros in a week per 100 population

	Access to services	Difficult accessing services Age-standardised rate (18) per 100 population
		Percentage of households with no motor vehicle
	Wellbeing	Population with age 15 of belove with fair or poor self-assess health per 100 population
	Place attachment	Percentage of residents in the same area >5 years
	Volunteering	Percentage of undertaking voluntary work
	Unemployment	Percentage of jobless families
	6. Information Access	
	Internet and mobile phone coverage	Percentage of areas with excellent ADSL cover
		Percentage of mobile phone coverage
	Community engagement and hazard education	Community engagement score
	7. Social and community engagement	
	Social engagement	Percentage of population with high life satisfaction
		Percentage of the population with high generalised trust
		Migrant Effectiveness 2012-2016
	Skills for learning	Percentage of of population with school certification
		People over 15 in further education
		Participation in personal interest learning
	8. Governance and leadership	
	Research and development	Presence of research organisation
	Capacity for development	Business dynamo sub-index
		Local economic development support
	Emergency services governance environment	Governance, policy and leadership score

Table B.4. Data extrapolated from the City Resilience Index, 2018 [45].

Program	Dimension descriptor target/goals/priorities	Promising indicators
City Resilience Index	**Infrastructure and Ecosystem**	
	7 Reduced exposure and fragility	
	Comprehensive hazard and exposure mapping	Percentage of city area for which a comprehensive exposure and vulnerability assessment has been undertaken within the past 5 years
	Appropriate codes, standards, and enforcement	Percentage of buildings within the city with planning permission records
		Number of years since the oldest current building code was reviewed
		Estimated percentage of new buildings completed within the city in the last 5 years that conform to current building codes and standards
	Effectively managed protective ecosystems	Percentage green, open space increase or decrease over the past 5 years
		Percentage of natural areas within the city that have undergone ecological evaluation for their protective services
		Percentage of city area that has been officially recognised for environmental protection (including shorelines down to low--tide mark)
	Robust protective infrastructure	Number of years since the last city-wide review of the adequacy of the city's protective infrastructure assets
		Number of years the city's stormwater (or other protective) infrastructure has been
		Percentage of the annual budget for stormwater infrastructure spent on upgrades
	8 Effective provision of critical services	
	Effective stewardship of ecosystems	Number of years since assessment of the city's ecosystem assets/services
		Percentage change in the number of native species
		PM10 concentration (ug/m^3)
	Flexible infrastructure	Update the frequency of the electric plan of the city
		Update the frequency of the water plan of the city
		Average annual expenditure invested by the city for the design of sanitation
		Number of different solid waste treatment or disposal plants handling at least 5% of the solid waste generated within the City
		Number of different supply sources providing at least 5 per cent of electricity generation capacity
		Number of different supply sources providing at least 5 per cent of water supply capacity
		Percentage of annual unsound waste disposal (as a percentage of total disposal)
	Retained spare capacity	De-rated capacity margin: percentage of excess electricity supply above peak demand
		City electricity supply capacity as a percentage of total demand
		Percentage of the city’s wastewater that has received no treatment
		Waste generation rate per capita (municipal solid waste, kg per capita per year)
		Average annual residential electrical use in kw hours per year per capita
		Total water consumption per capita (litres/day)
		Percentage of the city population with regular solid waste collection

Diligent maintenance and continuity	Average length of electrical interruptions (hours per year per customer)
	Annual percentage of wastewater system losses (due to storms or malfunction) prior to treatment and/or discharge to the environment
	Average annual hours of water service interruptions per household
	Percentage of defined medium- to long-term waste management service contracts e.g., Public Private Partnership and Public Private Community Partnership agreements (as a percentage of total waste service contracts)
Adequate continuity for critical assets and services	Number of years since the last citywide critical asset assessment
	Percentage of city's hospitals with backup electricity generators
	Percentage of city's hospitals with backup water supply to meet its needs for three days
9 Reliable Mobility and Communications	
Diverse and affordable transport networks	Average speed of road journeys from the city centre to the city boundary (km per hour)
	Percentage of journeys undertaken by walking or cycling
	Percentage of commuters using a travel mode other than a personal vehicle (as a percentage of total commuters)
	Number of other cities to which this city has daily connections by bus
Effective transport operation and maintenance	Average percentage of the city's transport budget spent on maintenance and upgrade over the past 5 years
	Number of years since the city evacuation plan was updated
	Transportation fatalities per 100.000 population
Reliable communications technology	Internet users (per 100 people)
	Percentage of emergency responders with arrangements which enable them to communicate in an emergency (e.g., MTPAS (UK), satellite phones, airwaves etc.)
	Number of media types used to alert people in an emergency
Secure technology networks	Percentage of city government data with secure backup remote storage
	Percentage of infrastructure which relies on operational technology protected by a dynamic proactive I.T. security system
	Percentage of government databases protected by a dynamic proactive I.T.security system
Leadership and Strategy	
10 Effective leadership and management	
Appropriate government decision-making	Number of training and knowledge-sharing agreements with international networks
	Percentage of non-sensitive city government documentation and data sets that are publicly available
Effective coordination with other government bodies	Percentage of major policy / regulatory decisions made within the last year that were the product of city-upwards, downwards (regional, national) government consultation
	Percentage of major policy / regulatory decisions made within the last year that were that are the product of cross--departmental government consultation
Proactive multi-stakeholder collaboration	Percentage of major projects within the last year which included private sector consultation
	Percentage of city government major policy and plan changes within the past year sent out to public consultation
Comprehensive hazard monitoring	Number of years since city hazard maps have been updated

and risk assessment	Number of times the 5 most significant hazards identified in the city's local risk profile have been assessed by multi-stakeholders in the last 5 years
	Percentage of local severe weather warnings issued by the national metrological agency which are received in a timely fashion by city emergency responders
Comprehensive government emergency management	Percentage of government departments that have tested their continuity arrangements in the last 2 years
	Number of times the 5 most significant hazards identified in the city's local risk profile have been exercised in the last 5 years
	Number of times the emergency response centre capability has been tested (and successfully passed) in the last 5 years
	Number of times the city's multi-stakeholder emergency management strategy has been tested in the last 5 years
	Number of times multi-stakeholder emergency responders meet and undertake joint activities (e.g., exercises, risk assessment, plan reviews) per year
11 Empowered Stakeholders	
Adequate education for all	Percentage of primary education completion rates
	Adult literacy rate (as a percentage)
Widespread community awareness and preparedness	Percentage of households that have a smoke alarm
	Percentage of citizens intended to be evacuated, which were successfully evacuated in the last disaster drill or disaster the event in the last 5 years
	Percentage of population that has made a household or a community resilience plan
Effective mechanism for communities to engage with city government	Percentage of major city plans published in the last year that incorporate consultation with communities
12 Integrated development planning	
Comprehensive city monitoring and data management	Percentage of census data available for planning
	Percentage of residential dwellings within the city that are situated within high-risk areas (which could be addressed by zonation and relocation?)
	Number of years validity of population projections
Consultative planning process	Percentage of current land use and zoning plans that have been subject to a formal consultation process
	Percentage of current land use and zoning plans that have been subject to a formal consultation process with minority communities affected by the development
	Percentage of current land use and zoning plans that have been subject to a formal consultation process with utility providers and transport agencies
Appropriate land use and zoning	Areal size of informal settlements as a percentage of the city area
	Amount spent on transport in the last 5 years as a percentage of the overall city budget
	Percentage of high-risk areas within the city where development is restricted or prohibited under planning guidelines
	Number of years since the city plan was updated
Robust planning approval process	Percentage of buildings [or new development] constructed within the city in the past 10 years that were approved or otherwise authorised by the relevant city planning authorities
	Percentage of planning applications submitted to the city during the past 5 years on which emergency services agencies have been consulted

Table B.5. Data extrapolated from Indicators for a Resilient Community 2011-2015 [46].

Program	Dimension descriptor target/goals/priorities	Promising indicators
Indicators for a Resilient Community	**Preparedness**	Existence of a locally tested community emergency plan
		Existence of integrated and validated emergency business continuity management plans by sector in hazard zone
		Percentage of households in the community subscribed to an early-warning system
	Response	Provision of temporary and/or permanent housing after a hazardous event
		Efficiency of disaster management system
	Recovery	Presence of a 3rd sector community disaster-loss compensating funding mechanism
		Percentage of persons with mandatory hazard insurance
		Percentage of hazard-exposed properties that are insurable at “affordable” cost
	Mitigation	Risk assessment developed in a participatory process
		Integration of community representatives in Integrated Emergency Management (IEM) planning groups
		Presence of cross-departmental municipality staff training programmes related to emergency management
	Social support	Receive psychological/ physical/financial support from others during and after the hazardous event
	Resource and Capacities	Presence of a (active) third-sector emergency coordination body
		Social/Mutual trust (A scale measuring whether community members trust each other)
		Availability of adequate economic resources for disaster-related activities
		Type of physical/infrastructural connection of community
		Dwelling type (Bedroom ventilation, orientation, floor number -nominal)
	Learning	Risk/Loss perception
		Knowledge about hazard events in the past
		Severity of impact experienced in the past
		Percentage of total damage covered by external financial support for previous hazards
		Satisfaction with external financial support received
		Individuals have considered resettling as a result of previous hazards

Supplemental Files - Annex D

Criteria elaborated and related indicators

Table C.1. Criterion 1: Risk dimensions

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
How many risk dimensions are analysed?	Number of risk dimensions analysed	no.	Quantitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Which types of risk dimensions are analysed?	Types of risk dimensions	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Do the city governance measures include and implement disaster risk reduction (DRR) approaches in multi-risk scenarios due to climate change?	Presence of DRR approaches due to climate change in governance measures	y/n	Qualitative	Overarching	Overarching	Number and type of approaches
Does the city have maps to evaluate the consistency of built heritage, updated within the last 5 years?	Presence of maps to evaluate the consistency of built heritage, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of informal settlements, updated within the last 5 years?	Presence of maps to evaluate the consistency of informal settlements, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
If yes, which types of informal settlements have been recorded?	Types of informal settlements recorded	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
What percentage of informal settlements has been recorded?	Percentage of informal settlements recorded	%	Quantitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of green spaces, updated within the last 5 years?	Presence of maps to evaluate the consistency of green spaces, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have maps to evaluate the consistency of open spaces, updated within the last 5 years?	Presence of maps to evaluate the consistency of open spaces, updated within the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have lists of skills needed to face the identified risk scenarios?	Presence of lists of skills needed to face the identified risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
If yes, which types of skills have been identified?	Types of skills identified	select one	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
Does the city have maps to evaluate the percentage of high-risk urban areas where development is restricted or prohibited under planning guidelines?	Presence of maps to evaluate the percentage of high-risk urban areas where development is restricted or prohibited under planning guidelines	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
Does the city have a catalogue of past hazard events?	Catalogue of past hazard events	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
If yes, does the catalogue include the impact assessment for the past hazard events?	Presence of impact assessment for past events	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies

Table C.2. Criterion 2: Ecosystem services, structures and green and blue infrastructures

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Does the city have a comprehensive catalogue of infrastructures?	Presence of a comprehensive catalogue of infrastructures	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Analysis of the plan
For which public services does the city have insurance measures?	Public services insured	multiple choice	Qualitative	Economic	Investing in disaster risk reduction for resilience	Public budget analysis
For which infrastructures does the city have insurance measures?	Infrastructures insured	multiple choice	Qualitative	Economic	Investing in disaster risk reduction for resilience	Public budget analysis
Does the city have protective infrastructures to face relevant risks?	Presence of protective infrastructures to face relevant risks?	y/n	Qualitative	Economic	Investing in disaster risk reduction for resilience	Public budget analysis
If yes, are all the protective infrastructures in place, monitored consistent with relevant risks?	Presence of a monitoring plan of the protective infrastructures in place consistent with relevant risks	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan and public budget analysis
How frequently is the city-wide adequacy of the protective infrastructures reviewed?	Revision frequency of city-wide adequacy of the protective infrastructures	single choice	Quantitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan and public budget analysis
Are all the protective infrastructures in place, maintained consistent with relevant risk?	Presence of a maintenance plan of the protective infrastructures in place consistent with relevant rick	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan and public budget analysis
Within how many hours can the 90% of injuries be treated in the most severe scenario?	Hours within the 90% of injuries can be treated in the most severe scenario	single choice	Quantitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan
Does the city have multiple sources providing at least 5% of the supply?	Presence of multiple sources providing at least 5% of the supply	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan
If yes, which types of multiple sources?	Types of multiple sources	multiple choice	Qualitative	Infrastructure	Understanding disaster risk governance	Infrastructure plan
Does the city have a long-term plan for comprehensive waste disposal management, updated within the last 5 years?	Presence of a long-term plan for comprehensive waste disposal management, updated within the last 5 years	y/n	Qualitative	Infrastructure Environmental Ecological	Understanding disaster risk governance	Infrastructure plan, public budget analysis
What is the percentage range of teaching facilities still working in the “most severe” scenario?	Percentage range of teaching facilities still working in the “most severe” scenario	single choice	Quantitative	Infrastructure	Strengthening disaster risk governance	Impact scenarios analysis
Which types of first response assets have been evaluated to be adequate in practice to deal with a “most severe” scenario?	Types of first response assets evaluated to be adequate in practice to deal with a “most severe” scenario	multiple choice	Qualitative	Infrastructure	Strengthening disaster risk governance	Impact scenarios analysis
Does the city have maps evaluating escape routes, updated within 5 years?	Presence of maps evaluating escape routes, updated within 5 years	y/n	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Infrastructure plan

If yes, which information does this map consider?	Type of information considered	multiple choice	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Infrastructure plan
Does the city monitor the efficiency of public transport compliance with the escape scenario?	Presence of a monitoring plan for the efficiency of public transport compliance with the escape scenario	y/n	Qualitative	Infrastructure	Strengthening disaster risk governance	Infrastructure plan
Does the city have structures dedicated to psychological support during and after the hazard event?	Presence of structures dedicated to psychological support during and after the hazardous event	y/n	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology
Does the city have policies promoting green and blue infrastructures?	Presence of policies promoting green and blue infrastructures	y/n	Qualitative	Infrastructure Environmental Ecological Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Infrastructure plan, impact scenarios
If yes, which percentage of the public budget the city allocates for green and blue infrastructures?	Percentage of the public budget allocated for green and blue infrastructures	%	Quantitative	Economic Environmental Ecological	Investing in disaster risk reduction for resilience	Infrastructure plan, public budget analysis
What is the percentage of the population over 75 years with difficulties in accessing services?	Percentage of population over 75 years with difficulties in accessing services	%	Quantitative	Infrastructure Social	Understanding disaster risk governance Strengthening disaster risk governance	statistic sources of Municipality
What is the percentage of the population under 75 years with difficulties in accessing services?	Percentage of population under 75 years with difficulties in accessing services	%	Quantitative	Infrastructure Social	Understanding disaster risk governance Strengthening disaster risk governance	statistic sources of Municipality
Does the city have services immediately available to face alert scenarios?	Presence of a list of resources immediately available to face alert scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies
If yes, which type of services are immediately available?	Type of services immediately available	multiple choice	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan and policies

Table C.3. Criterion 3: Practices validation and update

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Does the city have validated tools for pre-disaster assessment?	Presence of validated tools for pre-disaster assessment	y/n	Qualitative	Politic	Understanding disaster risk governance	Analysis of the plan
If yes, which types of validated tools are used?	Types of validated tools used for pre-disaster assessment	multiple choice	Qualitative	Politic	Understanding disaster risk governance	Analysis of the plan
Does the city update multi-hazard maps at least every 5 years?	Update of multi-hazard maps at least every 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Does the city update land use maps at least every 5 years?	Update of land use maps at least every 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have standards verified at least every 5 years addressing all multi-risk scenarios?	Presence of standards verified at least every 5 years addressing all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance	Analysis of the plan
Does the city have disaster management plans for all multi-risk scenarios?	Presence of disaster management plans for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Are disaster management plans validated at least every 5 years for all multi-risk scenarios?	Validation of disaster management plans at least every 5 years for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Does the city have preparedness plans available for all multi-risk scenarios?	Presence of preparedness plans for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Are preparedness plans validated at least every 5 years for all multi-risk scenarios?	Validation of preparedness plans validated at least every 5 years for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Does the city have emergency response plans for all multi-risk scenarios?	Presence of emergency response plans for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Are emergency response plans validated at least every 5 years for all multi-risk scenarios?	Validation of emergency response plans at least every 5 years for all multi-risk scenarios	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Analysis of the plan
Has the city conducted at least one practice drill each year in the last 5 years?	Presence of one practice drill each year in the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk	Database

					governance	
Has the city tested practice drills' efficacy in the last 5 years?	Presence of testing of practice drills efficacy in the last 5 years	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Database
If yes, how practice drills have been tested?	Types of methods used for testing practice drills	multiple choice	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance	Database
Does the city have the provision of buildings for temporary housing (shelters) after a hazard event?	Provision of buildings for temporary housing (shelters) after a hazardous event	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
If yes, is the number of buildings for temporary housing (shelters) after a hazard event adequate in the most severe scenario?	Adequacy of the number of buildings for temporary housing (shelters) after a hazard event with the most severe scenario	y/n	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
Does the city have the provision of buildings for permanent housing (shelters) after a hazard event?	Provision of buildings for permanent housing (shelters) after a hazardous event	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
If yes, is the number of buildings for permanent housing (shelters) after a hazard event adequate in the most severe scenario?	Adequacy of the number of buildings for permanent housing (shelters) after a hazard event with the most severe scenario	y/n	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
Does the city have the provision of areas for temporary housing (shelters) after a hazard event?	Provision of areas for temporary housing (shelters) after a hazardous event	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan

If yes, is the number of areas for temporary housing (shelters) after a hazard event adequate in the most severe scenario?	Adequacy of the number of areas for temporary housing (shelters) after a hazard event with the most severe scenario	y/n	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
Does the city have the provision of areas for permanent housing (shelters) after a hazard event?	Provision of areas for permanent housing (shelters) after a hazard event	y/n	Qualitative	Overarching	Understanding disaster risk governance Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
If yes, is the number of areas for permanent housing (shelters) after a hazard event adequate in the most severe scenario?	Adequacy of the number of areas for permanent housing (shelters) after a hazard event with the most severe scenario	y/n	Qualitative	Infrastructure	Understanding disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan
Does the city have a secure backup remote storage for city government data within the DRR databases?	Presence of a secure backup remote storage for city government data within the DRR databases	y/n	Qualitative	Infrastructure	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Analysis of the plan

Table C.4. Criterion 4: System of Stakeholders / Policymakers

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Does the city have a formalized partnership with Stakeholders?	Presence of a formalized partnership with Stakeholders	y/n	Qualitative	Overarching	Overarching	Analysis of the plan
Are Stakeholders involved in all the phases of DRR decision-making?	Involvement of Stakeholders in all the phases of DRR decision-making	y/n	Qualitative	Overarching	Overarching	Analysis of the plan
How many Stakeholder categories are involved in DRR planning?	Number of Stakeholders categories involved in DRR planning	no.	Quantitative	Overarching	Overarching	Analysis of the plan Scenario analysis Typology
Which types of Stakeholder categories are involved in DRR planning?	Types of Stakeholders categories involved in DRR planning	multiple choice	Qualitative	Overarching	Overarching	Analysis of the plan Scenario analysis Typology
Do Stakeholders identify the type of resources given for supporting DRR planning in the agreement?	Identification of the type of resources given by Stakeholders for supporting DRR planning in the agreement	y/n	Qualitative	Overarching	Overarching	Analysis of the plan Scenario analysis Typology
If yes, which types of resources given for supporting DRR planning are identified in the agreement?	Types of resources given for supporting DRR planning are identified in the agreement	multiple choice	Qualitative	Overarching	Overarching	Analysis of the plan Scenario analysis Typology
How often have DRR decision-making processes involved Stakeholders during the last 5 years?	Frequency of Stakeholder involvement in DRR decision-making processes during the last 5 years	single choice	Qualitative	Politic	Strengthening disaster risk governance	Institutional sources/service conferences and similar secondary sources
Does the city have a formalized partnership with research organisations?	Presence of formalized partnerships with research organisations	y/n	Qualitative	Overarching	Overarching	Institutional sources/service conferences and similar secondary sources
If yes, which types of research organizations are involved?	Types of research organizations involved	multiple choice	Qualitative	Overarching	Overarching	Institutional sources/service conferences and similar secondary sources

Does the city have a database of structured volunteer organisations, updated within the last 5 years?	Presence of a database of structured volunteer organisations, updated within the last 5 years	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Analysis of the plan
Does the city have a database of the resources that the volunteer organisation gives in support, updated within the last 5 years?	Presence of a database of the resources that volunteer organisation gives in support, updated within the last 5 years	y/n	Qualitative	Infrastructure	Understanding disaster risk governance	Analysis of the plan

Table C.5. Criterion 5: Empowerment of vulnerable groups

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Does the city have a database of vulnerable groups, updated within the last 5 years?	Presence of a database of vulnerable groups, updated within the last 5 years	y/n	Qualitative	Social	Understanding disaster risk governance	Database consultation, analysis, community profiles
If yes, which types of vulnerable groups have been identified?	Types of vulnerable groups identified	multiple choice	Qualitative	Social	Understanding disaster risk governance	Database consultation, analysis, community profiles
Does the city have a map of zones of vulnerable groups' concentration, updated within the last 5 years?	Presence of a map of zones of vulnerable groups' concentration, updated within the last 5 years	y/n	Qualitative	Social	Understanding disaster risk governance	Database consultation/analysis
If yes, which types of zones have been identified?	Types of zones identified	multiple choice	Qualitative	Social	Understanding disaster risk governance	Database consultation/analysis
Are vulnerable groups considered within the development of DRR plans?	Consideration of vulnerable groups within DRR plans	y/n	Qualitative	Social	Understanding disaster risk governance	Analysis of the plan Scenario analysis Typology
If yes, which types of vulnerable groups are considered within the development of DRR plans?	Types of vulnerable groups considered within DRR plans	multiple choice	Qualitative	Social	Understanding disaster risk governance	Analysis of the plan Scenario analysis Typology
What is the average per capita income of the city's residents?	Per capita income of the city's residents	€/year	Quantitative	Economic Social	Understanding disaster risk governance	Population database

Table C.6. Criterion 6: Public communication

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
How many public events have been organised related to DRR in the last 5 years?	Number of public events related to DRR organised in the last 5 years	no.	Quantitative	Social	Strengthening disaster risk governance Investing in disaster risk reduction for resilience	Media; institutional websites; and other secondary sources
				Cultural	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
Which types of public events have been organised related to DRR in the last 5 years?	Types of public events related to DRR organised in the last 5 years	multiple choice	Qualitative	Cultural	Strengthening disaster risk governance Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Media; institutional websites; and other secondary sources
Does the city have guidelines for practitioners (e.g. architects, landscape architects, engineers, etc)?	Presence of guidelines for practitioners	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology
Does the city have assessment tools for risk communication campaign efficacy?	Presence of assessment tools for risk communication campaign efficacy	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology
If yes, which types of assessment tools for risk communication campaign efficacy are used?	Types of assessment tools for risk communication campaigns efficacy used	multiple choice	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology
Does the city have tools to measure how many people have been reached by risk communication campaigns?	Presence of tools to measure how many people have been reached by risk communication campaigns	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology
If yes, which types of tools to measure how many people have been reached by risk communication campaigns are used?	Types of tools to measure how many people have been reached by risk communication campaigns are used	multiple choice	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the plan Scenario analysis Typology

Does the city have an open-access web portal regarding DRR?	Presence of an open-access web portal regarding DRR	y/n	Qualitative	Cultural	Strengthening disaster risk governance	Media; institutional websites; and other secondary sources
				Politic	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
If yes, which types of information does the web portal contain?	Types of information contained in the web portal	multiple choice	Qualitative	Cultural	Strengthening disaster risk governance	Media; institutional websites; and other secondary sources
				Politic	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
If yes, does the city conduct a periodical monitoring of accesses to the web portal regarding DRR?	Presence of a periodical monitoring of accesses to the web portal regarding DRR	y/n	Qualitative	Cultural	Strengthening disaster risk governance	Media; institutional websites; and other secondary sources
				Politic	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
Does the city have instruments to assess the population's risk perception?	Presence of instruments to assess the population's risk perception	y/n	Qualitative	Politic	Understanding disaster risk governance	Analysis of the communication plan
If yes, which types of instruments does the city use to assess the population's risk perception?	Types of instruments used to assess the population's risk perception	multiple choice	Qualitative	Politic	Understanding disaster risk governance	Analysis of the communication plan
Which types of media channels are used to alert people during an emergency?	Types of media channels used to alert people during the emergency	multiple choice	Qualitative	Cultural	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the communication plan; DPC interviews and confrontation.
Does the city have online communication materials produced in different languages used in the city?	Presence of online communication materials produced in different languages used in the city	y/n	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the communication plan; DPC interviews and confrontation.
Does the city have off-line communication materials produced in different languages used in the city	Presence of off-line communication materials produced in different languages used in the city	y/n	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of the communication plan; DPC interviews and confrontation.

Table C.7. Criterion 7: Training

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
How many training public events have been organised during the last 5 years?	Number of training public events organised during the last 5 years	no.	Quantitative	Social	Strengthening disaster risk governance Investing in disaster risk reduction for resilience	Media; institutional websites; and other secondary sources
				Cultural	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
Which types of training public events have been organised during the last 5 years?	Types of training public events organised during the last 5 years	multiple choice	Qualitative	Cultural	Strengthening disaster risk governance Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Media; institutional websites; and other secondary sources
Does the city have risk training initiatives?	Presence of risk training initiatives	y/n	Qualitative	Cultural	Strengthening disaster risk governance	Analysis of the plan Scenario analysis Typology
				Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
If yes, which types of risk training initiatives are organised?	Types of risk training initiatives organised	multiple choice	Qualitative	Cultural	Strengthening disaster risk governance	Analysis of the plan Scenario analysis Typology
				Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	
Does the city have training agreements with other territories?	Presence of training agreements with other territories	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; service conferences and similar secondary sources;
If yes, at which governance level have training agreements been signed?	Governance level of training agreements signed	multiple choice	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; service conferences and similar secondary sources;
Does the city participate in training courses organised by other subjects?	Participation in training courses organised by other subjects	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; service conferences and similar secondary sources;
If yes, which types of subjects organise training courses?	Types of subjects organizing training courses	multiple choice	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; service conferences and similar secondary sources;
Does the city have an annual fund for public training on disaster governance?	Presence of an annual fund for public training on disaster governance	y/n	Qualitative	Economic	Investing in disaster risk reduction for resilience	budget, training programmes
				Politic	Strengthening disaster risk governance	

If yes, what is the amount of the annual fund per inhabitant?	Amount of the annual fund per inhabitant	€ / no. of inhabitants	Quantitative	Economic	Investing in disaster risk reduction for resilience	budget, training programmes
				Politic	Strengthening disaster risk governance	
Has the city participated in training events during the last 5 years?	Participation in training events during the last 5 years	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources;
If yes, has the city implemented the results of training events in the design of DRR strategies?	Implementation of training events results in the design of DRR strategies	y/n	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; Analysis of plans
What are the main results of training events implemented in the design of DRR strategies?	Main results of training events implemented in the design of DRR strategies	multiple choice	Qualitative	Politic	Strengthening disaster risk governance Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Institutional sources; Analysis of plans

Table C.8. Criterion 8: Economic measures stored/invested for public and private resilience

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Does the city have financial resources dedicated to risk management in its last validated public budget?	Presence of financial resources dedicated to risk management in its public budget	y/n	Qualitative	Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans
If yes, what percentage of funding is covered by the municipality for DRR?	Percentage of funding covered by the municipality for DRR	%	Quantitative	Politic Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans
Does the city have financial instruments incentivising DRR?	Presence of financial instruments incentivising DRR	y/n	Qualitative	Politic Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
If yes, which financial instruments does the city have?	Financial instruments incentivising DRR	multiple choice	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for infrastructure maintenance?	Percentage of the budget allocated by the city for infrastructure maintenance	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for infrastructure monitoring?	Percentage of the budget allocated by the city for infrastructure monitoring	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for public building maintenance?	Percentage of the budget allocated by the city for public building maintenance	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for public building monitoring?	Percentage of the budget allocated by the city for public building monitoring	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for services maintenance?	Percentage of the budget allocated by the city for services maintenance	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans

What percentage of the last validated public budget is allocated by the city for services monitoring?	Percentage of the budget allocated by the city for services monitoring	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for householders' monitoring?	Percentage of the budget allocated by the city for householders monitoring	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
What percentage of the last validated public budget is allocated by the city for householders' maintenance?	Percentage of the budget allocated by the city for householders' maintenance	%	Quantitative	Economic	Investing in disaster risk reduction for resilience Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of economic plans
How often DRR financial plans are updated?	Frequency of financial plan updating	single choice	Qualitative	Economic	Strengthening disaster risk governance	Analysis of economic plans
In case of a recent disaster event, did the city register the amount of expenditure incurred in the emergency management phase?	Registration of the amount of expenditure incurred in the emergency management phase	y/n	Qualitative	Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans
Did the city cover the emergency management phase during the last recent disaster event with an internal budget?	Emergency management phase during the last recent disaster event covered with internal budget	y/n	Quantitative	Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans
If yes, what percentage of the internal budget covers the expenditure?	Percentage of internal budget used to cover the expenditure	%	Quantitative	Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans
Does the city have a budget for emergency services?	Presence of a budget measure	y/n	Qualitative	Economic	Investing in disaster risk reduction for resilience	Infrastructure plan, public budget analysis
If yes, what is the percentage range covered by the budget in the most severe scenario considered?	Percentage range of the budget consistent with the most severe scenario considered	single choice	Quantitative	Economic	Investing in disaster risk reduction for resilience	Analysis of economic plans

Table C.9. Criterion 9: Community engagement and social capital

Variables	Indicators	Measurement unit	Cluster 1 _ Measurability	Cluster 2 _ Dimension	Cluster 3 _ Sendai Priorities	How to measure/evaluate
Do community organizations participate in DRR planning?	Participation of community organizations in DRR planning	y/n	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of plans; stakeholders engagement activities (i.e., interviews)
				Politic	Strengthening disaster risk governance	
Are community organizations engaged through multiple media channels?	Engagement of community organizations through multiple media channels	y/n	Qualitative	Politic	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Stakeholders' engagement activities (i.e., interviews; focus groups)
				Social	Strengthening disaster risk governance	
Which media channels are most used to engage the community?	Media channels most used to engage the community	multiple choice	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Stakeholders' engagement activities (i.e., interviews; focus groups)
					Strengthening disaster risk governance	
What is the percentage range of the population covered by an internet connection?	Percentage range of population covered by an internet connection	single choice	Quantitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Confrontation with providers; consultation with public sources
					Strengthening disaster risk governance	
How many hazard education actions have been organised with community engagement during the last 5 years?	Number of hazard education actions organised with community engagement during the last 5 years	no.	Quantitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Stakeholders' engagement activities (i.e., interviews); reports of the actions/activities.
					Strengthening disaster risk governance	
How many people have been involved in hazard education actions during the last 5 years?	Number of persons involved in hazard education actions during the last 5 years	no.	Quantitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Stakeholders' engagement activities (i.e., interviews); reports of the actions/activities.
					Strengthening disaster risk governance	
Which types of people categories have been involved in hazard education actions?	Types of people categories have been involved in hazard education actions	multiple choice	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Stakeholders' engagement activities (i.e., interviews); reports of the actions/activities.
					Strengthening disaster risk governance	
Are community representatives involved in Integrated System of Civil Protection planning groups?	Involvement of community representatives in Integrated System of Civil Protection planning groups	y/n	Qualitative	Social	Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction	Analysis of plans; stakeholders engagement activities (i.e., interviews)
				Politic	Strengthening disaster risk governance	