Extended Partnership

Return

multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate

Spoke TS3 – Communities' resilience to risks: social, economic, legal and cultural dimensions

WP 7.2 - Innovative tools to evaluate risk mitigation effectiveness

TK 7.2.1 - State of art on MCA applied to natural risk management

Deliverable 7.2.1

Report on the-state-of-the-art of MCA applied to natural risk management

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1 Introduction

In the context of the Return Project Spoke TS3 – Communities' resilience to risks: social, economic, legal and cultural dimensions, the WP2 is aimed at defining national guidelines for the evaluation of the effectiveness of alternatives of intervention in natural risks management, by considering in detail Multi Criteria Analysis (MCA) tools.

Natural risk management is framed within the broader theme of Disaster risk management that aims at setting out the goals and specific objectives for reducing disaster risks, together with related actions to accomplish these objectives (UNDRR[1]). The interest of the WP is just in the selection of such actions (called "risk reduction measures" in the following), and specifically in their prioritization according to criteria of effectiveness.

The focus of the WP is on multi-hazard contexts, as the co-existence of many risks is the reality in many parts of the world (and especially in Italy). In such areas, a joint analysis for quantifying and comparing all risks and relative intervention strategies that potentially affect the territory is crucial for disaster risk management. In fact, as stated in de Ruiter et al. (2021), the UNDRR's Global Platform for Disaster Risk Reduction has called upon the science community for an increased understanding of the complexities of multi-hazard risk (UNDRR, 2019); and even the Sendai Framework for Disaster Risk Reduction (DRR) strongly calls for multi-risk perspectives (Djalante, 2018).

The evaluation of costs and benefits of alternatives of intervention is at the base of any policy on natural risks management and climate change adaptation (see, e.g., the UN International Strategy for Disaster Reduction, the Water Framework Directive, the Floods Directive, the European Green Deal, the Building Back Better Strategy). To this aim, several tools have been developed in the last decades (including, e.g., Cost Benefit Analysis, Cost Effectiveness Analysis, Environmental Impact Assessment, Regulatory Impact Analysis, Multi Criteria Analysis), with the final aim of supporting decision makers in the selection of alternative interventions (OECD, 2006; Mouter et al., 2020, §2).

Among available ones, Multi Criteria Analysis (MCA) seems the most promising tool in supporting decision makers in finding solutions to complex problems, where more than one goal has to reach, and there is always a trade-off between the different goals, advocated by different interest groups or stakeholders (Beria et al., 2012). This is typically the case of natural risk management problems where (often conflicting) technical, economic, cultural (psychological, social, ethical, and legal), and environmental aspects play a role in the definition of the goals (Perosa et al., 2022).

Still, the implementation of MCA in natural risk management is not a standardized practice, especially in multi-hazard contexts where complexity arises because of possible effects amplification due to hazards interaction and/or cascading effects. Nonetheless, different methodologies and spatial/temporal resolutions are usually adopted in the quantification of single risk and their mitigation actions. The metrics adopted to measure them could vary as well. This makes the outcomes of risk analysis related to different hazards hardly comparable but at the same time essentials (Tocchi et al., 2023).

As regard risk reduction measures, effective natural risk management requires that the best mix of solutions, both structural and non-structural, must be implemented, considering all phases of the risk management chain (namely: prevention, preparedness, response, recovery). How to frame MCA to support the selection of the best strategy is just the objective of the WP.

To reach this aim, the first step is the State of art on MCA applied to natural risk management, conducted in the Task 2.1, and described and summarized in this report at §3, after a brief overview of MCA tools in §2. The results of the literature review are the starting point for the development of the Task 2.2 of

[1] https://www.undrr.org/terminology/disaster-risk-management

the WP, aimed to the Problem definition, and specifically to the definition of attributes and indicators according to which reduction measures can be evaluated, as discussed in §4.

2 Approaches for prioritization of mitigation measures

The decision-making process poses a significant challenge in natural risk management. This is mainly due to, on the one hand, the inherent complexity that emerges from the participation of multiple stakeholders, each one having different points of view, background knowledge, and interests, with often conflicting goals compared to the others (Curt et al., 2022), on the other hand, the plethora of possible actions and intervention strategies and the high uncertainty related to the estimation of the frequency and intensity of natural hazards, as well as their associated impacts, even increasing in multi-risk contexts (de Kort and Booij, 2007).

Currently, several methodologies and tools are available in literature, assisting decision makers to manage natural risks through *ex ante* appraisals and/or *ex post* evaluations. Among the most used ones are the Financial Analysis, Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), Risk Benefit Analysis, Multi-Criteria Analysis (MCA), Environmental Impact Assessment (EIA), Regulatory Impact Analysis (RIA), Life Cycle Assessment (LCA), Social Impact Assessment (SIA), and expert judgements, as introduced in Singh et al. (2012). Despite all these tools are great in number, the majority of them lack comprehensiveness, given that either they focus on a single hazard (e.g., earthquake, flood), adopt an approach that is based on a mono-criterion, or consider only one aspect of the problem. Natural risk management is frequently based on the consideration of economic aspects, either because other problem dimensions are seen of lesser importance or because available methods are not able to derive reliable estimates of them. Ideally, natural risk management should take into account all relevant dimensions, including significant social (e.g., psychological, cultural), environmental, and political effects of choices, to obtain a more comprehensive picture of the problem. In such a context, there is a need for appropriate decision support tools that allows dealing with the wide range of stakeholders' preferences and objectives, alternative options (i.e., the different choices available for the decision maker), and evaluation criteria.

The existing methodologies and tools can be classified in several ways. One of the simplest classification schemes is based on the number of criteria and relative objectives considered in the analysis, which lead to the definition of two families of methods: the mono-criterion and multi-criteria. While mono-criterion methods analyze the problem through a single and specific objective, multi-criteria methods appraise or evaluates a management decision, accounting for, the various dimensions of interest in a more explicit way, as well as the interplay among the multiple, and often contrasting, objectives and criteria.

CBA is a mono-criterion method that assesses a given problem primarily against the objective of economic efficiency, translating all the potential impacts into discounted monetary terms, often expressed by criteria such as the Benefit-Cost Ratio (BCR) or the Net Present Value (NPV). BCR is related to the estimation of benefits calculated as the difference of the impacts before and after the implementation of a project and the comparison with the costs of the project by summing the maintenance and investment costs over time, whereas NPV is defined as the sum of discounted benefits minus the sum of discounted costs over the lifetime of a project. Moreover, CBA sometimes provides monetary evaluations of social well-being and environmental effects through criteria, such as the Cost per Statistical Life Saved (CSLS) and Internal Rate of Return (IRR). While the CSLS concerns the ratio between the costs of a project and the reduction in the societal risk, expressed for example by the expected annual loss of life, IRR refers to the value of the social opportunity cost that is the threshold value of risk acceptability, with the project having the minimal value to be considered as the one that employs the resources in the most efficient way.

Among the abovementioned methods for natural risk management, the application of MCA, included in the family of multi-criteria methods, seems the most promising. This is mainly for two reasons. First, because it enhances the effectiveness of decisions by explicitly structuring the context of the problem.

Second, because it allows the development of a participatory approach by promoting the role of participants through the better communication of their preferences. In doing so, it facilitates group decisions. In fact, the participation of decision makers during the process constitutes a key feature of the approach. This is why MCA has received a great attention during the last decades, not only from researchers focusing on a broad spectrum of disciplines, but also from decision makers and practitioners outside the scientific community, mainly because it helps finding solutions to complex and conflicting decision problems, where more than one goal has to be reached, and where there is always a trade-off between the different goals advocated by the different interest stakeholders (Beria et al., 2012).

2.1 Multi-Criteria Analysis

MCA emerged in the 1960s as an effective approach in decision-making that concerns the analysis of the full range of aspects related to a specific problem. To achieve this goal, several criteria (and eventually sub-criteria) are considered simultaneously in a complex situation. The approach can be applied to support decision makers to integrate the multiple and often contradictory objectives reflecting the different preferences of stakeholders concerned into a structured framework (Cinelli et al., 2014). More specifically, it establishes preferences between the different alternative options with reference to a set of objectives that have been identified, and for which evaluation criteria have been selected to assess the extent to which the initial objectives have been achieved. The framework usually requires in input the values of positive and negative impacts, criteria weights, utility or value functions, etc. The outputs include the ranking of alternative options or the assessment of their compatibility. The results are intended to provide recommendations to decision makers for the implementation of future actions. The main advantage of MCA is that it takes into consideration the complexity of decision-making process by coping with the wide range of stakeholders, conflicts, or legal and technical judgements. Moreover, it allows the use of both quantitative and qualitative elicitation of the indicators for the estimation of criteria scores. Despite that, no concrete frameworks are yet available, and as a consequence the analysis is still difficult to be conducted and implemented in practice.

MCA does not refer to a single specific method but is used as an umbrella term to denote a number of different techniques and tools that are capable of integrating multiple objectives and evaluation criteria in the analysis of a problem (Dean, 2020). MCA tools can be applied throughout the different "phases" of natural risk management process, including: the hazard assessment, vulnerability assessment, susceptibility assessment, risk assessment, emergency management, coping capacity assessment, and the ranking of alternatives for risk mitigation (de Brito and Evers, 2016).

The prioritization of alternatives concerns the selection of the best structural (i.e., physical construction) and/or non-structural (e.g., land-use planning, insurance premium, early warning system) risk reduction measure (or combination of them) to implement, from a set of potential alternatives, with the ultimate goal of mitigating the impacts of natural hazards. Their application leads to the reduction of hazard, exposure, and vulnerability that characterize a specific area as well as to an increase of communities' resilience, fitting into the prevention, preparedness, response, or recovery phase of the Disaster Risk Reduction (DRR) framework. The comparative assessment of alternative scenarios for natural risk management is a complex decision problem because different aspects need to be considered simultaneously, considering not only the technical performance of measures in reducing the hazard impacts, which are based on risk assessments, but also multiple social and environmental co-benefits (e.g., improved biodiversity, recreational services) and disbenefits (e.g., development of unwanted flora, pollutants concentration) (Curt et al., 2022). For this reason, methods that make part of the MCA family turn out to be extremely useful (Figueira et al., 2005).

Given the plethora of MCA methods available in the literature, the development of a comprehensive classification scheme that is able to identify all the existing techniques while capturing their common (or not) characteristics is challenging. A great number of different taxonomies have been suggested over the time. A first classification concerns the way in which the feasibility of option(s) is selected, categorizing methods as (i) ranking of alternatives, (ii) choice methods, (iii) description of the alternative's features, and (iv) sorting by groups. A second classification concerns the nature of information used, differentiating among quantitative, qualitative, or mixed methods. A third classification scheme is associated with the level of compensation that is allowed by the different methods, classified in compensatory, partially compensatory, and non-compensatory. Another classification of MCA approaches distinguishes among theories, classified into the following groups (Hajkowicz and Collins, 2007):

1. Multi-attribute utility and value functions
2. Pairwise comparisons
3. Outranking approaches
4. Distance to ideal point methods
5. Other methods

Multi-attribute utility and value functions

The methods of multi-attribute utility and value functions aim to define an expression for the preferences of decision makers. To achieve this goal, all criteria are transformed into a common dimensionless scale. The most commonly used methods are Multi-Attribute Utility Theory (MAUT) and Multi-Attribute Value Theory (MAVT), and Simple Additive Method (SAW). MAUT and MAVT methods are compensatory in nature, implying that the poor performance of one criterion (e.g., fatality rate) can be offset by the good performance of another (e.g., financial loss). Using the MAUT method, decisions are made by comparing the utility values of a range of attributes in terms of risk and uncertainty (Wallenius et al., 2008). MAVT, instead, is a simplification of MAUT that does not require modelling decision makers' attitudes towards risk (Belton, 1999). SAW is known as weighted linear combination method.

Pairwise comparisons

When the definition of utility and value functions is not feasible, pairwise comparisons are recommended. This approach, in contrast to the multi-attribute utility and value functions, defines a scale a priori, according to which pairs of criteria are compared by asking how much more important one is than the other. Among the most common techniques are the Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH). AHP is a structured technique that analyzes decision making problems of multiple criteria according to a pairwise scale by comparing the criteria with each other (Figure 1). It calibrates the numeric scale for the measurement of quantitative and qualitative performance indicators throughout Eigen vector method (Table 1). The linguistic scales of pairwise comparisons are converted to quantitative values that ranges from 1/9 for "least valued than", to 1 for "equal", and to 9 for "absolutely more important than", covering the full spectrum of comparison (Saaty, 1980). ANP is a generalization of AHP, which, however, allows for the interdependencies between criteria, using a network without specifying hierarchy levels (Saaty, 2004). MACBETH is an interactive questioning process that requires only qualitative preference judgements about differences of value to help an individual, or a group, to weight criteria and quantify the relative attractiveness of options in each criterion. The six semantic categories "very weak", "weak", "moderate", "strong", "very strong" or "extreme" are represented by non-overlapping intervals of real numbers to subsequently generate a numerical scale. In doing so, it facilitates decision makers to avoid producing numerical representations of their preferences (Bana e Costa et al., 2012).

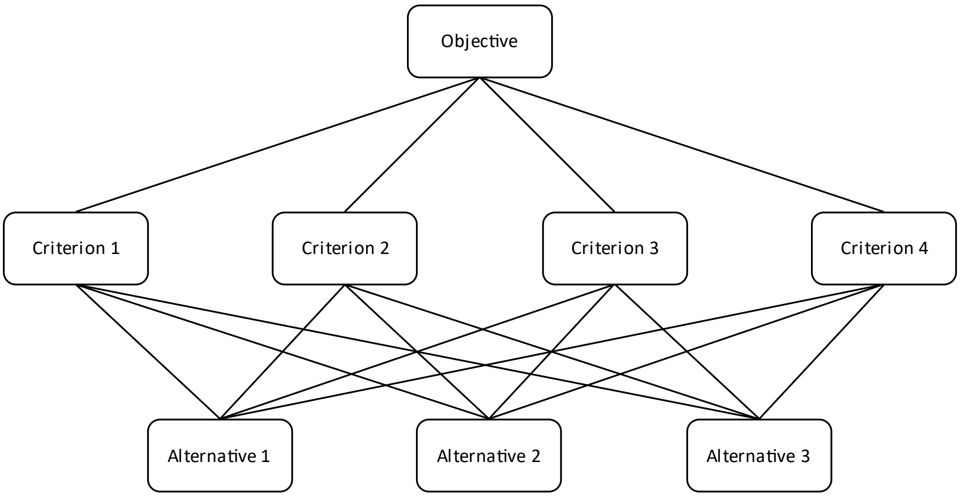

Figure 1. A simple AHP hierarchy with three alternatives to achieve the objective and four criteria for deciding between them.

Table 1. Numerical and linguistic values of criteria in Eigen vector method (Saaty, 1980)

Numerical value of importance	Definition of linguistic value
9	Extreme importance of one over another
7	Very strong importance
5	Moderate importance of one over another
3	Slight importance of one over another
1	Equal importance
2, 4, 6, 8	Intermediate values between two adjacent values

Outranking approaches

Outranking approaches assume that there is no single optimal solution, based upon the principle that one alternative may have a degree of dominance over another. Common methods include the ELimination Et Choix Traduisant La REalité (ELECTRE), Preference Ranking Organization METhod for Enrichment of Evaluations (PROMETHEE) and Organization Rangement Et SynThesE de donnes Relationnelles (ORESTE). ELECTRE outranks a set of alternatives by determining their indexes of concordance and discordance (Figueira et al., 2013). PROMETHEE method ranks the alternatives, which consists of positive and negative preference flows, on the basis of defined weighting criteria (Brans and Vincke, 1985). The ORESTE method was introduced by Roubens (1982) as an alternative to ELECTRE method, in which the superiority of the alternatives over each alternative is determined according to each single criterion. It simply ranks the alternatives without requiring the existence of quantitative data and the determination of criteria weights.

Distance to ideal point methods

By applying the methods of distance to ideal points, the alternatives are ranked based on their distance from an ideal point that represents the hypothetical alternative that best meets the goals of decision makers. The alternative that is closest to the ideal point emerges as the best solution. Some well-known methods are the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), Compromise Programming (CP), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). TOPSIS technique claims that the best alternative is the one that is closest to the ideal solution, or in other words, the one that is farthest from the negative ideal solution (Behzadian et al., 2012). CP uses different measures of distance to identify the most appropriate solutions, which are called compromise solutions and constitute the compromise set (Zeleny, 1973). VIKOR uses aggregation functions, focusing on identifying compromise solutions for a prioritization problem with conflicting criteria (Golfam et al., 2019). The main feature of these methods is their ability to take into account an unlimited number of alternatives and criteria.

Other methods

As other methods are considered all the techniques that cannot be included in one of the previous categories. In particular, they refer to fuzzy methods, hybrid methods, or tailored methods that allow for the modification and improvement of existing fundamental methods and the development of new ones for a specific context.

A detailed description of all the techniques is outside the scope of this deliverable. For more information, see the review article of Figueira et al. (2005).

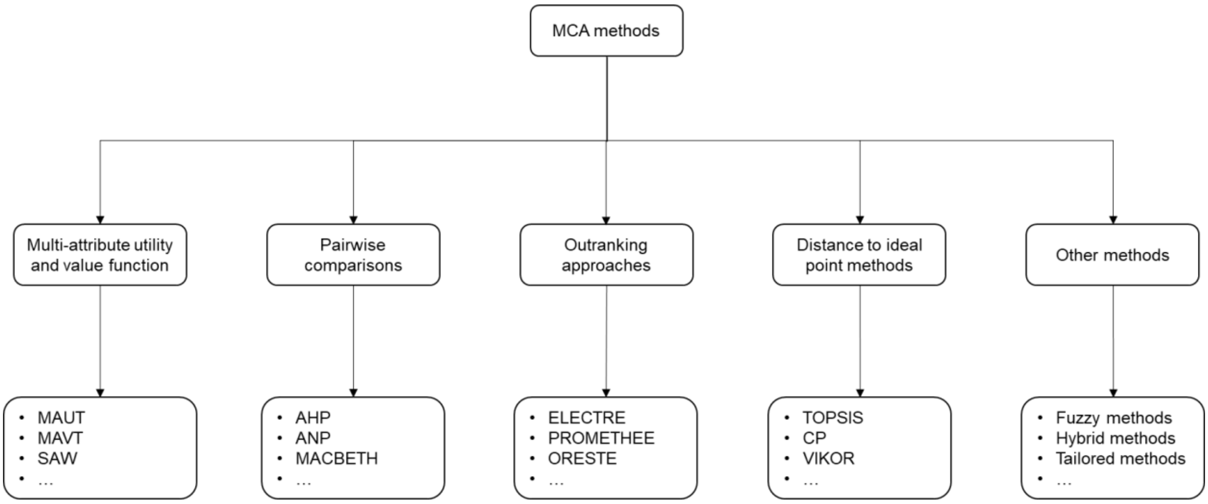

Figure 2. Classification scheme of MCA methods.

In the last decades, the number of MCA methods has been rapidly increased. Despite their numerosity, none of available methods can be considered as the best, applicable to all the problems of decision making, making it difficult for an expert to select the most relevant and appropriate one. The selection of an appropriate method depends on the specific type of problem and on the particular objectives of stakeholders. An initial consideration in the choice of MCA technique is the number of alternatives required to be evaluated, distinguished between infinitely variable outcomes (e.g., engineering problems) and finite number of options (e.g., policy decisions among alternative projects for investment). The former concerns continuous optimization problems where alternatives are infinite in number and predetermined (i.e., the decision space is continuous), whereas the latter evaluates a limited number of predefined alternatives with respect to weighted attributes (i.e., the decision space is discrete). Next key questions concern the kind of results needed (e.g., ranking problem, choice problem, categories-sorting), the type of data gathered by the stakeholders (i.e., quantitative and/or qualitative elicitation), the way the results are shared (i.e., data aggregation and display), and the problem characteristics in terms of compensability, uncertainty, and interaction between the evaluation criteria. The effectiveness of an assessment based on multiple criteria strongly depends on the comprehensiveness in the estimation process of the criteria selected.

3 Literature review

As introduced in Barry et al. (2022), literature reviews are essential in scientific research as they form the basis for knowledge progression. They contribute to the advancement of knowledge by gathering, describing, analyzing, and synthesizing extensive amounts of information and data. Literature reviews are indispensable in all scientific fields and must adhere to accurate and transparent methodologies. Various types of literature reviews have been established, each serving a specific purpose and employing distinct methods (Grant and Booth, 2009). Among them, the WP2 conducted a Scoping review that provides a preliminary assessment of the potential size and scope of available research literature. It aims to identify the nature and extent of research evidence; they share several characteristics of the systematic review in attempting to be systematic, transparent, and replicable (Grant and Booth, 2009). To follow these characteristics, a four-steps research design has been developed and illustrated in the §3.1, the results of which in terms of statistics, strengths and critical issues are presented in the §3.2.

The aim of the review is to describe available knowledge on the main approaches implemented for the prioritization of reduction measures in natural risk management, among which the MCA tool appears particularly promising. To reach this aim, different Research Questions have been placed:

i. Which are the tools for prioritization of reduction measures adopted in natural risk management? What are the advantages and disadvantages of each? Is the MCA the most promising for the objectives of the WP? When is it most used? Does it work better for certain mitigation measures?

ii. Among the various MCA methodologies identified in the §2, which is best suited to natural risk management problems? Can specific tools be defined for each of the different natural risks considered?

iii. Can they be used in the different phases of the risk management chain? Likely, MCA should be applied also for the evaluation of strategies to be implemented in the short time, like emergency planning and management? still, few examples can be found in these directions (Ball et al., 2012).

iv. What are the different factors and elements on which they are based? For example: the spatial extent of the area of influence of the alternatives of intervention, expected temporal frame of effectiveness (Hudson and Botzen, 2019), …

v. How structural and nonstructural interventions come into play in the analysis?

vi. How is it guaranteed the identification and inclusion of all relevant stakeholders (Andersson-Sköld and Nyberg, 2016; Lindfors, 2021)?

vii. How the different dimensions that play a role in risk management are integrated? For example, technical, economic, cultural (psychological, social, ethical, and legal) and environmental ones.

viii. Has been MCA applied only for single hazard or even multi-hazard analyses? Regarding the application of MCA in multi-hazard settings, are there any objective difficulties?

ix. Which are the different methodologies to define the parameters (e.g., weights, utility functions) on which the MCA is based? Is there a superior method for eliciting them, independent of a problem's context? Some methods do not require Stakeholder interventions (for example they are based on machine learning techniques); others do involve them.

3.1 Input

The Scoping review has been implemented through the following steps:

1. Identify key research terms and construe search strings.
   To build our initial corpus of articles, the key-terms to be explored in the various databases, as Scopus and Web of Science, have been identified, as well as to investigate non-bibliometric sectors of knowledge. The key research terms have been divided into transversals and specifics. The formers are common to all researchers involved in the WP, such as: risk mitigation, natural hazard, environmental hazard. The latter characterize the expertise and the study topic of each research group, and refer to: type of natural hazard, mitigation strategies, specific features. In fact, it is important to underline that TS3 is composed of many cores which are essential to study the different dimensions revolving around the development of risk resilient communities against the natural risk, such as: technical, social, economic, behavioral, cultural, legal and agricultural. In WP2 each dimension is represented and studied by the different research groups.

   Each key research term analyzed is listed in the Table 2.

   Table 2. Characterization of the different specific key research terms adopted in the study

Natural Hazard	Geological: Earthquake, Volcanic, Landslide Hydrogeological: Flood, Drought Forest Fires Avalanche (Mountain Risk) Pollution
Mitigation Strategies	Structural Non-Structural: Emergency Planning, Territorial Governance, Reconstruction planning, Insurance
Special features	Behavioral and soft policy, Climate Change, Precipitation extreme, Social vulnerability, Resilience, Multi-risk assessments, Multi-Attribute Utility Theory, Allocation of weights to the hazards, Natural risk perception, Risk of life and properties, Uncertainty, Sensitivity analysis, Agricultural and Forest Ecosystem

   These terms were combined into search strings to look for in the database through: Title, Keywords and Abstract. For example, some string can be:

   - "risk mitigation" OR "natural hazards" OR "environmental hazards" AND "structural measure" AND "flood";
   - "adaptation measures" AND "agriculture" AND "climate change" AND "vulnerability" AND "water scarcity" OR "drought" AND "MCA";
   - "climate change" AND "agriculture" AND "adaptation strategies" AND "mca" OR "MCDA";
   - "Risk mitigation" OR "adaptation strategy" OR "adaptation planning" AND "environmental hazard" AND "natural hazard" AND “governance” AND "precipitation" AND "policy" AND "hazard"
   - "Risk mitigation" OR "adaptation strategy" OR "adaptation planning" AND "environmental hazard" AND "natural hazard" AND “governance” AND "drought" AND "policy" AND "hazard"

   From all the strings more than 3200 articles have been collected.

2. Title, Key-words and Abstract analysis.
   The second stage involved exclusions of non-relevant articles to further refine the results. In fact, each researcher reviewed Title and/or Abstract to select all the papers to be read in its entirety. The selection criterion is the coherence with the purposes of the WP2, in particular,

the papers had to deal with reduction measures applied to natural risk management and the application of the approaches for their prioritization. The papers concerning resilience, risk and vulnerability assessments (in the bibliometric and not-bibliometric sectors) have been excluded from this first phase of literature analysis, but they have been stored because they can still be useful for the next tasks.

From this selection 68 papers have remained.

3. Extract data for analysis
   In Step 3, four kinds of information were extracted from the papers identified in Step 2 and collected in a database (prepared in Excel) created for the synthesis and restitution of the scoping review.
   First, general and descriptive data on each article were compiled (authors, journal, year of publication and title). The date is particularly interesting for defining the trend and diffusion of different approaches for prioritization over time.
   Given that the typology of selected papers introduces the approaches for prioritization of reduction measures through cases study, the Second group of information concerns the cases study, with data on: the country of application, if the analysis concerns a single or a multi-hazards problem; the type of reduction strategy(ies) implemented and the phase(s) of the risk chain involved (Mitigation, Preparedness, Response, Recovery); the spatial scale of application of the approaches implemented for the prioritization of reduction measures, in the following reworks also called "evaluation approaches".
   The Third group concerns the evaluation approaches, through the following items: type of approach (CBA, MCA, etc.); indicators involved in the different fields (hazard, exposure, vulnerability, resilience, capacity, cost, impact); criteria adopted in the MCA analysis; type of approach(es) (qualitative, quantitative, both); peculiarities of the MCA approach recalling the §2 (weighting methodology, sensitivity analysis/uncertainty management, stakeholders and experts to be involved in the decision process); advantages and limitations of the approach.
   The Fourth are general notes, as the link with other WPs of the Spoke (e.g.WP4 Comunity-Based approaches, codesign, policies…) and if climate change is considered.
   This information is converted into an excel file consisting of 23 columns. This structure assists the analysis of the papers, allowing a better understanding especially of the reduction strategy employed, methodologies for evaluation approaches, and the variables for their application.

4. Review of the data and homogenization
   After an initial compilation of the database with the information introduced in the previous point, a revision of the text was carried out to make the descriptions homogeneous to enable both the establishment of statistics (introduced in the §3.2), outlining guidelines and approaches, and to make synthesis for the objectives of the subsequent tasks (presented in the §4).
   The revisions affected in more detail the database columns concerning:
   - The naming of hazards to follow a common cataloging;
   - The description of reduction measures through the introduction of three elements that help explaining how and on what risk components the measure works, as:
     1) The definition of the measure as structural or non-structural;
     2) The explanation of which risk component it works on, such as: measure on hazard, measure on exposure, or measure on vulnerability. In the case of measure on exposure we also specified on which element, e.g., single building, whole population, etc. Regarding measure on vulnerability, we also specified e.g. the feature on which it acts (e.g., building height, color, etc.);
     3) A briefly description of the type of measure.

- The description of the variables at the base of the analysis, classified as hazard, exposure and vulnerability variables, resilience and capability variables (with reference to interested communities), impact variables; as well as the analysis of methodologies for their evaluation;
- The scale of application for which the following "classes" have been proposed: Single/individual-item, for the single exposure element (buildings, infrastructures); Sub-municipality (e.g. neighborhood, specific area of the city, historical centre); Municipality; Multi-municipality (e.g., catchment, provincial, regional); National; Global;
- Type of approach: indicating both the criteria/attributes adopted in the analysis (classified according to their dimension; approaches used to define the indicators (e.g., qualitative for environmental damage, monetary for building damage, etc.) and the approach used to define the parameters, in the case of MCA (e.g., stakeholder participation, GIS algorithm, machine learning, etc.).

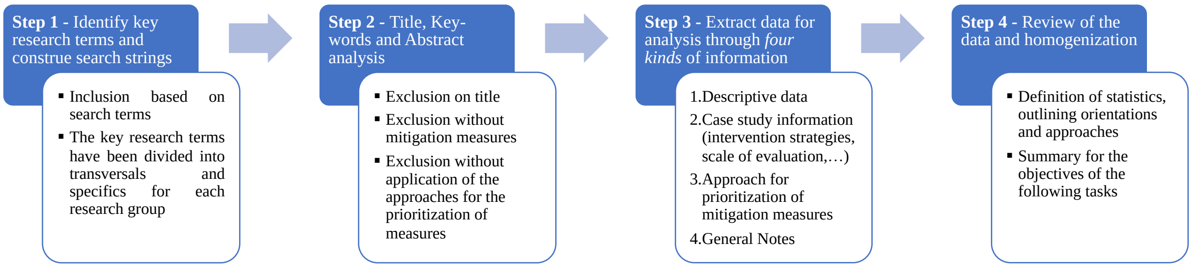

Figure 3. Four-steps process for the literature review: from the identification of the key research terms to the results

3.2 Results: description and analysis

The authors have analyzed the final list of the papers according to the different objectives list in the introduction §1 and the research questions of §3. So, in this context, this chapter presents the key findings from the literature review concerning:

- the different natural hazards considered and the presence of single or multi-hazard framework;
- the analysis of the intervention strategies employed for the mitigation of the different hazards;
- the tools for prioritization of reduction measures adopted in natural risk management and, also presented, in relation to the different phases of the risk management chain;
- the variables and criteria for the application of the different evaluation approaches.

These insights gained from the literature review are crucial in shaping the conceptual framework for the implementation of Task 2.2, as presented in §4.

First of all, the hazard field of the database was investigated, after a phase of name review and homogenization as introduced in step 4 of §3.1, from which it emerged that, as we expected, there is more research on single-hazard (75 %), than multi-hazard (24 %). In the individual hazard analysis, the 68% are hydro-meteorological hazards while 18% are geological hazards. The multiple hazards involved in the multi-hazard evaluations are listed in Table 3, the most numerous are the combinations of drought-flood and flood-earthquake.

Table 3. Hazards involved in the multi-hazards analyses described in the papers.

Coastal, pluvial, riverine flood
Drought, flood
Earthquake, flood, wind
Earthquake, flood, landslides

Earthquakes, cyclones, terrorism, flood
Flood, earthquakes
Flood, coastal flood, wildfire
Flood, landslide, coastline erosion, drought
Riverine, pluvial flood
Coastal flood, pollution
Drought, flood, pollution
Hurricane wind, earthquake, snow, flood
Coastal flood, tsunami, earthquake
Earthquake, landslide
Earthquake, landslide, tsunami, fire

The next key topic is the analysis of the intervention strategies according to the two criteria, represented in Figure 4: firstly if the measures adopted in the evaluation approaches are structural, non-structural or both; secondly on which element of the risk analysis the measures act. Figure 4 shows that most papers on single hazard propose evaluations in which structural and non-structural measures are proposed together, acting principally on hazard and vulnerability or on all three risk's elements together. While Figure 5 shows that most of the papers concerning multi-hazards problems are based on measures on vulnerability, and the types of measure are evenly distributed among the three choices. Among the non-structural measures we have different types of intervention covering different categories such as financial, social, behavioral, institutional, planning, law, regulation, etc.

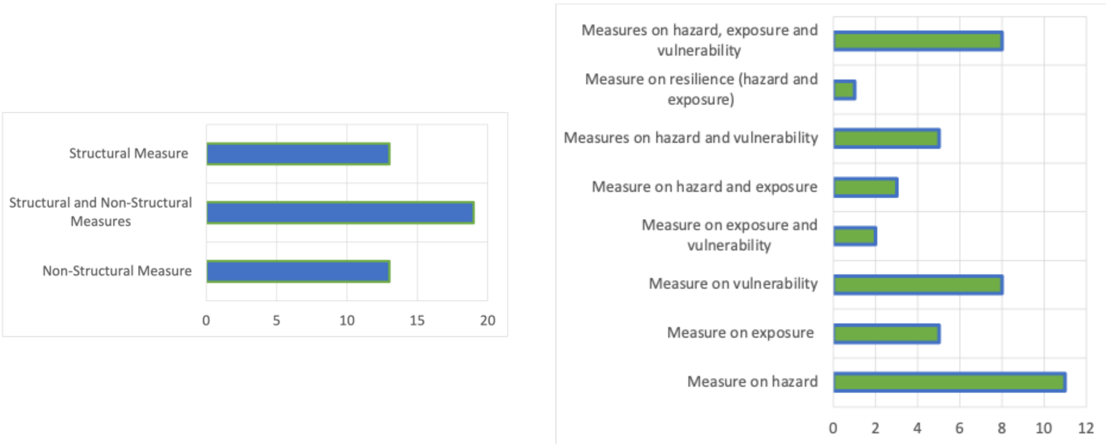

Figure 4. Distribution of the reduction strategies according to above-mentioned criteria for single hazard problems

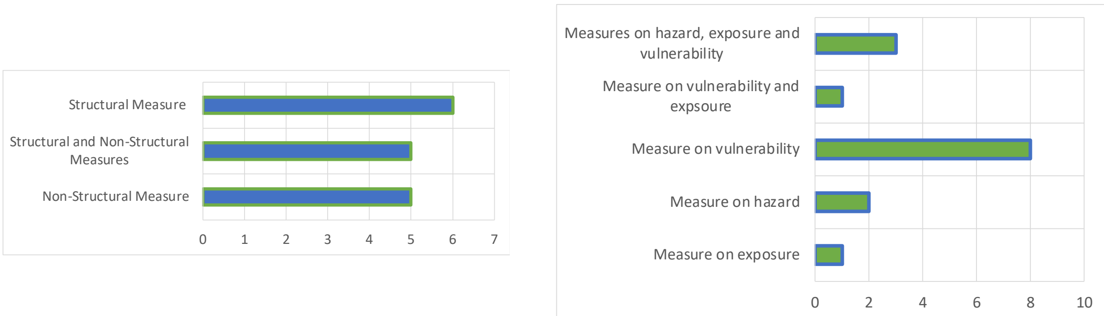

Figure 5. Distribution of the reduction strategies according to above-mentioned criteria for multi-hazards problems

The core of the research activity is the definition of the approaches for the prioritization of reduction measures. In Figure 6 there is a distribution of the approaches found in the literature that highlights how the most common approaches are CBA and MCA, while Figure 7 represents their application in time, demonstrating their continuous increase. The earliest publications were written in 1997, and publications started to increase rapidly in 2000. In this context, it is interesting to observed that the multi-hazards analysis has only received attention starting from 2010, more than ten years after the first articles analyzed.

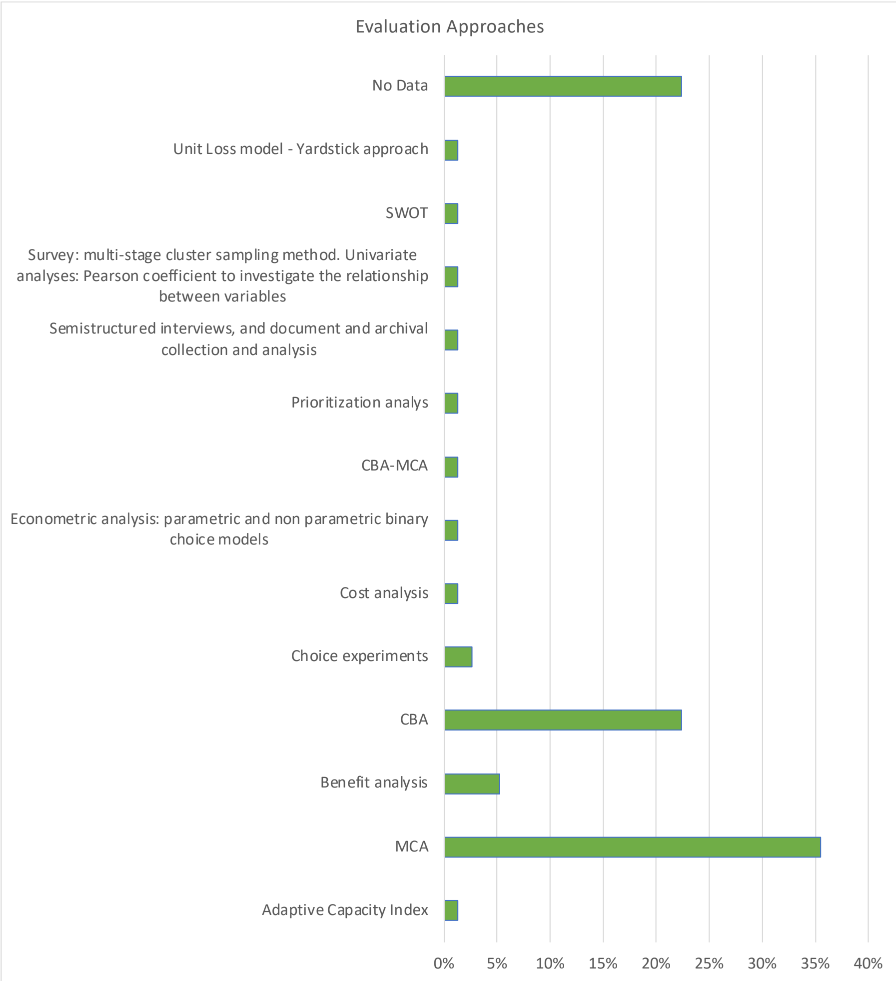

Figure 6. Distribution of the approaches for prioritization of reduction measures proposed in the papers.

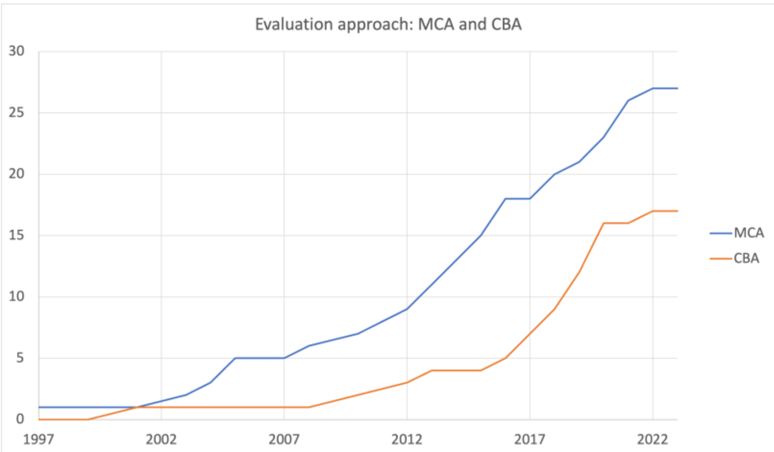

Figure 7. Trends over time of the papers with CBA and MCA.

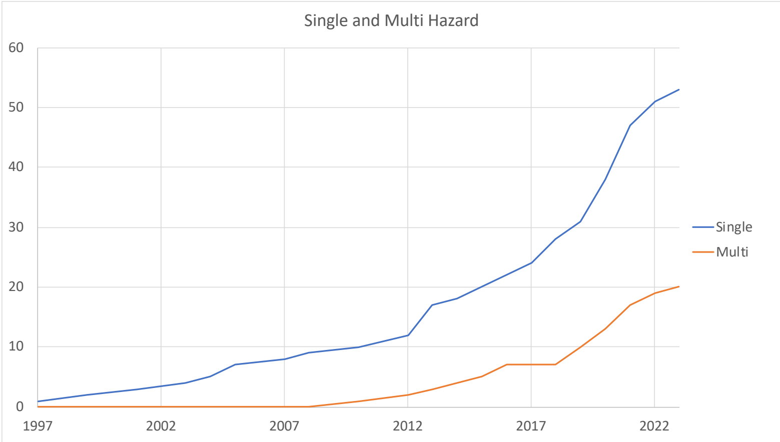

Figure 8. Trends over time of the papers with single and multi-hazards analysis.

Analyzing the different phases of DRR means considering the strategies that are aimed at reducing and managing disaster risks. As we might have expected, the strategies that have received most attention in this perspective are related to the prevention phase, followed by preparedness and the union of the two, together with response. In general, structural measures are mostly the measures that are positioned in the first phase, while non-structural ones can be found in a wide range of areas of the disaster management cycle, including prevention, preparedness, response, and recovery[2]. This issue is confirmed by our database, since in the prevention phase there are 17 structural, 4 non-structural and 6 mixed strategies, while in the preparedness step only non-structural interventions are present. In general[2], non-structural measures in the prevention phase include "building a cooperative and coordinated system," "raising awareness of disaster preparedness," "citizen participation" and "stable financial support". This selection is supported by our evaluation. The non-structural measures in the prevention category are more long-term than the non-structural measures in the preparedness category.

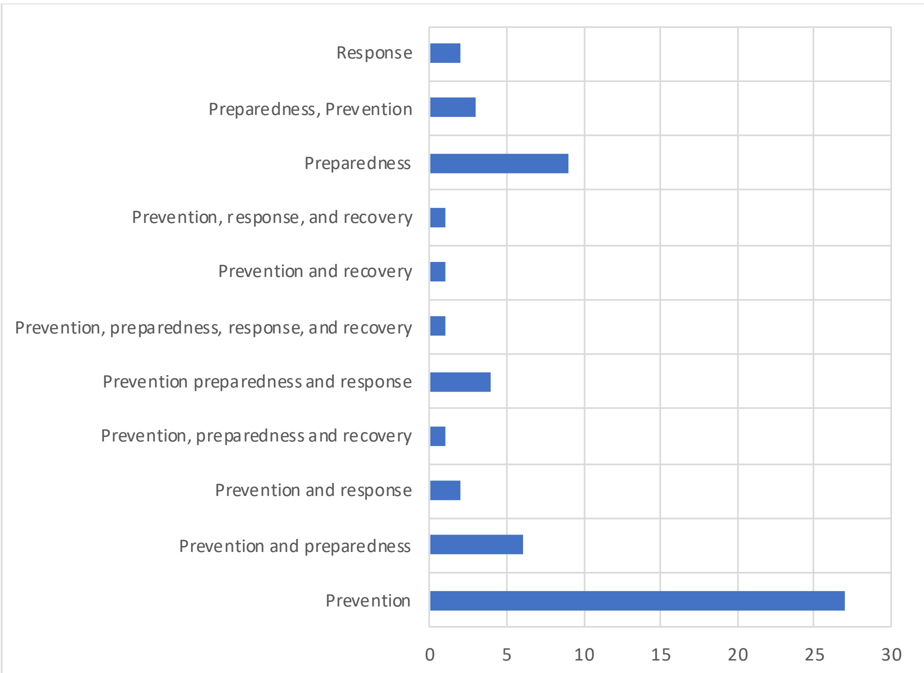

Figure 9. Distribution of the phases of DRR according to the risk reduction strategies proposed in the papers.

Going into more detail about defining the variables for applying the evaluation approaches, from the cases studies analyzed in the database, the spatial scale of application of the analysis ranges from

[2] https://disaster-management.piarc.org/en/mitigation/non-structural-measures

single/individual-items to the global level, as illustrated in Figure 10. The majority of studies carried out analysis in the multi-municipality scale, since there are a lot of flood risk assessment performed at the river basin. The other choices have a comparable trend. Data show that scale of analysis is strongly correlated to the definition of exposed assets and vice-versa (for when exposure is defined at the level of single items, risk analysis must be conducted at the micro-scale). The geographical localization of the case studies is very varied, from Europe (French, Italy, UK, Spain, Serbia, …) to Asia (Thailand, Afghanistan, Bangladesh, Iran, ...) and Oceania (Australia). In terms of geographical context, the evaluations are conducted in historical centres, rural and urban areas, followed by coastal, island, and mountain regions.

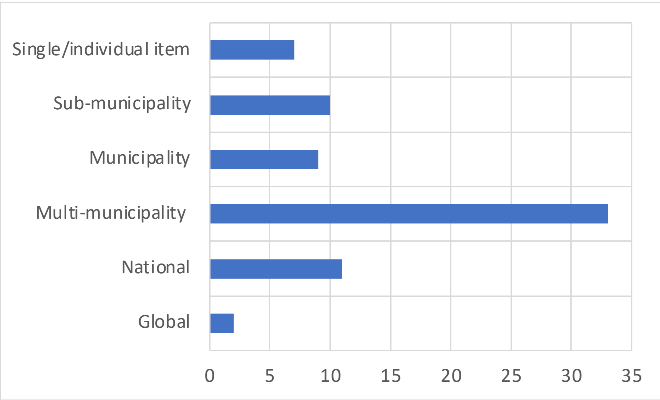

Figure 10. Distribution of the scale of application

As described in the §2.1, once defined the intervention strategies, the hazard of reference and the scale of application, the real components of the MCA should be introduced. They are:

- indicators and types of approach adopted to evaluate them, if qualitative and/or quantitative;
- criteria for both CBA and MCA, while only for MCA criteria weights and the weight assignment method;
- the role of stakeholders;
- uncertainty and sensitivity analysis.

For what concern the indicators, they are grouped according to the different components of the risk, as follows: hazard, exposure, vulnerability, impacts, costs, capacity and resilience. The most adopted are based on the first four categories as in Figure 11, as we might also expect because resilience and capacity are newer concepts in natural risk analysis. In most of the papers, they are evaluated according to a quantitative approach, followed by a combination of quantitative and qualitative methods (Figure 12).

Graphs in Figure 13 are very interesting since they represent the multidisciplinarity of the MCA compared with the CBA. This image illustrates the criteria dimensions investigated with the two approaches for prioritization of mitigation measures, analyzed with literature review. In the CBA, the economic and technical dimensions are predominant, while MCA is able to capture criteria representing the different dimensions (technical, economic, social and environmental) equally.

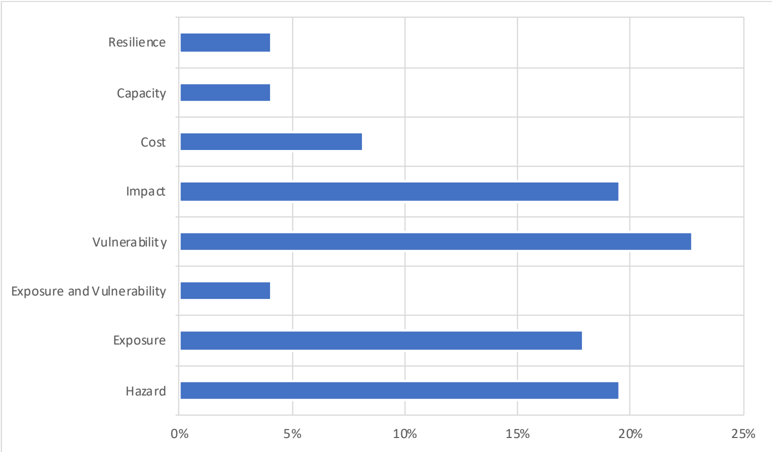

Figure 11. Distribution of the categories of indicators.

Table 4. Hazard indicators extracted from the papers.

HAZARD
- Daily precipitation, evapotranspiration, daily discharge
- Flood hazard scenarios, flood frequency analysis, flooded urban areas obtained by applying a hydraulic model
- Spatial distribution of flood depth, food duration, flood frequency, extent of the flooded area, flood velocity
- Hazard and threat probabilities
- Hydraulic model settings (including topography, terrain roughness, peak flows, hydraulic boundary conditions)
- Rainstorm, dam break, tsunami, typhoon
- Spatial distribution of PGA or spectral acceleration, frequency
- Rainstorm water-logging
- Topography, hydrometeorology, and hydraulics of the river
- Water depth, extent, duration of event, velocity of incoming water, runoff, combined sewer overflow restricted discharge to coastal waters
- Frequency of occurrence and associated return period for current codified design

Table 5. Exposure indicators extracted from the papers.

EXPSOURE	
Micro-scale	- Contribution to farmers'income - School buildings - Reconstruction/replacement cost (i.e., unit construction cost per building area), building type, building usage, number of buildings, surface area of the building, buildings height, value of buildings per square meter, footprint area classified by wall materials) - Proportion of building typologies, proportion of building height (i.e., number of stories) - Number of habitations
Meso-scale	- Overall contribution to rural development, contribution to environmental protection - Agricultural and residential areas - Land-Use/Land Cover (LULC), land-use classes, economic values - Elevation data - Length of coast, floodplain area, floodplain population, floodplain assets, GDP - Population living in the flood-prone areas at residential building level - Equipment including public administrations, schools, etc., companies and farms, networks including roads, railways, telephone, electricity, etc., number of people living in the flood zones - Population density, residential property, industrial production, agriculture, forestry, animal husbandry and fishing production - Population

	- Built-up area classified in three different land-use classes (commercial, industrial, residential) - GDP - Critical Infrastructures (CIs) including sewer pumping stations, sewer network area, electricity substation, electricity network area, rail station, rail line, telecom exchanges/boxes, telecom network area, roads

Table 6. Exposure and vulnerability indicators extracted from the papers.

EXPOSURE and VULNERABILITY
- Expected damage, repairability and CH value loss - Social and environmental, non-monetary terms - Ecosystem services, in monetary terms - Building features and value (combining several sources of open socio-economic data)

Table 7. Impact indicators extracted from the papers.

VULNERABILITY
- Evaluation of the total damage - Technical effectiveness in reducing vulnerability to climate change, containment of conflicts over water resources - Flood damage functions, relationship between flood intensity parameter and land-use susceptibility - Ultra-detailed magnitude-damage functions, developed for a single-house scale - Fragility curves - Incomes, agricultural yields - Damages to the building (structures, installation, fixtures) and to the content of the building through the Content to Structure Value Ratio (CSVR) - Damage percentage at the maximum flood depth and at the maximum flood duration - Socio-economic statistics - Residential and industrial damages; damages to vehicles; potential economic losses for each interrupted communication routes; costs related to cleaning and emergency services - Typology of habitations classified according to their prestige and the presence of basements and/or floors - Vegetation coverage, drainage density, terrain elevation, proportion of easily flooded farmland - Depth-damage relationship, interdependencies among CIs, infiltration rates; - Structural reliability-based methods - Vulnerability of the crop pattern - Physical features, lack of maintenance and monitoring of historical buildings and architectural heritage, urban features, such as the concentration of strategic/critical functions, the presence of narrow roads and the lack of open spaces, narrow roads are critical because they can be easily blocked and hinder the evacuation of people, social issues related to the lack of risk preparedness in resident population and capacity-building activities with key stakeholders. - Structural, hydraulic, geotechnical and functional characteristics of each road element (embankments, viaducts, etc.). - Structure, materials, immovable elements, and movable elements. For each component of susceptibility, a set of indicators has been developed - Vulnerability Indices on the basis of detailed survey that collected data on the main structural features of the buildings using a survey form.

Table 8. Impact indicators extracted from the papers.

IMPACT
- Environments (resources and emissions) - Human and civic resources (agricultural employment, adult literacy rate) - Agricultural innovation (irrigated area, irrigation technology, fertilizer consumption) - The level of well-being of a community - Losses as percentage of potential damages, the casualties and population at risk, Expected Annual Damages (EAD) - Expected Annual Damages Distribution Maps (EADDMs) - Structural performances

- Flood damage - AAL total annual expected losses and AAL as a ratio of the total exposure. - The damage not mitigated by the intervention: REsidual Annual Damage (READ) = Expected Annual Damages (EAD) - Prevented Annual Damage (PAD); - A simplified annual determination in monetary terms, the social benefits of the intervention were defined by the population affected in a 100-year return period flood - Damage incurred as a percent of its total worth (i.e., structure and contents) - Physical and indirect damages - Destruction of animal or vegetation species that are either rare, with patrimonial character, or common, restoration of natural surroundings - Mean absolute financial losses (i.e., repair and reconstruction costs) or mean loss ratio (i.e., expressed as a proportion of associated replacement values). - Tangible flood damages to residential and non-residential buildings and flood-borne disease outbreaks, including leptospirosis and diarrhea, expressed as number of infected people per flood area - Environmental benefits - Risk of discharge obstruction due to sedimentation - Expected Annual Number of Affected Persons (EANAP) - Dynamic generation of emergency schemes

Table 9. Cost indicators extracted from the papers.

COST
- Cost-benefit effectiveness for society, practical feasibility - Cost of protection, mitigation, response, or recovery option, discount rate - Investment cost, maintenance cost, discount rate - Net Present Value (NPV)

Table 10. Capacity indicators extracted from the papers.

CAPACITY
- Environmental capacity (agricultural water use, area salinized by irrigation) - Economic capacity (GDP, agricultural value added/GDP) - Flood control standard, accuracy of flood dispatching, early warning mechanism, disaster relief agencies - Flood awareness time (e.g., 1hr, 2hr, 4hr, 8hr case), maximum river flow (discharge), CN value for agroforestry - Level of responsibility (farm/stakeholder, local government), category (Agronomic, management), multifunctionality (effective only on farm or multifunctional and relevant to broader public)

Table 11. Resilience indicators extracted from the papers.

RESILIENCE
- Magnitude of damage that will not alter the main functions under equilibrium conditions of the human and physical systems - Pre-flood resilience: resistance capacity, during-flood resilience: coping capacity, Post-flood resilience: recovery and adaptation capacity - Recovery capacity according to physical, economic, and social factors - Resilience Features risks and threats aspects (risk assessment and vulnerability functions) and socio-economical strategies - Time reliability, resilience and sustainability of the water-supply system

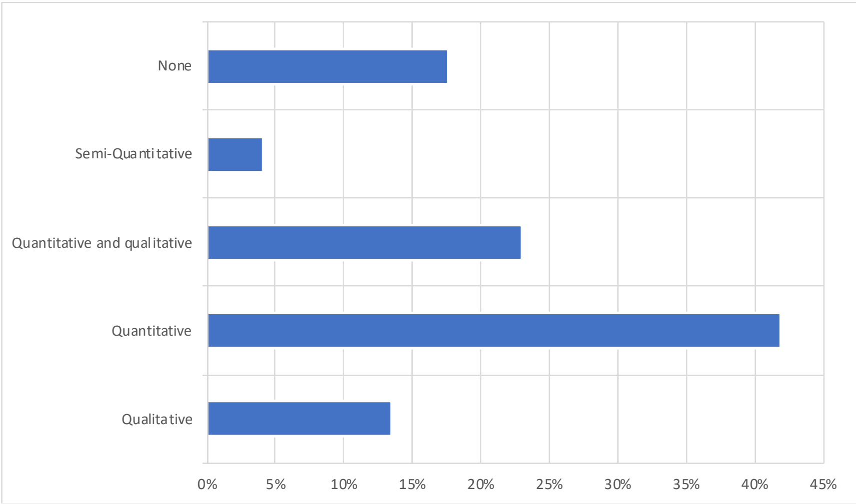

Figure 12. Distribution of the approaches adopted for criteria and indicators.

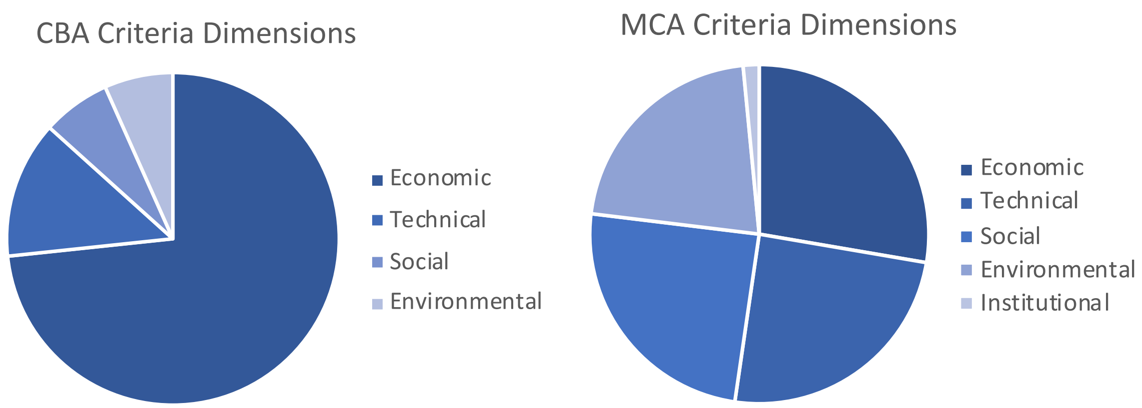

Figure 13. Distribution of the criteria dimensions for CBA and MCA

From the database the different MCA techniques have also been extrapolated (Figure 14) in order to know the most commons, that are: the Multi-Attribute Utility Theory (MAUT) and the Analytical Hierarchy Process (AHP), which fall respectively in the “Multi-attribute utility and value functions” and “Pairwise comparisons” groups, as introduced in the §2.1. From the graph, however, there is great variability in the different approaches taken in natural risk management.

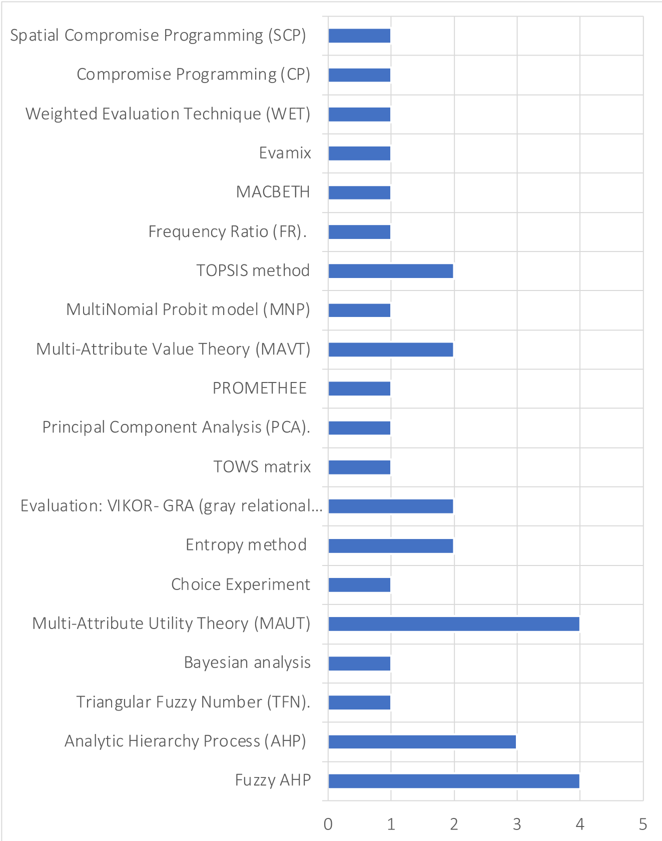

Figure 14. Distribution of the MCA techniques in the paper analyzed

In the paper investigated, the stakeholders have been involved in the 45% of the cases study. The decision-makers included in the papers can be described by the following categories: strategic and operational institutional planners; operational staff within care; group of vulnerable citizens; GO's and NGO's; officials from various institutions related to forest, environment, planning, technical, land, railways, and public works department; emergency managers; local communities; universities; scientists; insurance world; local and regional public authorities, … The stakeholders have been involved through the following ways: face-to-face interviews using a questionnaire, focus group interviews, informal interviews, participatory approaches, consultations, general questionnaire, workshops involving round table discussions and group meetings.

For what concern uncertainty and sensitivity analysis, despite its importance, given the subjectivity of defining weights and MCA approaches, it is present in only 19% of articles. It may be necessary to define operational procedures within which to include it and make known its necessity in the procedure of MCA.

The last information extracted from the article and with which the database was compiled is the presence of climate change considerations, recognized as an important factor that influences the sustainability of all regions all over the world. It is counted in the 14% of the cases study. In particular, it is present mostly in the hazard analysis, contextually with changes in exposure, above all in the reference population and agriculture pattern.

4 Towards Tasks 2.2

The literature review conducted in task 2.1 represents the basis to shape the specific objectives and the working phases of the following tasks of the WP, aimed at defining guidelines on how to frame a multicriteria assessment of alternatives of intervention to reduce risk, in a multi-hazard context. In fact, the literature review (Chitsaz and Banihabib, 2015; Curt et al., 2022) confirmed the idea that we had in the writing phase of the project that MCA is the most suitable and promising tool to support decision making in natural risk management; it allows considering all relevant aspects of risk management problems as the inclusion of both structural and non-structural measures, working in the different phases of the risk chain, as well as their tangible and intangible effects, also in a multi-hazard context. Nevertheless, its application is still limited in practice, in our opinion, for two main reasons that are strictly interconnected to each other: the lack of standards/guidelines and the lack of benchmark studies.

Beyond the analysis and the synthesis of available knowledge as presented in the §3.2, one of the main results of task 2.1 is the framing of a flowchart representing the process leading to the selection of alternatives by means of MCA, as depicted in Figure 15.

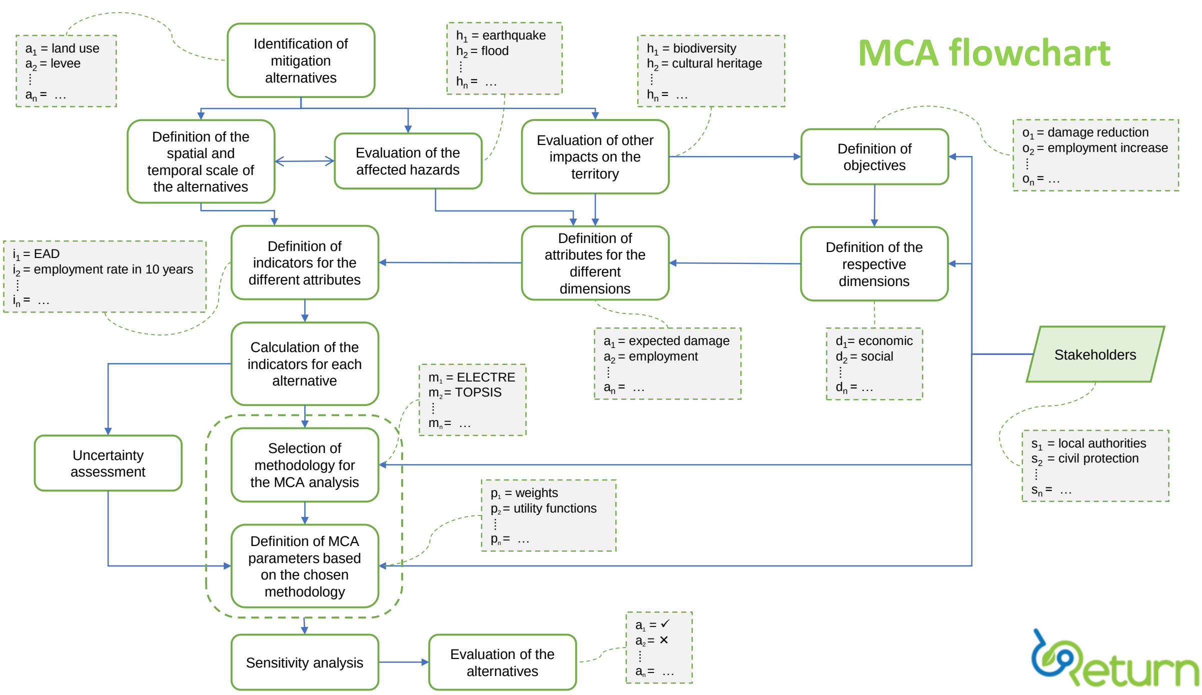

Figure 15. MCA flowchart

The flowchart not only allowed us to specify the objectives and working phases of task 2.2 and 2.3 but also to overcome the encountered problem of a missing shared terminology among MCA users, that typically come from different field of expertise or MCA "schools". In fact, by creating the flowchart we adopted our own definition of terms like criteria, dimensions, attributes, and indicators (see below).

The first step of the process is the identification of the risk reduction alternatives, for the context under investigation. The literature review highlighted that such alternatives could refer to both structural and non-structural measures and could work on different hazards/risks and/or on its components (hazard, exposure, vulnerability), in the different phases of the risk chain, presenting this way a high level of heterogeneity that increases the complexity of the decision-making problem.
In fact, two scenarios can occur. The one in which the various alternatives have been already identified by decision makers/stakeholders, and the one in which alternatives must be identified during the process. In this WP the first scenario will be analyzed, as the most common one occurring in natural risk management problems and the simplest to frame, considering the lack of standardized tools.

Each alternative is then characterized in terms of: (i) temporal and spatial scale of effectiveness, (ii) potential risk reduction, and (iii) other impacts on the interested communities (e.g., on environmental quality, labor market, cultural identity). In a multi-hazard context, evaluating whether a measure that has been designed to reduce a particular risk may have effects also on other risks is particularly important, especially when an increase is possible. The whole evaluation can then benefit from the existence of an abacus of alternatives that will be produced as one of the results of task 2.2. The abacus will first identify which are the most common and promising measures that can be implemented in the different phases of the risk chain (prevention, preparedness, response, recovery), and then will characterize each measure in terms of potential risk reduction or increase (with respect to different hazards), and temporal and spatial scale of effectiveness. The evaluation of secondary impacts (beyond risk reduction) is instead more context/problem-dependent and cannot occur without a proper definition of “interested communities” that will be a further objective of task 2.2.

The characterization of the alternatives, as well as the recognition of stakeholders’ needs and expectations, are at the base of the following step that is the definition of objectives (also called “criteria” in MCA problems). In fact, depending on the context under investigation, it is likely that other objectives exist beyond risk reduction, like improving environmental quality, increasing cultural identity, promoting sustainable development, equally distributing available funds, supporting the labor market, etc.

Each objective must be then classified according to a problem dimension (e.g., technical, economic, legal, cultural). This phase is crucial for the following definition of attributes and indicators, according to which alternatives are evaluated. The difference between attributes and indicators regards the specificity of the variable with respect to the analyzed context/problem. For instance, an attribute could be defined as the damage reduction linked to the implementation of the measures while the corresponding indicator can be the expected annual (monetary) damage calculated at the microscale level.

Attributes and corresponding indicators must enable modelers and decision makers to evaluate the capability of the different alternatives of meeting the problem’s objective. Especially, the definition of attributes must consider the impacts of the alternative measures, in terms of both risk reduction (or increase) and secondary effects. Such an analysis can benefit from an in-depth, generalized investigation of the types of elements that are exposed to different natural hazards, as well as of the potential direct and indirect damage to them in case of an event, that will be performed in task 2.2. On the other hand, the identification of indicators is strongly related to the spatial and temporal scales of the analysis, as the same attribute can be differently evaluated at different scales. The full characterization of indicators in terms of meaning, metric and evaluation approach will be the final objective of task 2.2. With respect to this, the literature review highlighted present challenges in considering climate change drivers and effects, as well as the dynamic nature of exposure and vulnerability that cannot be taken as constant when measures are expected to work on long time frame. Specific strategies must be then proposed in this regard in task 2.2.

Once the value of each indicator has been evaluated (for all the alternatives of intervention), it is possible to identify which MCA tool is more appropriate for the problem under investigation and to define the related parameters (e.g., utility functions, weights). Stakeholders’ involvement is crucial in these phases as well as the properly consideration of the uncertainty characterizing the different indicators. The identification of stakeholders for different community types and reduction measures will be one of the objectives of task 2.3, along with the identification of the most effective tools for their involvement. At last, the various alternatives are evaluated and ranked, according to the defined methodology. In doing this, particular attention must be given to how to consider the uncertainty characterizing the whole decision-making process to increase decisions’ robustness. Uncertainty can arise from both the choice of the MCA tool and the definition of parameters. A sensitivity analysis must be then conducted to analyze how the adopted modelling choices influence the evaluation of the alternatives. The literature review highlighted the need of further knowledge advancements with respect to this. Guidelines on how to conduct the sensitivity analysis will be the final objective of task 2.3.

According to the analysis carried out in task 2.1, the main working phase of task 2.2 will be then devoted to: (i) the definition of communities of interest; (ii) the development of the abacus of risk reduction strategies; (ii) the full investigation of hazards and related impact (including their dimension); the full characterization of indicators.

At the same time, the literature highlighted the importance of tuning the MCA approaches to real application; task 2.4 will start in parallel to task 2.2 with the identification of pilot case.

5 Conclusion remarks

This report has presented the results of a Scoping Literature Review from Scopus and Web of Science on the current research trends and progress related to the State of the art on MCA applied to natural risk management, contextualized in the broader framework of the Return Project Spoke TS3 – Communities' resilience to risks: social, economic, legal and cultural dimensions and WP2 - Innovative tools to evaluate risk mitigation effectiveness, that is aimed to define national guidelines and tools for the evaluation of the effectiveness of alternatives of intervention in natural risks management, by considering in detail Multi Criteria Analysis (MCA) tools.

The literature review was guided by different Research Questions, the most important being "Which are the tools for the prioritization of reduction measures adopted in natural risk management? What are the advantages and disadvantages of each? Is the MCA the most promising for the objectives of the WP? When is it most used? Does it work better for certain mitigation measures?"

To answer these questions and achieve the objectives of the task, a four-steps research design has been developed, which allowed to conduct a consistent literature review among different research fields. From step 1, multiple keyword strings were defined to capture 3200 papers focused on risk reduction measures, the approaches for their prioritization, natural or environmental hazards (for example flood drought, earthquake, etc.), considering single and multi-risk approaches. Step 2 has excluded non-relevant articles for the research questions and the aims of the WP, by reading titles and/or abstracts that resulted from the search, selecting only 68 relevant papers. In step 3 articles, whose abstracts were chosen due to their alignment with the research objectives, underwent a thorough and rigorous reading and examination. From this phase, information was extracted from the papers and collected in a database consisting of 23 columns created for the restitution of the scoping review, allowing a better understanding especially of the reduction strategy employed, methodologies for evaluation approaches, and the variables for their application. After an initial compilation of the database, a revision of the text was carried out in step 4 to make the descriptions homogeneous to enable both the establishment of statistics, outlining guidelines and approaches, and to make synthesis for the objectives of the subsequent tasks.

Analyzing the database, we discovered that some of the earliest publications were written in 1997, and publications started to increase rapidly in 2000. Most of the current research is still focused on individual hazards analyses, and those related to multi-hazards have only received attention starting from 2010, ten years after the first articles analyzed. It is found there are more publications on prevention, followed by preparedness and the union of the two, together with response for what concern the DRR phases. For what concerns the intervention strategies, the most papers on single hazard propose evaluations in which structural and nonstructural measures are proposed together, acting principally on hazard and vulnerability or on all three risk's elements together; while the most papers concern multi-hazards problems are based on measures on vulnerability, and the types of measure are evenly distributed among structural and non-structural ones. It has been seen that the majority of research focus on CBA and MCA procedures, among the approaches for prioritization of mitigation measures. From the paper investigated, the multi-disciplinarity of the MCA clearly emerges, allowing to consider the technical, economic, social and environmental dimensions of the decision-making problem in a rigorous procedure, compared with the CBA that is based on solely economic parameters. Furthermore, the procedure of MCA includes stakeholders in a prominent role, an aspect often ignored in quantitative risk assessments. In particular, they are involved in the 45% of the cases studies of the papers investigated.

The multi-disciplinarity and the active involvement of stakeholders are the best features of the MCA that make it the most suitable tool for build resilient communities to minimize the impact of natural hazards. At the same time, the state-of-the-art highlights that uncertainty and sensitivity analysis are present in only 19% of articles, stressing the need to strengthen these elements in the future of the project and the research activities. In fact, they are crucial for the reliability of results, given the subjectivity implied in MCA (e.g., for the definition of weights).

As expressed in the §4, the literature review represents the basis to shape the specific objectives and the ingredients of the following tasks of the WP, aimed at defining guidelines on how to frame a multicriteria assessment of alternatives of intervention to reduce risk, in a multi-hazard context.

6 Links

Full database Task1.2_StateofArt.xlsx

RETURN glossary RETURN_Glossary.xlsx

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