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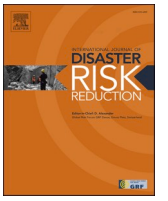

A participatory foresight approach in disaster risk management: The multi-risk storylines

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1. Introduction

Improving our current understanding of risk arising from extreme events is already a main pillar of the 2015 UNDRR SENDAI framework [1] and is now increasingly compounded by the need of Disaster Risk Management (DRM) to anticipate how natural hazards are being exacerbated by climate change. Disaster Risk Reduction (DRR) and Climate Change Adaptation are in fact converging towards a harmonized and comprehensive framework where the extreme events, once regarded as rare occurrences of largely stationary natural processes, are now acknowledged as increasingly intense and frequent because of global warming.

These needs apply, in particular, to urban management and decision making for city governments, as climate change is associated with a growing variety of impacts on cities, the surrounding ecosystems, and livelihood of population. The IPCC's 6th assessment report highlights that in urban areas the risk to people and assets due to climate-related hazard has already worsened, following the increase of intensity and frequency of extreme weather events [2,3] as well as on the interplay with a number of non-climatic risk drivers including extent and features of the exposed systems and assets (e.g., [4], 177) and their vulnerability (e.g., [5,6]).

Within this framework, one of the areas where innovation is most needed is in multi-risk management. This task requires a novel approach to risk management that aims to identify causal and temporal relationships between multiple hazards and to integrate the physical dimension of vulnerability with the socio-economic and environmental dimensions [7]. Achieving these goals requires the involvement of different social actors - such as researchers of different disciplines, local public administrators, and civil society structures - in a cooperative knowledge production process.

Scenario techniques [8] are a stimulating platform for integrating the cognitive diversity [9] of different stakeholders and fostering new knowledge generation between otherwise isolated or poorly communicated expertise [10]. Dozens of techniques have been developed in futures and foresight studies [11], and some of these, such as Delphi [12] and scenario planning [13], have been applied in DRM [14] to derive probable and plausible impacts of natural hazards in conjunction with the best way to respond. Scenario planning and participatory approaches have been extensively used also in urban planning and share many characteristics of DRM-oriented scenario approaches (e.g., [15]). In the latter family of techniques, storylines have been developed to realistically

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reconstruct plausible sequences of impacts of multi-hazard events and potential stakeholder responses to traumatic events [16]. Despite the growing use of this tool in DRM, there is no common definition of the basic design of a storyline or consideration of the role of stakeholders in its development.

This article describes an exploratory case study employing a participatory tool to organize and bridge cognitive distances between stakeholders by developing multi-risk storylines that illustrate the potential impacts, and the dynamics generated in a local context by a natural disaster. In particular, the case considered is that of a strong heat wave followed by intense rainfall in two different Italian territorial contexts (a peri-urban and a metropolitan area). We believe that the complexity of the experience could provide valuable insights into the ongoing debate on the use of storytelling and in defining a common methodology with which to implement storylines in various areas of DRM.

The multi-risk storyline framework presented in this article was developed as part of the Extended Partnership (EP) RETURN initiative, which focused on multi-risk science for resilient communities in a changing climate. The project, which is funded by the Italian NPRR (National Plan of Recovery and Resilience), addresses environmental, natural, and anthropogenic risks and their interaction with climate change. The objective of RETURN is to reinforce national research networks and enhance participatory approaches to DRM through improved knowledge transfer and technological application. One of the RETURN project's core objectives is to assess multi-risk and develop resilient communities, with a specific focus on urban and metropolitan contexts.

Section II provides an overview of the literature on risk storyline experimentation and the involvement of diverse actors in their creation. Section III outlines the proposed methodological design for the multi-risk storylines and the stakeholder involvement process. Section IV presents the results of the application in the RETURN project. Section V discusses these results, focusing on strengths and tensions that emerged in stakeholder interactions. Finally, the conclusions offer suggestions for future research directions.

2. Risk storylines and stakeholder's engagement: a brief state of the art

Scenario techniques have been developed to hypothesize plausible futures for complex, emergent phenomena characterized by high uncertainty [17]. One prominent example is the Delphi method, which originated in the U.S. defence sector during the Cold War to anticipate potential dynamics of a nuclear attack by the Soviet Union [18]. Another example is the Shell scenario approach, developed in the early 1970s to enhance oil company managers' anticipatory capabilities during a period of frequent geopolitical shocks to raw material prices [19].

Since the 1970s, scenario use has been prevalent in Disaster Risk Management (DRM) [20]. Within DRM, a distinction has been made between scenarios that assess emerging trends critical for a long-term sustainable development outlook and those focusing on catastrophic events (e.g., [13]), such as earthquakes [21]. The accelerating challenges posed by climate change further underscored the urgency of using such techniques. Slow-onset phenomena, such as ocean acidification, exemplify "slow burn" events [22], where catastrophic long-term effects are speculative yet potentially profound, necessitating scenarios that capture the immediate scale of ongoing transformations. Additionally, the increasing frequency and intensity of extreme events, such as heatwaves and severe storms [23], calls for updated tools for risk governance. These challenges are further complicated by the inherent uncertainties of current analytical models [24], intensifying the need for effective risk management communication and the promotion of knowledge-sharing practices among scientists, policymakers, and civil society.

More recently, the concept of 'storylines' has gained prominence in climate-focused research to address similar needs [16]. Unlike global climate models based on general circulation models (GCMs), which often lack the granularity to address localised impacts of climate change [25], storylines are designed to capture regional and local manifestations. Similarly, traditional risk scenarios tend to overlook indirect impacts that extend beyond the immediate area and often fail to consider sequential interactions with critical infrastructure, which are central to the structure of storylines [24].

While risk storylines share these characteristics with DRM-oriented scenarios, they also have distinct attributes. First, storylines adopt a narrative framework that prioritises risk understanding and mitigation over immediate emergency response. Secondly, storylines are contextually adaptive, focusing on two primary factors: the local environment (e.g., large city, regional area) and the characteristics of hazards (e.g., multi-hazard scenarios, intensity, duration). This approach contrasts with traditional scenarios, which may rely on a variety of specific drivers, such as temperature increase and policy measures in climate change contexts. Lastly, risk storylines are not restricted to future timelines; they may also explore present or historical contexts or a combination of these. For example, this article utilizes storylines to envision alternative responses to past events [26].

The development of storylines does not follow a specific design; various approaches are employed. The most common steps, though rarely present in a single application, include: i) identifying the event context and characteristics; ii) reconstructing the sequences of impact at both physical-environmental and socio-economic levels; iii) outlining plausible responses. These steps integrate quantitative and qualitative data collection techniques, such as data and trend analysis, interviews, and workshops [27].

A consistent feature in the development of storylines is the active involvement of stakeholders with responsibilities or interests in risk management. Storylines are collaboratively created by researchers from various fields and institutional actors, including civil protection agencies, ministries, regional or local administrations, and socio-economic actors such as trade associations, insurance companies, and critical infrastructure operators. The engagement method varies. Often, stakeholders provide information that researchers can use to independently create storylines [24,27]. In some cases, researchers facilitate the process while stakeholders construct the storylines, detailing impact chains and appropriate responses [16].

While the literature describes stakeholder involvement in storyline development, it rarely critically examines it. Extending the analysis to similar practices, such as constructing causal risk maps [7] or econometric models of catastrophic events' indirect effects [28], reveals several fundamental themes that will also be explored in this study. Firstly, the criteria for identifying and evaluating

stakeholders are crucial. There is a need to go beyond traditional variables of "power and influence" [29] and incorporate factors more relevant to DRM, such as prior experience with events and expertise in applicable knowledge production [30]. Secondly, the interaction between disciplines, particularly between hard and social sciences, and the roles assigned to each, is an important consideration [31]. Finally, a significant theme concerns post-engagement activities: how to institutionalize stakeholder consultation, making it a permanent practice, and how to integrate and highlight the outcomes of these consultations in public policy?

3. The multi-risk storylines design

In this paragraph we illustrate the design of the multi-risk storyline, developed, and applied in RETURN project. The process can be summarized in five steps (Table 1): 1) Scoping: description of purpose and objectives, 2) Setting: identification of the urban context and the characteristics of the multi-hazard event; 3) Engagement: selection and engagement of stakeholders; 4) Exploratory Phase: joint definition and conceptualization of relevant impact chains, 5) Prescriptive Phase: identification of strategic actions in response, regeneration and preparedness.

3.1. Phase I: scoping

The scope of the risk storyline includes the definition of its main purpose and goals as well as the indication of any further assumptions and boundary conditions necessary to better contextualise it. This phase, common in scenario planning approaches [15], is akin to provide a set of *metadata* to the storyline, increasing its potential for comparability and replicability. In the scoping phase a preliminary identification of risks should be carried out according to the reference sectors, purpose and potential stakeholders and risk owners.

3.2. Phase II: setting

Defining the urban context of interest is crucial for developing multi-risk storylines, as it helps identifying local vulnerabilities and exposures, as well as the relevant hazards. The presence and amount of certain assets (e.g., people, housing, infrastructure, species, or ecosystems), along with various vulnerability factors, significantly influence the level of impact and the effectiveness of response and recovery efforts against natural hazards, such as heat waves and floods, that are characterized by cascading impacts.

When developing a storyline, this step may turn out quite 'critical'. One viable option is to identify an existing urban context and imagine the unfolding of the story within it, and thus account for its social and geographical uniqueness. Otherwise, as proposed in this study, it is possible to construct, following a data driven methodology, a set of ideal-typical urban contexts that do not refer to any particular city, but rather take on characteristics common to different places. Without claiming to generalize the results of the storylines for a specific territory, this expedient can be useful to facilitate the engagement of stakeholders belonging to different territorial contexts and, in the case of similar contexts, to identify common criticalities/opportunities.

In our methodological proposal, the characterisation of a territorial context and the selection of the related multi-hazards is carried out in four steps schematically listed in Fig. 1.

In the proposed procedure, the municipality is used as the boundary for urban settlements. Data from ISTAT (the National Institute of Statistics in Italy) are used to characterise the Italian municipalities for the purposes of urban context selection. Specifically, information adopted is related to: (i) the degree of urbanization, that accounts for geographical contiguity and population density; (ii) urban centeredness degree, that quantifies the level of centrality of an area within an urban context; (iii) the number of inhabitants, derived from the last census [32]; (iv) the altimetric zone, that refers to the classification of the geographic area based on its elevation above sea level. Additional demographic and socio-economic information (e.g., age, income level, employment status, education level) can also be obtained from ISTAT. These data can be used to classify municipalities based on their social vulnerability [33,34].

For the identification of urban context, it is also essential to determine its level of exposure to natural hazards, which is related to the presence of people, property, infrastructures, economic activities, and other assets that could be adversely affected by various hazards like earthquakes, floods, and tsunamis [1,35]. This involves assessing the presence and value of assets in hazard-prone areas, as well as the frequency and severity of hazards. A GIS-based procedure is proposed herein to evaluate the exposure level of urban

Table 1
The "multi-risk storylines" Path.

Scoping	Definition of main purpose and goals of storylines as well as the indication of any further assumptions and boundary conditions necessary to better contextualise it.
Setting	Assessment of level of exposure of territorial contexts to the hazardous events of interest. Definition of the main features of the selected territorial context that play a crucial role in managing risk and description of the multi-hazard scenario.
Mapping and Engagement of Stakeholders	Identification of multidisciplinary expertise from different social fields (academia, politics, economics, civil society etc.) in the development of storylines
Exploratory Phase	Identification of possible direct effects on the population, services, natural environment and critical infrastructure during and immediately after each event.
Prescriptive Phase	Identification of strategic actions in the event response, medium-long term restoration and preparedness phase

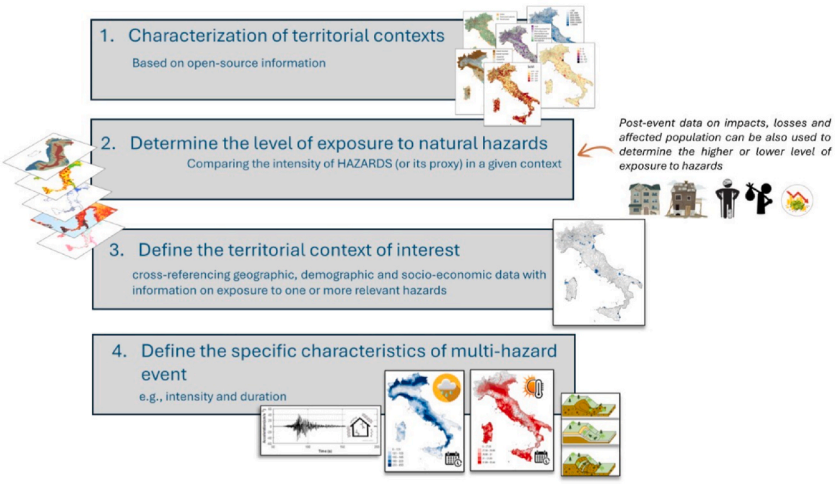

Fig. 1. – Proposed procedure for the identification of territorial context.

settlements to several hazardous events. For the hazards of interest, intensity measures values at municipal level are derived from the related hazard maps. When hazard maps are unavailable, a significant proxy for the intensity measure is adopted. This approach enables the ranking of various hazards for each urban setting, according to the related risk, and the identification of municipalities with high exposure to one or multiple hazards. Historical damage data, if available, can also be integrated to identify consistently vulnerable urban settlements and regions.

The urban context for the development of risk storylines is defined by specifying the characteristics of the selected context based on the investigated information (e.g., a municipality that is an attraction hub, with over 50,000 inhabitants, located in a hilly area) and cross-referencing this data with information on exposure to one or more relevant hazards (e.g., extreme rainfall and landslides). The aim is to define an ideal-typical context that is abstract yet concrete, resembling one or more real urban contexts without explicitly referring to any specific one.

In addition, the setting for risk storylines also requires defining the specific characteristics of the hazard or multi-hazard event. To explore complex risks, more than one hazard can be identified, according to the morphological, geological, hydrological, and climatic profile of the urban context of reference. Cascaded or compound events can be defined, ensuring their scientific plausibility but considering also extremal conditions compatible with climate change. The range of hazards in Italy is unfortunately wide, including for instance fluvial and pluvial floods, earthquakes, landslides, and debris flows as well as heatwaves and droughts, with different potential interactions (e.g. [36]). Each specific process or event has relevant characteristics, such as its intensity, duration, and frequency, which significantly influence the extent of impacts and losses. For instance, rapid landslides, such as debris flows and rock avalanches, occur suddenly and move at high speeds, causing immediate and severe damage to structures and infrastructure, and posing significant risks to human life. Slow landslides, like soil creep and earthflows, progress gradually over time, leading to long-term ground deformation and damage to buildings and roads, often without immediate catastrophic impacts but with persistent and costly effects [37,38].

3.3. Phase III: stakeholders engagement

The term “stakeholder” refers to any group or individual who can impact (i.e., can influence) or can be interested (i.e. can be influenced) in the organization’s resources and outcomes [29,30]. In the context of the RETURN project, this concept of corporatist derivation [39] can be reconsidered, since it is not the company’s profit that is at stake, but the production of knowledge aimed at innovating the DRM. In the elaboration of multi-risk storylines, stakeholders’ engagement has a specific objective: to reduce the complexity and uncertainty inherent in the impacts of natural hazards in different urban contexts, and to track the strategic actions to be practised through the organisation of the cognitive diversity of different stakeholders. Therefore, the stakeholders are mapped and classified according to their interests, competences and capabilities that can influence, or be influenced, by the research results.

This purpose makes the ’stakeholder’ a carrier of interests, knowledge, and experience. These considerations led us to identify stakeholders based on two main criteria: i) heterogeneity; ii) territoriality.

- The heterogeneity criterion implies the involvement of actors with distinctive characteristics. In the case of scientific actors, they may have different disciplinary backgrounds or even different theses on the same topics. In the case of institutional actors, such as public administrators with expertise in DRM, they may have experienced different risks in different areas in terms of geography and resources. In the case of civil society actors, they may have direct experience of risk and a better knowledge of socio-territorial specificities (e.g. socio-economic and cognitive vulnerabilities, social capital, information/communication network), which are often not available to academic and not always recognised by local public actors.

- The territoriality criterion favours actors who have expertise or specific knowledge of a territorial typology, such as large urban centres or inland rural areas. The storylines are set in ideal-typical territories whose characteristics, as described in the previous paragraph, cumulate various indicators of exposure and vulnerability typical of real territories. Whether mayors, law enforcement officials, entrepreneurs or representatives of voluntary associations, the value of stakeholder knowledge depends on how well it is focused on a specific territory.

The structure of the storylines has an exploratory phase, aimed at reconstructing the impact of a multi-hazard event, and has a prescriptive phase, aimed at identifying the good DRM practices to mitigate it. Here we use the term “prescriptive” as it is used in decision analysis, namely, to recommend the best course of action, contingent on data, stated objectives and resources. This framework also suggests a division of labor in the involvement of stakeholders, i.e. in the things we "do together" with them.

Maintaining the criteria of heterogeneity and territoriality, we propose to privilege actors with explicit knowledge in the elaboration of the exploratory phase (knowledge-holders) and those with practical knowledge and direct experience in the prescriptive phase (experience-holders).

- Knowledge-holders are organisations whose main purpose is to produce and validate specialised knowledge on DRM, universities, research centres, specialised civil protection structures.
- Experience-holders, on the other hand, are more diversified and refer to a heterogeneous set of organisations with distinct roles in the management of DRM: multi-level public authorities, prefectures and police forces, professional associations of operators and entrepreneurs, trade unions, voluntary civil associations, grassroots.

3.4. Phase IV: definition and interactive exploration of the impact chains

This phase consists of identifying the impact chains describing the risk drivers related to the multi-hazard conditions on the territorial context chosen as the "setting" of the storyline.

Impact Chains (ICs) are an exploratory tool that helps to understand, systemise and prioritise the factors that drive risks in a specific system of concern and serve as a backbone for an operational risk assessment. Impact chains provide conceptual models that describe risk-related impacts as cause–effect relationships within a socio-ecological system, focusing on identifying and describing important linkages between the different components of risks.

The concept was first co-developed by Eurac Research for studies on climate vulnerability in the Alps, and then proposed in collaboration with the German Institute for International Cooperation (GIZ) as part of a methodological framework to assess vulnerability to climate change [40,41]. This approach, in the last years, gained significant attention in the international community of (mostly climate) risk scholars and practitioners due to a combination of useful and appealing features, including.

- The clear and intuitive conceptual and visual representation of the main drivers of risk (hazard, exposure, vulnerability) and their relationships, including aspects related to cascading of risks,
- the explicit reference to impacts as key observable components of risk, and their (possibly causal) interrelations,
- the clear focus on vulnerability as a paramount risk driver which is often underrated due to its inherent complexity,
- the potential for the explicit consideration of risk mitigation and climate change adaptation measures
- the potential for integration of quantitative, semi-quantitative, qualitative, and narrative approaches

We have developed a design thinking tool to assist in identifying impacts as well as different domains in which they can be observed (Fig. 2).

This scheme considers the combined impact of two different hazards that have a relationship (causal or temporal) between them. The impact of each hazard is reconstructed across four dimensions.

- Physical and natural environment, observing the impact chains on flora and fauna

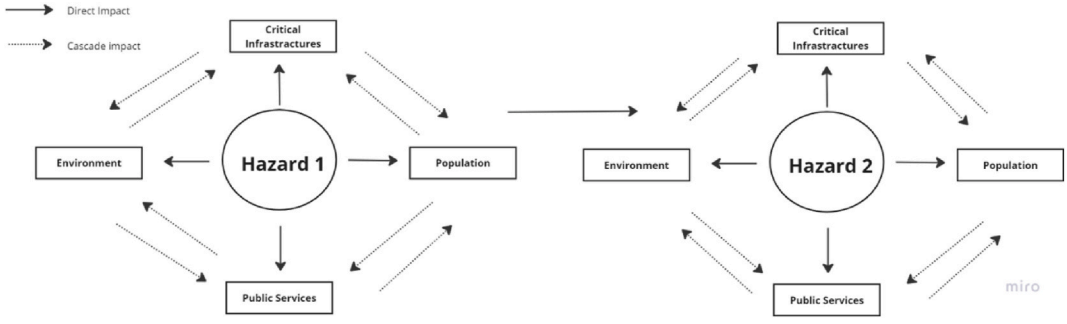

Fig. 2. Processing the impact chains of a multi-hazards event.

- Population, particularly the most vulnerable groups
- Public services, including schools, health, and commerce
- Critical infrastructure, especially electricity, water, and transport networks

Once the direct impacts of a hazard on a given dimension are identified, the next step is to consider potential "cascading" impacts. This involves examining how an impact on one dimension (e.g., natural environment, or critical infrastructures) could also affect other dimensions (e.g., population, public services etc.). The final step is to analyse the integration of impacts between the two events, identifying impacts that only arise when both events occur. This contributes to improve our understanding of the multi-hazard nature of the event.

The mapping of the impact chains can be carried out entirely jointly with the involved stakeholders or in hybrid mode. This entails a preliminary definition of the main risk drivers and cascading impacts by domain experts or based on available literature, and a subsequent review and feedback together with the stakeholders. The latter approach is more efficient in terms of time and process, and more productive in terms of knowledge production, although it requires more resources or a consistent knowledge base to start from.

3.5. Phase V: identification of strategic actions

The narrative and impact chains are managed by the panel of stakeholders engaged in the implementation phase of the storylines. As anticipated in section 3.2, the panel of experts in this case is composed of subjects who, in real life, could be confronted with the event, and who have a different level of responsibility and/or representation in the implementation of a response: from civil protection to local administrations, from utilities to the insurance sector, from environmental associations to the grassroots committees. In this final part, the aim is to reconstruct the actions that an effective risk management unit would implement, if it was faced with the multi-hazard event described in the previous steps.

Just like in the reconstruction of the impacts, the targets of the strategic actions are the population, essential services, critical infrastructures and buildings, and the natural environment (Fig. 3)

For each of these dimensions, the experts involved in a panel are required to identify: i) the actors most responsible for making decisions or likely to intervene; ii) the best actions they can take, either individually or in a network; iii) the contextual variables that may enable or inhibit effective action.

The storylines follow a timeline divided into four segments: (i) immediate response to the first hazardous event, i.e. a set of activities carried out from the moment the event occurs; ii) immediate response to the second hazard; (iii) restoration actions during and immediately after the event; (iv) preparedness actions aimed at improving preparedness after the event. If the event consists of two or more hazards, as is the case with the storylines described below and tested in the RETURN project, the immediate response is reconstructed in relation to each event and based on what has already been done in terms of strategic actions.

The panelists work in sub-groups, simulating a real emergency control room. At the end of each phase (response, restoration, and preparedness) they compare their outcomes with those of other sub-groups, presenting their theses in a plenary discussion, with the aim of assembling a single storyline.

4. Results

This section is dedicated to the restitution of the results obtained in the elaboration of two storylines on the same multi-hazard event (heat wave followed by extreme rainfall) on two different urban contexts (peri-urban area and metropolitan area, respectively). The restitution follows the model set out in the previous paragraph.

4.1. Characterization of territorial context and multi-hazard event

Heatwaves and floods are identified in this study as key hazards for developing specific risk storylines. In Italy, over the past 20 years, heatwaves resulted in significant mortality, with around 38,000 heat-related casualties, while, since 1970, more than 100 major flood events occurred, affecting over 1 million people, and causing economic damages exceeding 26 million Euros (EM-DAT). Due to climate change, these adverse events in Italy are occurring with increasing frequency and in a cascading manner, thereby increasing the complexity of the disaster risk management (DRM) process. This is the reason why we designed the following storylines focusing on

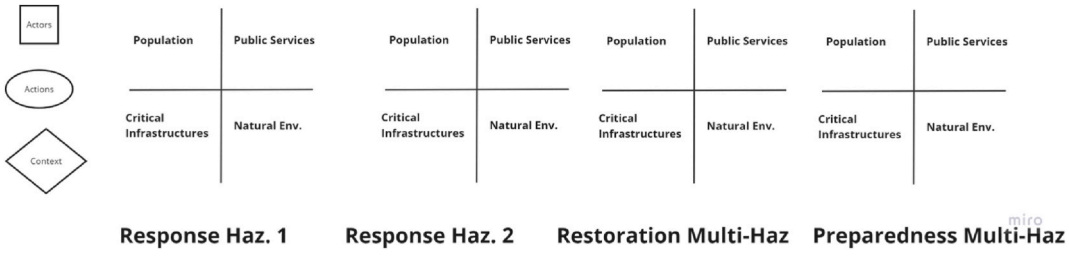

Fig. 3. Processing strategic actions for response, recovery and learning during and after multi-hazards event.

these two specific hazards.

The exposure level of Italian municipalities to floods was assessed by the percentage of inundated area at the municipal level, based on ISPRA's (Istituto Superiore per la Protezione e la Ricerca Ambientale) medium probability flood hazard maps, which correspond to events with an average return period of 100 years. This calculation was performed using GIS software (Fig. 4: a). Cumulative precipitation data from the past 10 years (sourced from ISPRA) and records from localities most impacted by floods over the last 50 years (sourced from EM-DAT and supplemented by newspapers and civil protection bulletins) were utilized as additional data to assess the level of exposure and susceptibility of Italian municipalities to these hazardous events. For heatwaves, the average monthly maximum temperature was adopted as a proxy for the hazard intensity. Specifically, the average monthly maximum temperature in the months of July and August, was adopted (Fig. 4: b).

Once the municipalities with an important level of exposure to both hazards were identified, the territorial contexts for developing risk storylines were determined by their geographic, demographic, and socio-economic characteristics. To emphasize the differences in expected impacts, response, and recovery among various urban settlements, two distinct contexts were selected for the development of the storylines and described in the following narrative form.

- Context 1: a *peri-urban area with about 8000 inhabitants, located in an inland plain. It has a medium population density (approximately 300 inhabitants* per *square kilometre) and low social vulnerability, due to high employment rates and high per capita income. Regarding primary services (higher education, healthcare, rail transport), the municipality cannot offer a wide range of essential services that attract significant users from afar or serve as a "hub." Only through a network with neighbouring municipalities can it fully meet the demand for these essential services. Additionally, the municipality is located at a considerable distance from the nearest urban centre (*e.g.*, provincial capital), with a maximum travel time of 20 to 30 min. The urban centre is in the vicinity of a river that has a large flow and has had histories of previous flooding.*
- Context 2: *a large city with about 800,000 inhabitants, located in an inland plain. As the provincial capital, it serves as an attractive hub, drawing significant numbers of users by offering a wide range of essential services (higher education, healthcare, rail transport). The city has a remarkably high population density (6000 inhabitants* per *square kilometre, compared to a national average of less than* 200/km^2*) but low social vulnerability, thanks to employment rates, education levels, and per capita income above the national average. The urban center is near a major river with a history of flooding.*

Note that, as mentioned before, these contexts do not refer to any specific location and can be related to several localities.

The last step has been the definition of the multi-hazard event. Characteristics of past events were investigated to define a plausible multi-hazard scenario. It was assumed that the considered event occurs in early summer. A short text was then drafted with the description of essential elements to frame the severity of the event. Below is an excerpt:

"A significant heatwave hit the city following an unusually long and intense rainy period in the previous month. Temperatures reach 40 °C during the hottest hours, and high humidity levels persist at night, with temperature not dropping below 30°. The heatwave lasts for seven days and ends up with the arrival of extreme rainfall, causing some rivers in the urban centre to overflow within three days".

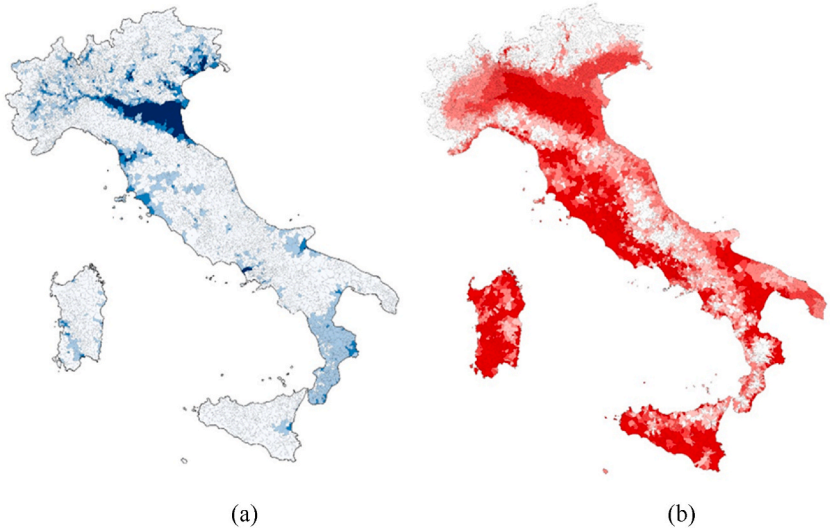

Fig. 4. (a/b) – Percentages of municipal area expected to be inundated according to on ISPRA's medium probability flood hazard scenario (a); average monthly maximum temperature in the months of July and August recorded in the period 2018–2022 at municipal level (b).

4.2. Stakeholders mapping and engagement

The storylines were developed by two panels of stakeholders (Table 2), whose characteristics are in line with heterogeneity and territoriality criteria exposed in paragraph 3.2. A preliminary panel was set up, comprising researchers from the RETURN project, which examined and validated the design of the storyline, during an online workshop. This panel, though not involved in the elaboration of the storylines, proved to be particularly useful, suggesting not to disclose from the very beginning the second hazard which would follow the first event, as well as to provide a well-defined timeline both for reconstructing the impacts and for organising prevention actions.

The exploratory phase of the storylines was developed during an in-person workshop held in Naples in October 2023 (see Fig. 5).

An accurate mapping of RETURN stakeholders and partners was carried out, grouping them according to the following main criteria: geographical location (north-centre-south and islands of the country); academic/research centres; scientific domains; public/private/foundation entities; local/regional scale. Based on this mapping, the representatives of each identified entity were formally invited to the first workshop via email, outlining the workshop's objectives and modalities. The response "drop-off" (duly considered) required continuous reworking of the working-table compositions, which adhered to the following criteria: a maximum of 8 members per table (plus any non-participating observers); interdisciplinary expertise; geographical diversity, and diversity of academic and institutional affiliation. Each working-table was guided by an expert facilitator (a working group member) and a junior supporter. The process of composition of the tables was lengthy and complex. As a result, 4 working tables were composed, satisfactorily but not always perfectly balanced according to the established criteria. A notable over-representation of geological and geotechnical components was observed, alongside with the absence of representatives from local and regional governmental institutions (e.g. Arpa; Regions; Metropolitan Cities; etc.). Several non-participating observers moved among the 4 tables, and their comments were collected.

A second workshop was organized during the project plenary meeting held in Turin in February 2024 (Fig. 6), aimed at focusing on the prescriptive phase, encompassing response, restoration, and preparedness actions. The close collaboration between our working group and partners from the Politecnico di Torino was strategic and fundamental, significantly facilitating interactions with local actors.

The main criteria for identifying local decision-makers included.

- Diversity of functions, skills, and institutional roles.
- Diversity in technical profiles (e.g., professional orders) and political profiles (e.g., metropolitan city mayors, prefects, public servants).
- Various kinds of organisations (public, private, no profit).

These criteria responded to the need to distinguish between the decision-making level (those who take the decisions to be translated into actions/practices) and the action level (those who must implement the actions). It was also necessary to involve the actors within the Turin metropolitan area. The possibility of keeping the two levels distinct corresponded to the objective of verifying the configuration of multilevel decision-making networks, which can allow the emergence of models of virtuous actions, as well as divergences and/or convergences of visions. The involvement of stakeholders from the Turin metropolitan area was primarily aimed at facilitating the participation of the invited stakeholders in the workshop, and it also benefited from the accessibility of these stakeholders through the Politecnico di Torino, given the well-established and extensive collaborative links between the university and the local territory.

The preliminary informal exploration revealed a wide availability of relevant actors. An email invitation was sent by the Politecnico di Torino to a comprehensive list of potential participants to account for the drop-out effect. Due to an overwhelmingly positive response, registration had to be closed early to ensure workshop effectiveness. Consequently, four working groups were formed, each consisting of eight members, along with several external observers who participated in the brief final debate.

Many participants in this workshop had direct experience of managing heat waves or floods and were currently working in organisations with specific expertise in local DRM. However, the "cognitive distance" to be organised was not small: in addition to mayors and councillors from municipalities particularly exposed to the two hazards, senior prefectural staff and local civil protection officials also took part. The public component was joined by representatives of the private social sector, particularly those responsible for helping the most socio-economically vulnerable, as well as representatives of environmentalist and voluntary associations. Finally, private economic entities were also involved, in particular professional associations and insurance companies.

Table 2
Typology, number and criteria of stakeholder's identification.

Storylines phase	Stakeholders Typology	Number of Stakeholders	Criteria of Identification
Exploratory Phase	University (10); Research Institutions (4); National Civic Protection (2); Utilities (2).	18	Interdisciplinarity Geographical location affiliation
Prescriptive Phase	Municipality (6); Prefecture (2); Professional Orders (3); No profit association (6); Utilities (4); School (2); Finance (2); Environmental Agencies (4)	32	Institutional roles; Technical profile; Public, private and no profit sector.

Fig. 5. Photo of a sub-groups during the Naples workshop.

Fig. 6. Photo of a sub-groups during the Turin workshop.

4.3. Impact chains

This section presents the main findings of the exploratory phase of the experiment, as derived from the workshop held in Naples. Due to space constraints, we only present a summary of the findings of one sub-group, which focused on the heat wave and flood in a peri-urban municipality of 8.000 inhabitants.

The panel highlighted the most significant expected impacts from the two events, including increased hospitalisations among older

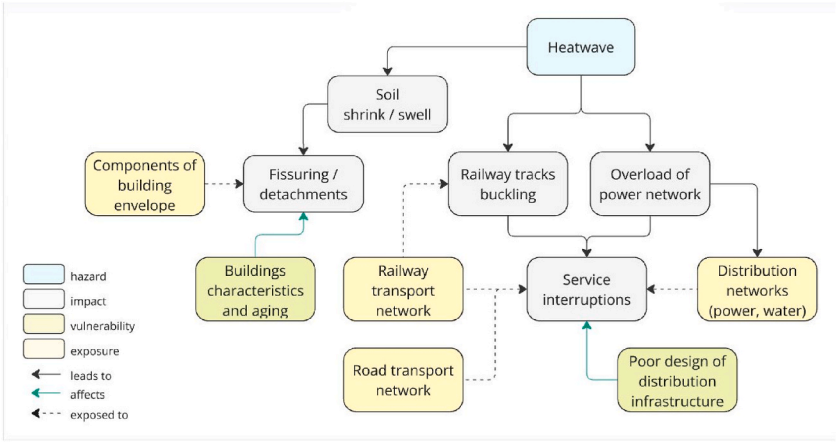

Fig. 7. Impact chain described as an interactive directed graph using the KUMU platform.

people due to the heat wave, and flooding of transport routes due to heavy rain. However, the integrated impacts of these events were also considered. In particular.

- it has been observed that after a prolonged heat wave, individuals may have an increased tendency to stay in locations near watercourses, which can lead to an underestimation of the risk of flooding and a heightened sense of danger.
- it was also noted that, in the event of an overload of the electricity network due to the intense use of air conditioning, the arrival of an extreme disturbance could have a significant impact on the energy transmission network, with a higher occurrence probability in small cities.

The workshop yielded several key insights, which were then used by the research team to construct an impact chain. This involved establishing a set of relationships between the identified factors, based on their specific relationships. The resulting impact chain were displayed as a (oriented) graph, as shown in Fig. 7:

Furthermore, considering the impact chain, other partial narrative components were developed, considering only specific risk pathways, as shown in Fig. 8.

Based on these kinds of structured representations, a textual narrative of the whole storyline was generated, which turned out to be much more thorough than the initial seeding story. In the following lines, a brief excerpt:

"The heatwave is affecting an area where the *per capita* income is above average, but where there is a high proportion of elderly people, home care is limited to very serious cases, health services are scarce and the inhabitants are not used to long periods of extreme heat, often lacking air conditioning and water tanks. The buildings are aesthetically and historically valuable, but they are old and unsuitable for the installation of modern technological equipment. Other conditions typical of small Italian municipalities make the area vulnerable to the effects of heat waves and subsequent heavy rainfall: water and energy distribution networks that are inadequate for extraordinary workloads, lack of reservoirs and reserve water sources, poor maintenance and cleaning of watercourses. From the point of view of critical infrastructure, the heat wave overloads and disrupts electricity and water networks and deforms local railway lines. The consequences are considerable: there are power cuts, the local authorities reduce the flow of water with some hours of total suspension, public transport by rail is delayed and the town is effectively isolated. The commune is situated in a flat area, but outside the town there is forest. On the one hand, this is a relief for the population, who can seek shelter in the shade, but on the other hand, it increases the risk of fires, which do occur and have a devastating effect on local flora and fauna, as well as on agricultural land. Just a few days after the start of the heat wave, the local health service reaches its peak: elderly people with serious health and psycho-physical problems must be taken to the nearest town. It is not only the elderly who suffer, but also the outdoor workers, especially construction and agricultural workers, who are an integral part of the town. In this hot environment, a rainstorm breaks out, with three days of heavy rain. The neighbouring forests pose a second risk for those stressed by the heat and seeking relief, who are caught in the wind and rain storms. Trees and branches are uprooted, affecting people and creating obstructions in the nearby riverbed, leading to the first flooding of neighbouring areas of the centre. Rainfall also causes flash flooding in the city centre, where drains and canals are poorly maintained. The spread and descent of large amounts of rain also affects the watercourse that runs through the city centre. Inadequate urban drainage systems and the lack of protective barriers contribute to flooding on the last day of rain, which is unexpected by the population. The persistence of the rain frightened the citizens, who adopted the wrong behaviour: they went to get their cars in a risky area, they went to their relatives and friends who were more vulnerable, during the most intense moments of the rain. The city centre is completely flooded. Many public and private buildings have been damaged. There is no list of basement dwellings and no organisation capable of alerting the inhabitants of these buildings in time. Injuries and deaths have been reported, as well as damage to homes so severe that people have had to be evacuated. Local health systems, already weakened by the heat wave, are put

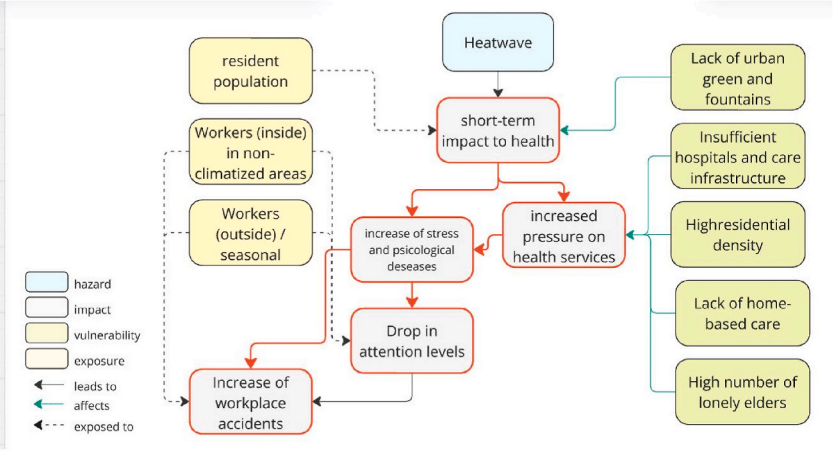

Fig. 8. Risk pathway within the resulting impact chain. The considered factors and relationships are highlighted in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

under great strain by the arrival of injured people. Some public services, such as rubbish collection, have been disrupted. Many shops are not open, making it difficult to find food immediately. The railway line, already closed due to the heat, cannot be reactivated, and help takes longer to arrive. The flooding, which is taking place on land previously burned by the fires, is also causing a series of landslides, blocking the main access routes to the city.

4.4. The strategic actions

This section presents the main findings derived from the workshop held in Turin, in February 2024, with an overall duration of 4 h. For this second workshop the guide-track was reshaped, shifting the focus on the decision-making process. In particular, with respect to each dimension under analysis (which remained the same) and considering the disaster impacts identified in the first workshop, the following changes were introduced.

- Two distinct phases were considered: a) emergency response (short-term); b) mitigation and preparedness (medium-long term)
- For each phase (in a sequence), participants were requested to indicate: the presumed response times; the 3 main actions that should be activated; the actors involved in the decision-making; the actors who would be involved in implementing the actions; the reference regulatory framework; the main necessary skills.

At the beginning of the session, the facilitators of each working-table illustrated the results from the previous workshop (held in Naples), related to the same type of multi-hazard and similar contexts, providing information about the impact chains for each considered dimension. The responses, resulting from lively group interactions, were recorded on post-its and then collected on a single board, specifically set up for each working group. The main points emerging from the discussions were the following.

- The optimal course of action is prevention, which can be achieved by establishing a continuous flow of information between the actors responsible for various emergency response actions and citizens.
- While infrastructure and technological equipment are important, information is also crucial. All municipalities should have civil protection plans, which should include detailed plans for the risks to which their territories are most exposed, and should be properly disseminated
- Remarkably, many territorial realities lack the resources to respond adequately to this type of event. A network approach between municipalities is recommended.
- It is crucial to plan and conduct periodic simulations of emergency situations to assess the effectiveness of emergency plans and to adopt improvements.

These recommendations are familiar to DRM experts. However, they may not be obvious to all actors, such as those participating in the workshop, who have in-depth experience of only one phase, or specific sub-phases, of the risk management cycle. For instance, the centrality of organisational aspects, such as the adoption of a transparent architecture for the flow of information between the various actors, and the preventive collection of rather detailed data about socio-economic and health vulnerabilities, is relevant. These are "soft" tools that local actors can acquire with economic and cognitive resources within their reach. This evidence should be regarded as a call to action rather than to delegation, as might be the case with recommendations that merely point to the need of acquiring infrastructures or technologies that are within the reach of more "macro" actors, such as state actors.

This aspect becomes clear when reading the narrative developed as a result of the evidence gathered during the workshop:

The municipality's civil protection services have anticipated the arrival of a long heat wave. The municipality has a Municipal Operations Centre (COC) chaired by the mayor and other relevant stakeholders, including the local health company, which worked with local doctors to draw up a list of patients at risk based on age and pre-existing conditions. Volunteers from neighborhood associations visited vulnerable patients in the 24 h before the temperature soared, providing them with some of the doctors' recommendations and delivering respirators to those without them. On the first day of the heat wave, the COC set up a shelter in a municipal gymnasium, with air conditioning, basic medical care and the possibility of sleeping in a cot for people with housing problems identified by the municipal social services. The company that manages the water supply in the area has assessed the state of the resource and predicted the risk of an interruption in the flow due to increased consumption. It therefore decided to reduce the flow of water at night and to station tankers of drinking water at various points in the city. At the peak of the heat wave (between the third and fourth day), the local health authority sets up a dedicated line to the health emergency number (112 in Italy) and asks all health facilities in the area, including private ones, to help, particularly in home care. At this stage, the mayor, in agreement with the Prefect, issues a decree suspending outdoor work activities (construction sites, agriculture, sports), providing only for the collection of organic waste, whose collection is shifted daily to the detriment of other less degradable fractions. This regulation will remain in place for the next 72 h, with the arrival of a disturbance that will lower temperatures but create a new emergency. After the first day of heavy rain, the mayor banned access to green areas near waterways and the use of basements. Shortly before the first rains, the Civil Defence stocked up on perishable food in one of its cold stores, in case of an emergency. A team of municipal and civil protection technicians is visiting bridges and underpasses to check their condition and report which ones should be closed. This team is also constantly monitoring the condition of the areas most exposed to flooding and the level of water in the waterways. On the third day of heavy rainfall, flooding occurred, affecting some parts of the city. The most exposed houses in these neighbourhoods had already been evacuated, and the gymnasium set up for the heat wave was used as a first aid station.

5. Discussion

We introduced this article by arguing that cognitive distance is a valuable resource for innovation in DRM and that multi-risk storylines are one of the tools that can help to connect different expertise and to produce new Knowledge. The results of the experiments conducted within RETURN, at this stage of the research project, do not yet provide a definitive answer about it. So far only few multi-risk contexts and events have been tested and there was no systematic collection of participant feedback. The logical design underlying the structure of the multi-risk storylines is still in its start-up phase. In the prescriptive phase, the resources available in each context to respond to the disaster were not clearly stated, and actors therefore imagined the best possible actions in a basically positive scenario, which may be unrealistic in many real-life contexts. However, by summarising the observations made during the workshops and the feedback received from participants during the experiment, it is possible to identify some key issues and critical aspects.

Firstly, the storylines appear a good opportunity to the search for a shared lexicon between different expertise, which is one of the primary challenges in implementing interdisciplinary work [42,43]. In fact, the communication barrier is the one that most complicates the transition from a multidisciplinary approach, where the same object of study is analysed using methods and theoretical approaches from various disciplines, to an interdisciplinary one, where the object of study is common, and the knowledge is co-produced by the interaction between different expertise [44]. Clearly, storylines are not sufficient to bridge this gap, but they are effective in bringing it to the surface and showing how it can affect specific courses of action. To produce more incisive results, storylines should be more recurrent and accompanied by knowledge co-construction tools, such as glossaries to share the meaning of common terms.

Indeed, during the exploratory phase, the participating sociologists, geologists, and physicists attributed disparate meanings to the fundamental concepts under investigation. To illustrate, some parties defined resilience as a property that could be identified in advance of a traumatic event, whereas others only recognised it subsequently, as a system ability to cope with stress. Similarly, some considered a multi-risk event to be one where causal relationship existed between the hazards, whereas others deemed the mere temporal sequence of events, occurring in relatively proximity within the same territory, to be sufficient. This interpretive flexibility was further evidenced in the workshop on strategic actions, where institutional actors referred to codes and regulations that were not accessible to the other actors. Furthermore, the storylines demonstrated the challenges encountered by all actors, particularly the knowledge holders, in adopting and implementing a multi-risk approach [28]. Some difficulties were associated with the design of the storylines and the time available for their development. The initial hazard was accorded greater consideration than the subsequent one, largely due to a decline in attention after the first 2 h of the workshop. However, the difficulty in indicating cascading impacts that was encountered may also reflect other causes, partially already underlined by literature [45]. The traditional risk management often operates in silos, with separate entities responsible for different risks. This can create cognitive bias: not all experts involved fully comprehended the "divergent" objective of the storylines. A significant number of participants opted to “navigate in safe waters”. This entailed indicating impacts that were perceived to be predictable in nature, or which could be categorised as trivial rescue and mitigation actions. Additionally, there were complaints regarding the lack of precise details in the contextualisation, which were deemed necessary to facilitate more probabilistic or realistic assessments. Nevertheless, in numerous other instances, the challenge was successfully addressed, yielding some unexpected outcomes.

The use of impact chains to base the risk storyline upon a sound and comprehensive conceptual representation of the identified risks and their drivers has proved successful and starkly increase their potential for standardization and replicability. However, the generation of a linear narrative for the storyline based on the analysis of the related impact chains can be challenging. In fact, multi-hazard events often result in complex multi-risk conditions which are best represented by reticular (network) rather than sequential structures. While impact chains can efficiently accommodate such conceptual models, the resulting narratives can become cumbersome and require either more efforts by the reader, or a further simplification phase which will result in less information and potential bias.

This experience confirms what is already obvious to anyone involved in facilitation: a good panellist is not necessarily the best expert on a particular topic. Participating in activities such as the elaboration of multi-hazard storylines requires a creative mindset and an open relational approach: it is, in a sense, a game, albeit played with scientific rigour. Stakeholders in DRM are often understood as collective actors, and it is very complex to include character or personality traits in the identification criteria. However, a step in this direction should be taken, for example by explicitly requesting the selected organisations to delegate their representatives to participate, not in view of his/her power and role, but rather in view of his/her suitability for the requested activity. There is also the challenge of creating a mindset before the storylines are worked out. It is necessary to pay more attention to the preliminary part of the workshop, to make it clear from the first engagement that the activity to be carried out is innovative and that the output is the emergence of new ideas, of unexpected associations. This requirement, however, conflicts with the little time allocated to activities such as the elaboration of storylines, which, at least in the Italian national research scene, are considered an “marginal” activities.

A third element to be discussed concerns the evaluation of storyline design, in particular the distinction between exploratory and prescriptive phases, and the division of labor between knowledge and experience holders. The distinction between exploratory and prescriptive purposes is present in the scenario literature, particularly in the field of strategic foresight [46]. Exploratory techniques aim to define plausible futures against which the scenario-projecting organisation can decide how to adapt, while normative techniques aim to prefigure the organisation’s ’preferred’ futures and, through backcasting, reconstruct the steps on the timeline that enable a satisfactory transition [47]. This ’dual logic’ is present in the storyline literature, although most applications [24,27] focus more on the exploratory part, namely the reconstruction of impact chains. In addition, the concept of a ’preferred future’ is problematic in our multi-risk storylines. The two main factors contributing to their elaboration - the characteristics of the hazards and the specificities of the context in which they occur - are wholly or partly outside the agency of the human component of the system. Finally, storylines do not necessarily project themselves into a future time horizon and do not aim to cultivate aspirational capacities, as

normative scenarios do. Storylines aim, hic et nunc, to improve the ability to focus on the cascading effects of catastrophic events and how to best to reduce the damage and adapt the exposed community to their recurrence.

However, some participants highlighted that the assessment of indirect impacts, and particularly the analysis of combined impacts between two closely related hazards, is inextricably linked to the simulation of response actions. The incorporation of a timeline into the storylines, with the indication of impacts and actions on individual hours/days, is a potential avenue for next experimentations.

A fourth element pertains to the overall satisfaction expressed by the actors involved in the experimentation, a considerable number of whom were facing such an experience for the first time. The feedback from those who had direct experience of the situation, and from public administrators and civil protection managers, was particularly positive. Several aspects facilitated this satisfaction. In particular for the most responsible actors in emergencies, the fact that they were working in a non-emergency environment and the "horizontal" setting of the workshops, which encouraged an open and at the same time non-oppositional debate. For all, there was a growing awareness that comparing experiences and knowledge can lead to more effective DRM scenarios and practices (a kind of reflexivity effect). There was also the opportunity to get to know a tool (storylines) that can be used in current DRM practices. A mayor articulated the intention to utilise the storylines for the purpose of revising the civil protection plan of their municipality. A representative of the national civil protection agency expressed interest in utilising this tool to enhance the scenario techniques currently employed by their organisation.

The potential institutionalisation of storylines in DRM therefore poses several challenges, beyond systematising their design and validating the stakeholder selection process. By institutionalisation, we mean the recognition of the storyline tool as a DRM “norm” at the national policy level. It entails first and foremost clear indications of what is meant by the concept, what steps are required to consider it implemented, and with the provision of robust incentives for its adoption at multiple levels of government. It must be clarified that institutionalisation is therefore not about the specific content of the single storylines, which is subject to obsolescence, but about the adoption of a shared scheme of what it is and how it is put into practice. Such storylines could be conceived, as a training exercise, in which case they should also be designed for members of at-risk communities without a specific and recognised social role. Indeed, based on the definition adopted (section 3.2), a stakeholder is a holder of interests, knowledge and experience. From a more ambitious perspective, storylines could also be seen as a participatory planning tool with the potential to produce binding or at least guiding results for decision-makers and to enhance capacity building of local communities.

6. Conclusion

The need to re-think DRM in a multi-stakeholder and multi-risk perspective nowadays is no longer debated. However, there is still much to be discussed and understood about how this can be achieved. Multi-risk storylines, which we have modelled in this article, and reported an application of, are an example of a structure that aims to organize cognitive diversity between different social actors and to orient it towards innovation. In DRM, one of the frontiers of innovation is to prefigure unexpected cascading effects of single hazards on multiple dimensions and territories, or multiple hazards on the same territory. Innovation is also about going beyond the protocols and recognising that it is not enough to write and plan strategic actions to implement them.

The RETURN project has chosen to invest in storylines. The application described in this article is the first in a series that will target different multi-hazards in different contexts. The analysis of the results should provide several insights useful for the next steps of the experimentation. This involves the validation of the storylines design, properly refined, and of the storyline tool through the joint engagement of three ecosystems of actors: knowledge, decision-making, and knowledge transfer (media, information dissemination channels, educational institutions, etc.). The involved actors will be identified based on the criteria consolidated so far, properly integrated. The validation phase – also aimed at considering improved and more realistic storylines – will be conducted in specific territorial contexts identified as case studies. Hundreds of territorial stakeholders and national and international researchers are expected to participate.

CRediT authorship contribution statement

Claudio Marciano: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Antonella Peresan:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Andrea Pirni:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Massimiliano Pittore:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Gabriella Tocchi:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Anna Maria Zaccaria:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Claudio Marciano reports financial support was provided by RETURN Foundation. Claudio Marciano reports a relationship with University of Genoa that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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