A Regional Multi-Risk Assessment Approach to Support the Definition Public Mitigation Strategies

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ABSTRACT: In order to define mitigation strategies, the regional public administrations in charge of prevention policies have to manage large territories characterized by multiple types of risks, i.e. natural and technological risks. They need to identify scientifically sound solutions, based on a compromise between the conflicting objectives of the relevant stakeholders. Natural and technological risks are characterized by different phenomenology, frequency of occurrence, magnitude of impact. They also present different level of acceptability and perception among stakeholders. Therefore, multi-risk assessment is an innovative approach for identifying the most critical areas of a region and it can support public authorities in defining and prioritising mitigation and emergency management strategies.

Keywords: multi-risk, mitigation, prioritization, prevention policies.

1. INTRODUCTION

1.1 Public Authorities Needs

Public policy and strategies for mitigation of natural and technological risks and the related resource allocation strategies have simple clear objective: protect individuals and communities and reduce losses. From a theoretical perspective risk assessment and analysis provides the necessary inputs for rational decision-making for public policy and resource allocation. In practice it is quite difficult to reach such goal due to several different aspects such as for instance, the uncertainty related to risk assessment process and the related results, the conflicting objectives of the stakeholders involved in the decision-making processes, the difficulty of laypeople to properly understand the information related to risk evaluations. The authorities should then in their planning and prioritising do both (Hokstad, P. and T. Steiro, 2006):

1. Perform an overall risk assessment across different areas and regulatory bodies. This should include various aspects of risk/vulnerability that are quantified in a relatively straightforward way.

2. Perform a systematic identification of the other relevant factors (e.g. psychological and ethical) that should be taken into account for allocation of the authorities' resources. These factors are accounted for in a more qualitative way.

This kind of analysis puts risk-related strategies into perspective, which in turn can help policy makers think through the impact of their decisions. Thus, the information from risk analysis contributes to the making of well-informed and responsible policy priorities and decisions. Anyway it is not easy exercise. The decision-making process become even more complex because typically a region and the related communities are exposed to multiple types of hazard that differ from each other in terms of frequency of occurrence, magnitude and impact that they may generate. Moreover, the multiple hazards can generate multiple type of loss (e.g. losses related to human, environment, material and production, etc.), which can imply a different evaluation and judgement for the decisions makers and stakeholders.

Therefore, considering the complexity of such decision-making process, that has to consider in a consistent way multiple-hazard and multiple risk assessment information, it should be argued that a reference framework for prioritizing the hazards present at regional scale and for evaluating potential risk mitigation strategies is required. (Murphy, C. and Pardon, 2007)

Among the number of aspects that decision-making process has discriminate, the following to intermediate objectives can be recognised the most relevant in order to support the definition of mitigation strategies at regional scale:

1. Identification of critical areas for further investigations;
2. Identification of suitable non-critical areas for safe urban development strategies;

3. Identification and ranking of critical areas to support the definition of mitigation strategies and the prioritisation of public resources to be allocated.

1.2 Multi-risk assessment approaches

The concept of multi-risk can be defined as a risk situation, combining multiple hazardous sources and multiple vulnerable elements coinciding in time and space. The concept was developed in order to support risk management approaches that may be as close as possible to the reality of managing an area for decision-makers. Decision-makers, when assessing and managing risks over their territory of competency, do rarely have to deal with only one type of risks, but often with several ones (Di Mauro 2005). This therefore requires a shift from single risk approaches, too often based on a hazard-centred perspective, towards a multi-risk perspective based on the assessment of the territorial vulnerability against multiple sources of hazard. A focus on the vulnerability of a territory allows embracing of the consequences of various hazards on various elements at risk and therefore leads to multi-risk assessment.

At the national or trans-national scale, some studies were developed to compare risk levels in different countries (e.g. Cardona et al, 2004; UNDP, 2004; ESPON, 2005) or to detect areas where the risks deriving from natural disasters are particularly high (e.g. "hot-spots", Dilley et al., 2005; Lari et al., 2009). These works define risk in a quali-quantitative way, based on relatively simplified approaches that can make use of national or regional level indicators. Only a few local scale multi-risk analyses were proposed including multiple sources of natural (e.g. Granger and Hayne, 2001; Middleman and Granger, 2001; Bell and Glade, 2004; Van Westen et al., 2002; Kappes et al., 2012) and natural/technological hazards (e.g. Barbat and Cardona, 2003; Ferrier and Haque, 2003). These studies are based on a more accurate description of each hazard, exposed element and vulnerability, at the temporal and spatial scale, and are suitable for smaller areas already recognized as "hot spots".

2. MULTI-RISK ASSESSMENT APPROACHES

This chapter illustrates the gained knowledge by some multi-risk analyses, which have been developed for different regions in the Northern Italy. Risk generally is defined as a set of scenarios, their associated probability of occurrence, and consequences

$R = F(f, C)$

where f is the expected annual frequency of occurrence, which depends on the type, intensity and the spatial distribution of each hazard, and C is the potential consequence (life loss in case of social risk, monetary loss for economic risk), which depends on the intensity of the threat, and the vulnerability and exposure of elements at risks.

The combination of these two components results in the expected annual loss for a threat with a specific intensity for a certain terrain unit. This analysis has been performed considering landslides (rock falls, debris flows, shallow and deep seated slides), floods, snow avalanches, earthquakes, forest wildfires, industrial accidents, and road accidents. The methodology has been progressively refined thank to the collaboration with decision-makers which defined the relevant information and the user requirements. Since it difficult to compare maps and characterised by multi-risk patterns a GIS-based decision support tool has been developed. It allows discretising the territory and to compare the several dimensions of the risks according to different level accuracy (terrain units multi-scale representation: 20, 200, 500, 1000 m square cells). In the following chapters, it is reported a short description how the method can support decision-makers to define some mitigation strategies at regional scale.

2.1 Risk integration for the identification of critical areas

Societal risks calculated for all threats are commensurable quantities that can be summed up to define a total societal multi-risk, i.e., the total annual expected loss of life for each terrain unit. Similarly, the total annual expected cost for each terrain unit was calculated by summing up the economic risk of each threat.

In order to compare this two risk dimensions, a simple bi-variate plot have been produced, with economic risk in the x-axis and societal risk in the y-axis (Fig. 1a). The points on the plot represent single terrain units. Points closer to the upper right corner correspond to extremely critical terrain units (Fig. 1). This plot also allows to immediately recognising if criticality is related to high population density (higher left corner) or high economical exposure (lower right corner).

Societal and economic risks have been also spatially up-scaled by averaging values within progressively larger terrain units (200, 500, 1000 m square cells) in order to recognize patterns of critical risks at different scales. This analysis is fundamental, since risk patterns at high spatial resolution can be extremely fragmented, thus hampering a clear definition of critical areas. A multi-scale analysis allows to better recognising the critical areas, and the optimal scale of analysis. This also allows identifying the appropriate territorial authority (e.g., Municipality, Province, Region).

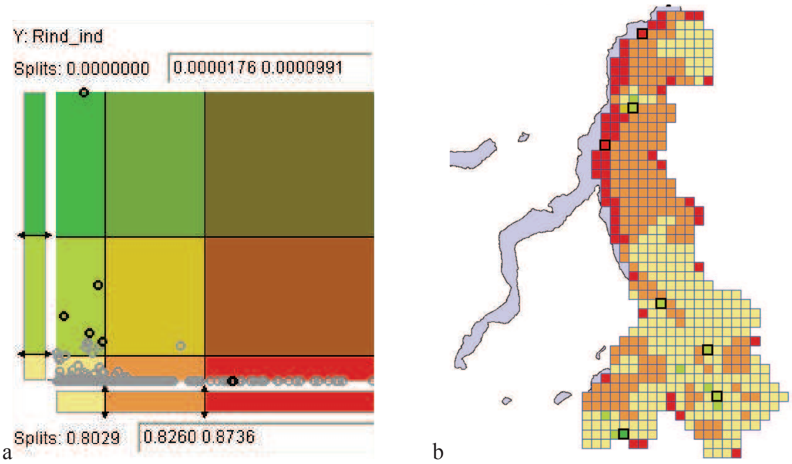


Fig. 1: identification of critical areas: a) bi-variate plot of societal and economic risk, and re-classification of terrain units according to different sectors of the plot; b) map resulting from the combination of two risk dimensions, with 1000 m square cell.

2.2 Risk dominance and de-composition to support the definition of mitigation strategies

For an optimal definition and prioritization of mitigation strategies, two different aspects need to be provided by the analysis of multi-risk.

First of all, it is fundamental to recognize for each terrain units (at different scales) the most critical threat, in order to manage risk with the suitable tools. Performing a dominance analysis, which allows ranking the different threats in terms of risk for people or goods, can do this. Thus, the dominant threat for each cell can be mapped for the entire Region (Fig. 2). Beside the information of the dominant threat, it is also important for decision makers to easily access, for each terrain unit, to information regarding the value of risk of this threat, and the value of risk of other threats potentially affecting the terrain unit (Fig. 2).

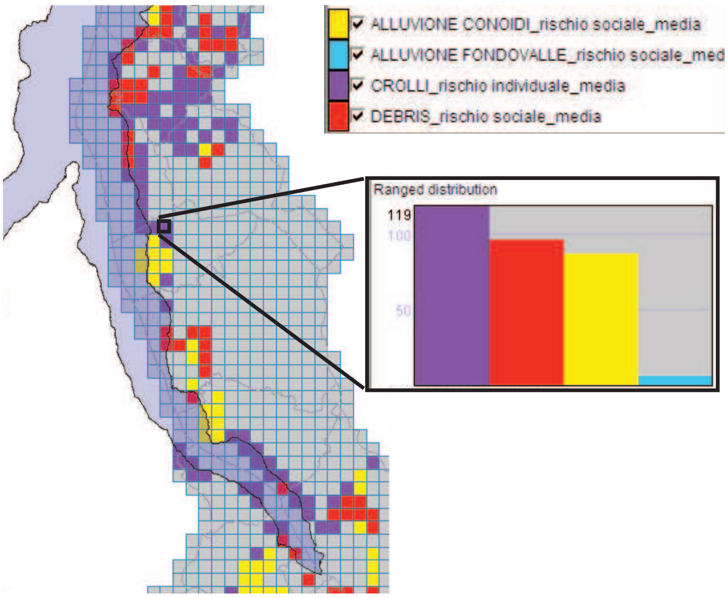
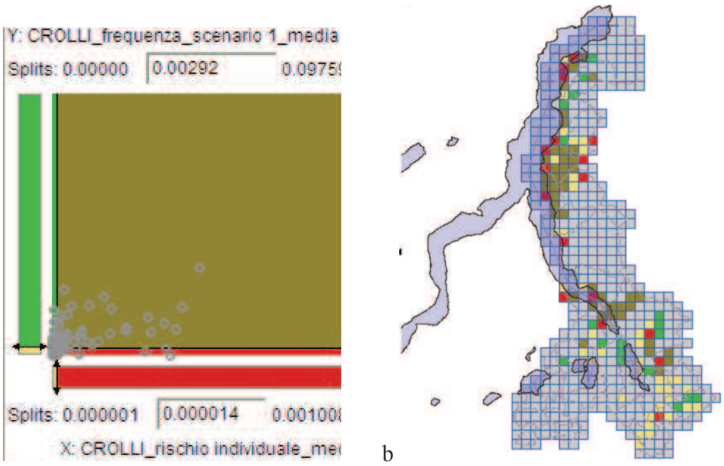


Fig. 2: Example of dominance analysis for hydro-geological risks. For each terrain unit, a histogram with the level of risk for each threat is available for comparison.

In addition to the identification of the most critical threat, it is important to de-compose the risk value in its main components (*f*, frequency, and C, consequences) in order to identify the optimal mitigation strategies (Fig. 3).

If the risk value dominated by the frequency, the mitigation needs to be oriented toward the reduction of the hazard, by implementing structural control measures (e.g., for landslides, drainage systems, retaining walls or barriers, etc.). However, this kind of mitigation can be ineffective for some threats that are almost uncontrollable, such as earthquakes, meteorological extremes, and large landslides.

If the risk value is dominated by consequences, this means that the problems are related to either the vulnerability of the elements at risk or the high value of exposed elements. In the first case, the mitigation should be oriented toward the reduction of vulnerability, by reinforcing and retrofitting of existing structures or by the introduction of strict building codes for new structures. In the second case, the mitigation needs to reduce the economical value of exposed elements, by relocating the structures, if possible. For people, the reduction of consequences can be basically achieved through the implementation of monitoring and early warning systems to provide a rapid evacuation in case of events.



a b

Fig. 3: example of decomposition of risk for rock falls: a) bi-variate plot of consequences and frequency, and re-classification of terrain units according to different sectors of the plot; b) map resulting from the combination of two risk components, with 1000 m square cell.

4. ADDED VALUE TO INTEGRATIVE RISK MANAGEMENT

With regard to the difference with single risk approaches, dealing with one source of hazard and the related vulnerability of exposed elements, the experience gained in the field of multi-risk assessment and the decision-making support, shows that, the multi-risk approach aims at adopting a territorial perspective: a piece of territory is composed by elements at risks diversely vulnerable against the various sources of hazards that can affect this area. The concept of multi-risk can therefore be defined as a risk situation, combining multiple hazardous sources and multiple vulnerable elements coinciding in time and space. The concept was developed in order to support risk management approaches that may be as close as possible to the reality of managing an area for decision-makers. Decision-makers, when assessing and managing risks over their territory of competency, do rarely have to deal with only one type of risks, but often with several ones (Di Mauro 2005).

A multi-risk approach entails, therefore, a multi-hazard and a multi-vulnerability perspective. The multi-hazard perspective has three dimensions: (1) it refers to the fact that different sources of hazard might be spread over territorial entities (e.g. administrative area), which remain the spatial reference for risk-management; (2) one hazardous event can trigger another hazardous event, as the result of a domino effect. Cascading hazards can be, for instance, a seism triggering landslides, or an industrial explosion triggering a fire, etc.; (3) two hazardous events can also appear simultaneously, without any cause–effect relationship. For instance, both flood and blackout can strike simultaneously, owing to complete different causes. The multi-vulnerability perspective refers to the variety of exposed sensitive targets, for example, population, infrastructure, buildings, cultural heritage, etc. that show different types of vulnerability against the various hazards and that require different types of capacities to prevent and cope with them.

5. CONCLUSION

It is obviously not a simple task for decision makers to perform overall planning and prioritisations to allocate public resources to mitigate risk at regional scale. Nevertheless, resources must be allocated, and choices and prioritisations must be carried out. To use such a principle first of all means making the choices more explicit than what is done today. It is difficult to make risk comparisons across different territorial contexts without a systematic approach in methodologies of risks assessment. Without a geographic comparison, it is difficult to prioritize the geographic focus of risk reduction strategies.

In order to overcome such problem and to support public decision makers in such difficult task, a GIS-based multi-risk Decision Support Tool have been developed. The tool mainly allows categorising a region according to the spatial distribution of the several different types of risks and the related components.

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