DEFINITION OF MULTI-RISK MAPS AT REGIONAL LEVEL AS MANAGEMENT TOOL: EXPERIENCE GAINED BY CIVIL PROTECTION AUTHORITIES OF PIEMONTE REGION.

Di Mauro, C. [1]**, Bouchon, S.** [1]**, Carpignano, A.** [2] **, Golia, E.** [2] **and Peressin, S.** [3]

[1] **EC - DG - Joint Research Centre, Institute for the Protection and Security of the Citizen (IPSC), 21020 Ispra (VA), Italy**
[2] **Politecnico di Torino, Dipartimento d'Energetica - 10129 Torino, Italy**
[3] **Regione Piemonte, Direzione O.P., Settore Protezione Civile - 10146 Torino, Italy**

ABSTRACT

A multi-risk approach should allow having a better understanding of the variety of risks over a territory. This raises though conceptual, methodological, operational issues: a multi-risk analysis cannot result from the simple aggregation of single risks maps. An objective multi-risk assessment raises difficulties due to the problems of comparing hazards, vulnerabilities and risks among them. The review of existing risk mapping practices in Europe shows that methodologies often provide simplified maps where the potential number of deaths or of economic losses has been chosen as common unit of comparison. This does not allow any qualitative assessment of multi-risks situations. Therefore, we think that a way to address the complexity of multi-risk situations is to replace the use of this concept within the decision-making process, integrating stakeholders' perceptions in the definition of multi-risk maps. A multi-risk approach should not be seen as a way to replace single risks approaches but as a way to improve the understanding of the complexity of risks over a territory. The example of the project carried out in the Region Piemonte allows illustrating these issues, and shows a possible way to address them. It helps also reflecting about the accuracy and limits of a multi-risk approach.

1.0 INTRODUCTION

The number of technological and natural disasters worldwide and in Europe has been significantly increasing during the last decades. These disasters acted as reveltors of a greater exposure of Europe to multi-risk situations, and showed an increased vulnerability of our societies to more complex risks. The public awareness of this concerning trend, increased the worry of decision makers at all levels about sustainable risk management practices. Risk management activities (prevention, mitigation, crisis management and recovery) at various scales require therefore appropriate supports, tools and methodologies addressing these issues, with respect to the governance principle [1]. The elaboration of multi-risks maps is at the heart of this risk management process. We consider the definition of vulnerability maps that can express the consequences of hazards, as well as their appreciation by stakeholders and their relevance for the decision-making process, one of the most important issues in improving and developing the interpretation of multiple-risks at different scales. This raises conceptual, methodological and operational issues:

- From a conceptual standpoint, the multi-risk concept allows addressing the risk management issues from a territorial standpoint. This requires therefore a review of existing definitions of risk, hazard, exposure and vulnerability within a multi-risk perspective;
- From a methodological standpoint, multi-risk mapping require a multidimensional and coherent approach, variable in time and space. Issues are mainly related to the choice of accurate risk indicators, as a function of data availability, of the scale of the analysis, of tools and approaches adopted to meet the objectives of the multi-risk assessment;
- From an operational standpoint, the elaboration of multi-risk maps should contribute to the integration of stakeholders' perception and sustain better governance within a participative decision-making process. Stakeholders have different objectives that may be conflicting, constrained by their role, the legislative and regulatory context.

With respect to these issues, this paper presents an overview of the challenges laid by the need to address multi-risk and vulnerability within a risk management process based on the principle of good governance in Europe and focuses on the results of the collaboration between the JRC and the Civil Protection Authorities of Piemonte Region in the field of Civil Protection planning activities. The first part provides an analysis of the multi-risk situation in Europe, as well as an overview of the existing multi-risk mapping practices, which benefits and limits are analyzed. As a response to these challenges, the research carried out in the Region Piemonte is presented in the second part, as a possible way to improve multi-risk and vulnerability evaluation within an improved decision-making process.

2.0 MULTI-RISK ISSUES AND MULTI-RISK PRACTICES IN EUROPE

2.1. The concept of "multi-risk"

To the difference with single risk approaches, dealing with one source of hazard and the related vulnerability of exposed elements, 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 has been 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. [2]

This requires thus a shift from single risk approaches, too often based on 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 the consequences of various hazards on various elements at risks and therefore leads to multi-risk assessment.

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 a result of a domino effect. Cascading hazard 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, due to complete different causes.

The multi-vulnerability perspective refers to the variety of sensitive targets exposed, e.g. 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.

As a consequence, the concept multi-risk refers to a complex variety of combinations of risks, i.e. to various combinations of hazards (e.g. multi-natural hazards combination, multi-technological hazards combination, multi-natural and technological hazards combination, etc.) and to various combinations of vulnerabilities (e.g. multi-population and buildings vulnerabilities, multi-cultural and environmental vulnerabilities, complex urban vulnerabilities, etc.). The choice to focus the analysis, e.g. multi-vulnerability against one source of hazard, or on multi-hazards analysis, depends on the objectives and priorities of the decision-makers carrying the multi-risk analysis. The shift towards a multi-risk perspective raises though a great number of issues:

The first difficulty is linked to the comparability of hazardous events among them, since they differ by their nature, intensity, return periods, and by the effects they may have on exposed elements. From the standpoint of disaster prevention, it might be difficult to deal with events, which probability is very different: a single hazardous event, like a low probability/high-magnitude earthquake can cause as much losses as recurrent high-probability/low-magnitude floods. Their magnitude are also measured in different ways, using different units of reference, e.g. discharge or inundation depth for floods, ground motion or macro-seismic intensity for seism.

The second difficulty is related to the comparison of the vulnerabilities of exposed elements. Since exposed elements are different in nature (e.g. population vs. buildings) the parameters to measure the vulnerability against one source of hazards might be different (e.g. potential number of deaths vs. potential amount of destruction) and cannot always be expressed using one synthetic indicator. In addition, if we consider various sources of hazards, the parameter used to express the vulnerability of an exposed element may be different: for instance, in case of flood, the vulnerability of a building can be expressed as a potential degree of damages, while in case of toxic release, the vulnerability could be expressed in terms of required time to clean it.

The last difficulty is due to the fact that a multi-risk approach aims at providing a synthetic view of risks over a territory to decision-makers. This introduces the issue of weighting the relevance of certain hazards or exposed elements for the territory. Decision-makers and stakeholders may have different perceptions on the importance of each single risk, according to them, values that must be taken into account in the multi-risk assessment. These perceptions might be conflicting and the multi-risk assessment process must be based on the principle of a participative approach.

Since a multi-risk approach aims at supporting the risk management process, the requirements of the decision process should guide the definition of the multi-risk approach.

2.2. Multi-risk maps as risk management tools

The issues related to multi-risk require therefore to be addressed in the context of the risk management process. As shown in Figure 1, the risk management process starts with the assessment of needs to improve the existing risk management process.

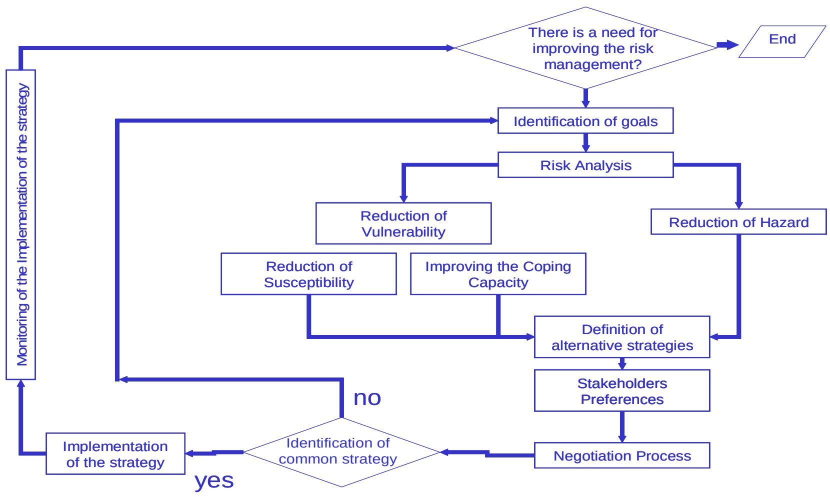

Figure 1. The Risk management Decision Process

The first step consists in the risk analysis, as a response to the identified goals by the authorities or stakeholders. The results of the risk analysis should drive to the definition of alternative strategies of risk prevention, i.e. to the reduction of vulnerability, and/or the reduction of hazard. The decision of the strategy to adopt should be made by the involved stakeholders, i.e. national, regional, local authorities, experts, emergency services, civil protection authorities, etc. within a negotiation process, in order to define a common strategy to be implemented. The choice of accurate strategies depends strongly on the definition of the acceptable risks for the stakeholders. The monitoring and feedback of the implementation of the adopted strategy must be taken on board to assess the improvement of the risk management process.

Risk maps are considered as essential tools supporting the entire process, since they allow the visualisation of the risk characteristics over a territory. They support therefore the diffusion and communication of the spatial information among stakeholders and are used as a basis for discussion over the main issues. Though, maps are different, supporting different objectives, as a function of each step of the process: hazard maps, vulnerability maps, final risk maps are the results of the risk analysis and refer to the type of methodologies the experts have used to identify and characterise the areas at risk. Detailed maps on vulnerable elements or on hazards spatial characteristics can support the deliberation on the best strategy to adopt. During the negotiation phase, maps can be used as a tool to communicate between experts and decision-makers or between decision-makers and the public. Maps can also serve as a basis for the delimitation of the areas where regulatory measures have to be taken. The risk mapping process relies, thus, on the end-users' requirements, which determine the scientific, regulatory or communicational uses of the maps.

With regards to the actual use of risk maps, multi-risk maps must be considered as a way to improve the risk management process, but they are not meant to replace single-risk maps. They can help understanding how hazards and vulnerabilities are combined over a territory and give a more accurate representation of the complexity of the risks for an area. The multi-risk mapping process can also help the stakeholders defining the importance they give to various sources of hazards or to vulnerable elements and represent stakeholders' main concerns. In this view, they support the negotiation phase, showing a prioritization of the areas, where it is more urgent to take measures to reduce the risks.

1.3. Existing multi-risk mapping practices in Europe

The increasing awareness of the need to develop multi-risk approaches has led to the development of risk mapping practices. We may distinguish different approaches, as a function of the scale:

- At the world level, multi-risks maps aim at representing the areas where the risk is at the highest and at highlighting the fact that some continents or countries are more affected than others. In general, these large-scale maps are based on a multi-natural hazard perspective and represent one simple risk indicator, like average or potential economic losses (e.g. Munich Re1) or the average risk of deaths [3]. They are easily readable and accessible for the public and stakeholders.
- At European level, existing approaches are carried out in the context of the European Union 6th Framework Program. The ESPON 1.3.1. project (European Spatial Planning Observation network) aims at proposing recommendations to integrate inclusion of risks into EU policy and at providing an overview of risks with the help of an integrated approach. The objective is to develop a multi-risk analysis from a territorial perspective to support the distribution of EU investments relevant to the cohesion of the European territory (Structural and Cohesion Funds). Based on the assessment of a number of natural and technological hazards in Europe (characterized with 15 indicators weighted through the Delphi method), the assessment of vulnerability (damage potential and coping capacity), first results show multi-risks maps at NUTS-level 3 [4]. The Armonia project2 (Applied multi Risk Mapping of Natural Hazards for Impact Assessment) aims at providing the European Commission with a set of harmonised methodologies for producing integrated risk maps that can be used to achieve more informed and effective spatial planning procedures in areas prone to natural disasters in Europe.
- At national and regional level, very few countries have adopted a multi-risk approach (e.g. the Research from the Centre for Disaster Management and Risk Reduction Technology conducting an interdisciplinary study aimed at assessment, mapping and comparison of

[1] http://www.munichre.com/
[2] www.armoniaproject.net

different kinds of risks for the territory of Germany [5]). The risk mapping process remain constrained by a single risk approach and the diversity of the methodologies makes it difficult to compare results and trigger inconsistencies among international, national, regional and local risk assessments.

This review of risk mapping practices in Europe reveals weaknesses and challenges that are to be addressed. Most of existing multi-risk approaches are based on multi-natural hazards approaches. Technological and industrial risks are less systematically taken into account. Research on the comparability of man-made and natural hazards is still a research challenge. The difficulty to define a basis for multi-risk comparison led to the definition of quite simple risk indicators (average economic losses or average number of deaths). These indicators answer the needs of a communication strategy but fail at representing the complexity of multi-risk situations over territories. Particularly, qualitative aspects of vulnerability (e.g. values attributed to environmental or cultural assets) and risk perceptions are not taken on board. Vulnerability is indeed weakly represented, while vulnerability assessment should be at the heart of territorial multi-risk assessment. This is an issue that needs to be addressed both by single risks approaches and multi-risk approaches. Debate on the definition of accurate parameters and indicators to express vulnerability and coping capacities are still ongoing.

As described previously, multi-risk practices are used most often at large scales, while in the perspective of disaster prevention and management, regional and local scales remain essential levels for the risk analysis and the adoption of risk management strategies (e.g. the project carried out by the German Research Network for Natural Disasters for the urban area of Cologne, Germany, [6]). In addition, the analyses performed remain constrained by political boundaries, while hazards rarely respect the administrative levels. Finally the existing methodologies have been mainly developed by experts and research centers and show therefore a very low level of governance. The application of risk management strategies depends strongly on the good representation of stakeholders' concerns and a more systematic involvement is a great challenge for the development of coming multi-risk mapping practices.

Many reasons may explain the limits of existing multi-risk approaches. All existing methodologies acknowledge the difficulties raised by the data availability, quality and accuracy. The temporal and spatial resolution of existing datasets limits the efficiency of multi risk approaches. In addition, it remains difficult to compare risk data from one country to another. This issue is currently addressed by some EU Integrated projects[3], aiming at structuring databases and at developing format and interoperability standards, in order to improve risk management practices. Though at national, regional and local levels, the gathering and organization of data, especially on vulnerability parameters, remains a great challenge. There is also a need to improve existing multi-risk methodologies, since every country lacks a coherent framework for coping with natural and man-made disaster risks by means of a consistent all-hazards approach. Methodological issues are related to the precautions to be taken when using multi-criteria analysis (validity, accuracy of indicators, weighting system, criteria relationship, etc.). These issues have to be addressed through a multidisciplinary perspective, allowing the analysis of complex territorial risk situations and within a decision process based on the principles of governance. As last factor of explanations, it must highlighted that the scarcity of multi-risk mapping practices is due among others to the lack of legislative constraints, requiring a more systematic multi-risk approach, when carrying out risk management. Even if the European Union and Member States policy paradigm has recently been shifting towards a more comprehensive approach that emphasizes ex-ante measures taken before the disaster occurs, there is still the need for a systematic approach able to provide an all-comprehensive risk management strategy that could be implemented into legislative requirements [7].

---

[3]Open Architecture and Spatial Data Infrastructure for Risk Management (ORCHESTRA), http://www.eu-orchestra.org/
Infrastructure for Spatial Information in Europe (INSPIRE), http://inspire.jrc.it/

This overview allows identifying the gaps and challenges related to multi-risk mapping at various scales, i.e. a coherent conceptual framework to deal with multi-risk and vulnerability, a methodology addressing their multidimensional and variability in space and time, the need to involve stakeholders' perception on these matters, the need to develop an approach flexible enough to be adapted across Europe, in order to provide standardized and comparable results. The project carried out with the Civil Protection Authorities in the Region Piemonte has been developed in order to contribute to the improvement of multi-risk approaches, as a response to the request of decision makers. The experience gained by this project can be seen as a possible way to address the conceptual, methodological and operational issues we have underlined.

2.0 DEFINITION OF MULTI-RISK MAPS AS MANAGEMENT TOOLS: EXPERIENCE GAINED BY CIVIL PROTECTION AUTHORITIES IN PIEMONTE

2.1. Piemonte Region as a good representative of a European multi-risk situation

The Piemonte Region is located in the geographical context of North Italy, which shows a quite good representation of typical multi-risk situations in Europe. The physical environment of the Piemonte Region combines two types of geographical areas, both concerned with different sources of natural hazards: the mountainous area is subject to landslides, flash floods, forest fires and the plain area is prone to floods. In addition the entire region is a seismic area. The land use patterns of the Piemonte Region are related to a highly populated area, associated with a high concentration of industries and infrastructures that make North Italy one of the richest region in Europe. The highest population densities and the major part of industries are mainly located in the plain where technological risks are at the highest. As a consequence on risk analysis, there is a need to adopt a multi-hazard and multi-vulnerability perspective to address the multi-risk issues for the Piemonte Region.

2.2. Brief presentation of the project

This project is the result of a collaboration between JRC Ispra, Politecnico di Torino and Piemonte Region - Civil Protection Department. The study has been developed to obtain an instrument, which can improve the risk management practices addressing the complexity of the regional territory. Considering the regional scale, a multi-risk approach has been chosen, in order to combine different risks and the aspects concerning the prevention and the response to catastrophic events. The main goals of the project are a better integration of stakeholders within the decision-making process and a better communication among various levels of administration (e.g. Provinces, Communes, etc.). In particular, this work has been based on following questions: "How to evaluate each type of risk?"; "How to compare different hazards, different risks, and different effects?"; "How to weight the relevance of hazard, vulnerability and damage to describe risk?"; "What are the relevant attributes to assess the vulnerability of an area?"; "How do socio-politic weights/criteria modify risk assessment?".

After a preliminary state of art on vulnerability and risk analysis, a methodology has been developed to characterise and assess multi-risk at regional level. This methodology allows evaluating the complexity of a territory considering both the risk factors and the stakeholder judgments. The final product consists in a methodology for the development of regional maps, which may support the stakeholders' decisions in risk management.

In accordance with the goals of projects and the priorities of the involved stakeholders (e.g National, Regional, Provincial, Local Authorities of Civil Protection, Regional Land-use planners; Social educator and communicators, etc.), it was decided to consider only the four most relevant sources of hazard for the region, i.e. earthquakes, industrial activities (e.g. chemical-industrial plants and transportation of dangerous goods); hydrological hazard (e.g. floods and landslides); and forest fires.

2.3. Methodological approach

The methodological approach is defined in accordance with definitions and concepts found out in the literature and in the Italian legislation in the field of natural and technological risk management. The main reference has been the "Guidelines for the editing of communal plans of Civil Protection – Piemonte Region 2004" [8], which provided with a conceptual framework.

According to the four hazard sources, which have been investigated, the analysis considered seven types of scenario: seismic events, explosions, fires, toxic releases, floods, landslides and forest fires. Each of source of hazard has a different phenomenology, i.e. a peculiar behaviour to impact potential targets. Independently from the type of hazard, we elaborated a conceptual model which describes the logical pathway to link a hazard event to the impacts on targets. Considering the fact that we were investigating a territory that is characterized by several different types of target, it was necessary to evaluate the several different damages. Most of the damages are not comparable in quantitative terms, therefore it is required a weighting interpretation of the damages. The conceptual model for the vulnerability and risk assessment at regional scale is reported by the Figure 2.

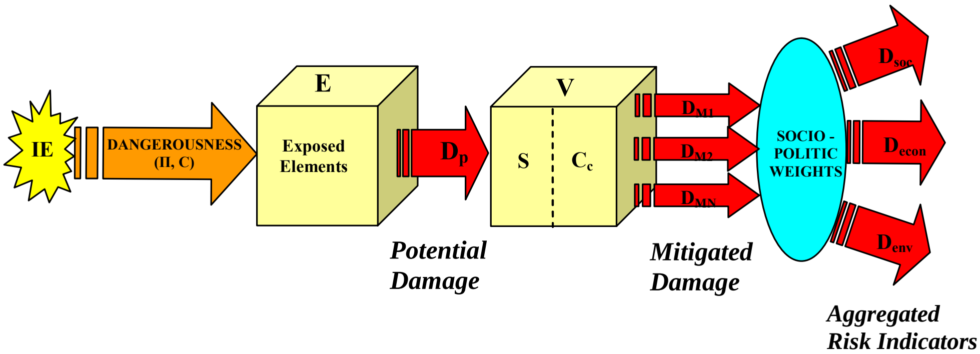

Figure 2. Scheme of the vulnerability model [9]

An initial event (*IE*) may trigger an accidental sequence (scenario) which produces some consequences. These consequences are the physical effects of the phenomena, which may cause damages to the territorial elements. The hazard associated to the initial event is represented by the impacted area Π in which the elements (e.g. people, buildings, etc.) suffer the consequences *C* (e.g. loss of life, structural damage, etc.). These elements are called "exposed elements", or sensitive targets.

The potential damage (*Dp*) was considered only for exposed targets, which level of exposure was calculated as a function of the territorial density.

The evaluation of Vulnerability (*V*) of the territory allows assessing what can be the real impact according to intrinsic characteristics of the territory and the existing protective measure. Therefore, vulnerability assessment allows shifting from the potential damage assessment to the real damage assessment, i.e. mitigated damage (D_M).

The vulnerability is composed by two main parts: the *Susceptibility (S)*, which combines the likelihood of a hazardous event, the differential exposure, the potential sensitivity of a target, i.e. the degree to which a target could be potentially damaged or affected by a given hazard and the capacity of the area to protect it (e.g existing measures of prevention, mitigation, etc.). [9]; the *Coping capacity (Cc)*, which refers to the real capacity to deal with the state of emergency and to balance short-term impacts, e.g. organization capacities, emergency resources, the Civil Protection organisation, etc. [9].

Risks related to specific types of damage (e.g. loss of life, structural failure, economic losses, etc.) might be merged by socio-politic weights, in order to obtain aggregated risk indicators (Social Risk, Economic Risk, Environmental Risk, etc.). These indicators express stakeholders' perception, interpretation and prioritisation of territorial impacts.

2.4. Mathematical model

In this paragraph is described in detail the mathematical model used to define multi-risk maps.

The model considers an area of interest characterised by different sources of hazard: Seismic hazard; Industrial Hazard; Flood hazard; Landslide hazard; Forest fire hazard. The sensitive targets of the territory, which have been considered in the analysis, are: Population; Infrastructures (for human, goods and energy transportation); Buildings (dwellings or other building); Environmental and historical-cultural assets.

Each source of hazard can generate an *i*-type of incidental scenario which may cause a *j* mitigate type of damage ($D_{M,j,i}$). Different types of damages have been chosen to describe the losses caused by a catastrophic event as reported in Table 1.

Table 1. Sensitive targets and related impact indicators

Sensitive target	Impact indicator
Population	Deaths; Injured persons; Persons who aren't in safety conditions.
Infrastructures	People who feel the effects of poor service
Buildings	The collapse; The unsuitability for human habitation
Environmental and historical-cultural assets	Reversible; Not reversible.

Each specific hazard characteristic may be determined with the historical analysis of the events recorded in the past and with the analysis of land characteristics (for example, the presence of industrial plants for the industrial risk, or the presence of rivers for risk of floods, etc.). These analyses concur to determine the likelihood of occurrence of an event with intensity *m* in terms of probability or frequency. The intensity of a seismic event is expressed by peak of acceleration of the ground during the shaking. For an explosion, a fire and a toxic release with industrial origin, the intensity is respectively measured in terms of peak of overpressure (bar), radiation (kW/m^2) and absorbed dose. In case of flood, the intensity is expressed as maximum height of the water level (m), whereas for a landslide and a forest fire, the intensity depends on the involved area (m^2).

Thus, the risk value may calculate by multiplying the probability of occurrence of the hazard by the related damage.

$$R_{ji} = P_i \cdot D_{M\,ji}, \tag{1}$$

where:
R_{ji}: risk for the *j* type of damage and related to the *i* scenario;
P_i : *i*-scenario probability of occurrence;
$D_{M,j,i}$: *j*-type *M*itigated damage related to the *i*-scenario.

Mitigated damage is evaluated from the potential damage that is "mitigated" by the susceptibility and coping capacity of the area. The *j*-type mitigated damage relative to the i-scenario ($D_{M,j,i}$), which is calculated through the following equation, is the sum of all damages referred to the intensity threshold values *m*.

$$D_{M,j,i} = \sum_m (D_{P,j,i,m} \cdot V_{j,i,m}), \tag{2}$$

where:
V_{jim}: vulnerability related to intensity *m* of the *j* type of damage and related to the *i* scenario;
$D_{P,j,i,m}$: *j*-type *Potential* damage related to to *i*-scenario, to *j*-damage and to *m*-intensity.

The potential damage $D_{P,j,i,m}$, is determined by overlapping the map of the impact areas with the targets density map. This operation is expressed by the following relation:

$$D_{P,j,i,m} = \prod_{i,m} \times E_{j,i,m} , \qquad (3)$$

in which the symbol $\Pi_{i,m}$ represents the impact area relative to m-intensity of the i-scenario. For each type of scenario, the thresholds m have been set according to the legislation and technical consideration and standards [10]. The exposition level $E_{j,i,m}$ represents the number of elements which are exposed to risk. The exposition level can be expressed by the density of sensitive targets (e.g. population, buildings) or by the surface of the territory intersected to a hazard area (e.g. for natural parks or environmental targets). The input data to evaluate $E_{j,i,m}$ is drawn from the Ontology arranged in a previous study [11].

The vulnerability $V_{j,i,m}$ refers to i-scenario, to j-damage and to m-intensity, and is calculated as sum of susceptibility $S_{j,i,m}$ and coping capacity $C_{C,j,,i}$. The coping capacity has a negative sign, because it refers to a damage mitigation:

$$V_{j,i,m} = S_{j,i,m} - C_{C,j,i} , \qquad (4)$$

Susceptibility and coping capacity are expressed by a range of values from 0 to 1 or from 0% to 100%. In case of susceptibility, the 0 value means no damages and the 1 value means that potential damage coincides with effective damage. For the coping capacity the 0 value means no damage reduction and 1 value means total reduction of damage.

The susceptibility parameter S represents the probability of damage because of territorial intrinsic characteristics. The land orography facilitates the propagation of flood in the valley but provides barriers to the flood propagation on the hills and mountains; buildings density increases the seismic damage but building age mitigates the effect of seismic events; population density increases the effects of industrial accidents but the presence of buildings allows protecting people against industrial accidents and fires, and so on. The estimation of parameters to set S has been derived by technical literature and lessons-learnt from natural events and industrial accidents. In case of lack of data or information this value has been assumed by hypothesis [10].

The coping capacity comprises activities which guarantee the safety conditions for people and assets, for example evacuation of an area, assistance, etc. The coping capacity decreases in relation with the scarce accessibility of an area, scarce availability of means of aid, absence of monitoring system, etc.. By determining the critical aspects of Civil Protection Organization, it has been possible to choose efficient factors to evaluate the coping capacities. These factors involve monitoring networks, instruments, financial resources, means, and operators. The value of coping capacity parameters was assessed in accordance with expert judgements, which have been expressed by civil protection technicians. A questionnaire was arranged to gather the expert judgements through questions about the relevance of some aspects of civil protection organization and, respectively, about their degree of performance in risk management for the area in which they operate. The Civil Protection factors, which have been investigated with the questionnaire, have been chosen in accordance with Civil Protection Activities carried out to manage territorial risks. The factors are grouped in some components called “Civil Protection Components”. Table 1 contains the components of Civil Protection and shows what factors compose each component.

The Cc value is obtained as sum of performance degrees of each factor weighted by respective importance. Both performance degrees and importance judgements are expressed as percentages values: the percentage of importance is calculated by considering all importance judgements of the factors, whereas the performance degree is assessed by considering that the 100% value means optimal performance of a factor and the 0% value means no relevancy of a factor.

This model allows determining a value of *Cc* parameter relative to type of scenario *i* and type of damage *j* as shown in the following equations:

$$C_{C,j,i} = \sum_{comp} I_{comp,i,j} \cdot L_{p,comp,i,j} \ , \tag{5}$$

$$L_{p,comp,i,j} = \sum_{fact} I_{fact,i,j} \cdot L_{fact,i,j} \ , \tag{7}$$

where:
$I_{comp,i,j}$ is the importance level of Civil Protection component;
$L_{comp,i,j}$ is the performance level of Civil Protection component;
$I_{fact,i,j}$ is the importance level of Civil Protection factor;
$L_{fact,i,j}$ is the performance level of Civil Protection factor.

Table 2. Parameters for assign the coping capacity defined by Civil Protection Authorities and stakeholders

Component of Civil Protection System	Monitoring System	Alert System	Protection measures for population	Protection measures for infrastructures	Assistance measures
Factors of a component	Characteristics (preventive, evolutionary, manual, instrumental, with threshold)	Characteristics (manual, instrumental, with threshold)	Plan (quality, certification)	Plan (quality, certification)	Accommodations
	Human Resources	Human Resources	Procedures	Procedures	Alimentary assistance
	Instrumental Resources	Instrumental Resources	Information, formation, training	Information, formation, training	Sanitary assistance
	Financial Resources	Financial Resources	Resources	Resources	
			Sanitary intervention, technical intervention	Technical intervention	

In order to evaluate or to rank a territory characterized by several different sources of hazard, for each type of damage the cumulative risk may be calculated as

$$R_j = \sum_i R_{ij} = \sum_i (P_i \cdot D_{M,j,i}), \tag{8}$$

Finally, considering that the damages are incomparable and incommensurable among each other, an exhaustive and aggregated vision of multi-risks at regional level, may be estimated only if the relevancy of each type of damage is expressed. In other terms, aggregated index of risk can be defined only if the preference or the weight of risk is made explicit. The weights, which have a politic nature, are typically chosen by stakeholders in accordance with the most relevant goals and priorities.

In this study the Aggregated Risk Index *R* has been defined as weighted sum of specific risk values

$$R = \sum_j \alpha_j R_j \ , \tag{9}$$

where:
R: aggregated risk index;
α_j: politic weight attributed to the damage of type *j* by stakeholders;
Rj: risk index associated to the damage of type *j*.

This formula that is rather simple from a mathematical point of view, is very sensitive when is implemented because it aggregates indicators which have different nature and meanings for different stakeholders. For such reason the application of the full methodology needs a preliminary clear definition of the goals of the decision-making process based on stakeholder's objectives.

2.5. Results

This methodology allowed to address the issues related to multi-risks analysis as described above. The evaluation of multi hazard has been considered as a characteristic of the territory. The integration and the comparison of each hazard have been obtained considering the effects of each single hazard on different sensitive targets. This has been performed defining a vulnerability model and related indicators for assessing the impacts. With respect to existing methodologies and approaches, we tried to focus on the definition of vulnerability factors, distinguishing territorial susceptibility and coping capacities related to civil protection organisations. The definition of accurate vulnerability parameters and the related weights reflect the relevant issues for stakeholders of the Regione Piemonte. If the set of indicators could be applied to another territorial context, the expression of their relevance would need to be discussed with stakeholders of this new region.

In conclusion, multi-risk maps allowed carrying out a multi-level analysis. The cartography shows which are the most relevant risk areas of a region and the related distribution and spatial variation. The maps can support politic decisions oriented to preview and prevent the local risks. The model introduced can be applied both in aggregated analyses, relative to regional contest, and in detailed assessments, referred to a smaller scale, as Provinces, or Communes contests. Moreover, it is possible to represent the overall situation, considering all the hazards or a specific vulnerability state related with one or some type of risk.

The maps edition allows introducing politic criteria to evaluate aggregated indicators in such way it is possible to attribute a level of importance to each damage indicator. The choice allows highlighting the most critical aspects of a territory in agreement with politic strategies carried out by Authorities. At the same time, it is possible to verify how changes in politic criteria modify the results.

As a result, this methodology can be applied like a useful instrument in resources planning. The definition poof multi-risk maps allow supporting and prioritising the actions for reducing the territorial risk. As a flexible methodology, it can help focusing on factors that are the most relevant (e.g Hazard, Sensitive targets, Vulnerability, Susceptibility, Coping Capacity) for the final multi-risk patterns. This aspect it extremely important for the definition of definition risk management strategies. For instance if a final multi-risk map shows areas with very high level of risk, it could make clear that even the level of hazard is equal for some areas the risk can be reduced increasing the coping capacity or reducing the territorial susceptibility. On one side the planning of resources can improve the Civil Protection performances and the organization of territorial services and, on the other side, can improve the management of territory. Besides, periodical updating of the databases used by the model allows carrying out monitoring over time the efficiency of policy implementation.

Figure 3 illustrates graphic interfaces of the Ontology Tool, used to organize territorial information, and the Geospatial Multi-Criteria Decision Aiding Analysis Tool, which produces the maps.

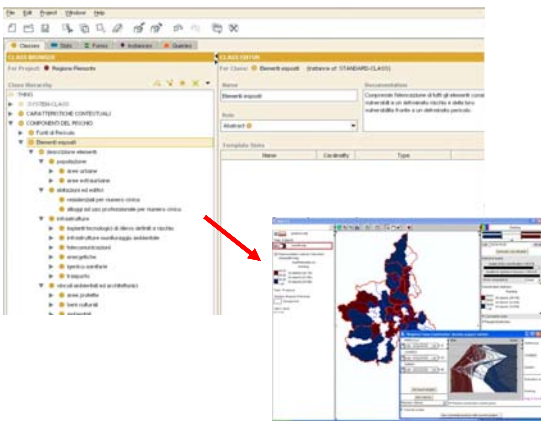

Figure 3. Ontology Tool and Geospatial Multi-Criteria Decision Aiding Analysis (MCDA) Tool [11].

3.0. CONCLUSION

This paper highlights the experience gained during a project that tried to define a method for evaluating the complexity of region characterised by many different sources of hazard and various vulnerable elements. The project is first attempt to provide a consistent response to the emerging concern of public authorities and stakeholders involved in regional risk management.

Even though this work has obtained a useful instrument, which supports stakeholders' decisions, there are some open questions to solve. In the next developments of the model it will be necessary to analyze the model sensitivity, to test the instrument on a real case and to reduce the uncertainties on estimations of susceptibility and coping capacity. Moreover, the model is built to analyse the territory at regional scale and its structure reflects the level of detail required by this scale. In case of other territorial scale, the general approach and the model remain valuable but it is necessary to redefine the set of the indicators according to new scale decision-making needs.

In any case, the result of the project is extremely successful even if we are aware that some further effort are required in order to reduce the discretionarily of some assumptions and judgement, because it has developed according a participative approach and for such reason reflects the real needs of end-users.

REFERENCES

1. European Governance A white paper (COM(2001) 428), July 2001 http://europa.eu.int/comm/governance/white_paper/en.pdf
2. Di Mauro, C. Regional vulnerability map for supporting policy definitions and implementations, Submitted to ARMONIA Conference "Multi-Hazards: Challenges for Risk Assessment, Mapping and Management" 5-6 December, 2005, Barcelona (E)
3. United Nations Development Programme (UNDP), Reducing Disaster Risk, A challenge for Development, UNDP, Bureau for Crisis Prevention and Recovery, 2004, New York.
4. GTK Geological Survey of Finland (Eds), The Spatial Effects and Management of Natural and Technological Hazards in Europe-ESPON 1.3.1., 2005, http://www.espon.lu/online/documentation/projects/thematic/thematic_60.html
5. Tyagunov, S., Heneka, P., Stempniewski, L., Zschau, J., Ruck, B., Kottmeier, C., CEDIM: From Multi-Hazards to Multi-Risks, Proceedings of the 1st Armonia Conference Multihazards: Challenges for Risk Assessment, Mapping and Management, Barcelona, Spain, 5-6 December 2005.
6. Thieken, A., Merz, B.,Grunthal, G., Schwartz, J., Radtke, K.S., Smolka, A., Gocht., A Comparison of Storm, Flood and Earthquake Risk fort he City of Cologne, Germany, Proceedings of the 1st Armonia Conference Multihazards: Challenges for Risk Assessment, Mapping and Management, Barcelona, Spain, 5-6 December 2005.
7. A. Amendola, Management of change, disaster risk, and Uncertainty: an overview", Journal of Natural Disaster Science, Vol 26, No 2, 2004, pp 55-61
8. Regione Piemonte, Linee guida per la redazione dei piani comunali di Protezione Civile, Regione Piemonte, 2004
9. Di Mauro, C., Carpignano, A., Golia, E., Redazione di carte tematiche di vulnerabilità e rischio – Rapporto Finale - Regione Piemonte, JRC/IPSC, Mars 2006
10. Di Mauro, C., Carpignano, A., Golia, E., Redazione di carte tematiche di vulnerabilità e rischio – Rapporto Finale - Regione Piemonte, JRC/IPSC, Mars 2006, Appendice A1 - Studio sullo stato dell'arte sull'analisi di vulnerabilità territoriale: metodologie e normativa di riferimento
11. Mazzucco, E., Pozzoni, M., Di Mauro, C., Nordvik, J.P., Definizione degli standard di acquisizione delle informazioni a supporto delle attività di Protezione Civile – Rapporto Finale – Regione Piemonte, JRC/IPSC, 07/04/2005