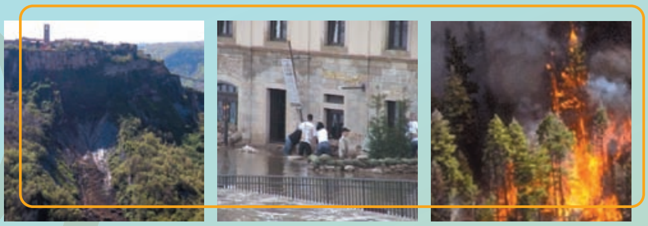
armonia

ASSESSING AND MAPPING MULTIPLE RISKS FOR SPATIAL PLANNING

APPROACHES, METHODOLOGIES AND TOOLS IN EUROPE



A summary of the research undertaken by the ARMONIA
(Applied multi Risk Mapping of Natural Hazards for Impact Assessment)
research project, funded under the Sixth EU Framework Programme
for Research and Technological Development.

SIXTH FRAMEWORK PROGRAMME

COMMISSION EUROPÉENNE

Acknowledgement

The publication was funded by the European Union as a part of the Sixth EU Framework Programme for Research and Technological Development project 'Applied multi Risk Mapping of Natural Hazards for Impact Assessment' (ARMONIA), contract no. FP6-2003-Global-2-511208.

The ARMONIA project was co-ordinated by T6 Società Cooperativa, Italy.

Web sites for further information:

www.armoniaproject.net
www.t-6.it

Edited and published by Lancaster University, Department of Geography, with support of T6 Società Cooperativa.

Contributions by all ARMONIA project partners:

T6 Società Cooperativa;
Staffordshire University, Institute for Environment and Sustainability Research;
Geological Survey of Canada, Natural Resources, Terrain Sciences Division, Canada Landslide Project;
Ceske Centrum pro Strategicka Studia, Water Management Department;
Università degli Studi di Napoli Federico II, Department of Spatial Planning;
Geological Survey of Finland, Land use and environment department;
HR Wallingford Ltd, Department of Water Management;
Universität Dortmund, Institute of Spatial Planning;
European Commission - DG Joint Research Centre, Institute for Environment and Sustainability - Land Management Unit;
Potsdam Institut fuer Klimafolgenforschung, Departement Integrated Systems Analysis;
Politecnico di Milano, Department of Land Use and Urban Planning;
Algosystems SA, Research & Development Department;
Lancaster University, Department of Geography.

Design: Wizard Comunicazione Integrata, Rome, Italy

Date: March 2007

Figure references:

Fig. 3.1: Préfecture des Pyrénées Orientales (2005): Les Risques Majeurs dans les Pyrénées-Orientales. (online) http://www.risquesmajeurs66.com/ (Accessed: 14.02.2005)
Fig. 4.1: Section author, HR Wallingford UK
Fig. 4.3: Buchele, B. et al. (2006) Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks Natural Hazards and Earth System Sciences 6 485-503
Fig. 4.4: ISTAT (2001) Italian Census 2001
Fig. 4.5: http://inforest.jrc.it/effis
Fig. 4.6: Orsi G., Di Vito M.A., Isaia R. (2004), Volcanic hazard assessment at the restless Campi Flegrei caldera, Bulletin of Volcanology (2004) 66:514–530, Springer-Verlag
Fig. 4.7: Kropp J., Block A., Reusswig F. & Schellnhuber HJ (2005): Semiquantitative Assessment of Regional Climate Vulnerability: The North-Rhine Westphalia Study Climatic Change, in press
Fig. 5.1: Walz, U. (2005) Actor-oriented flood risk maps as support for societal decision making. Presentation held in Dresden, 24 November 2005

Picture references:

Gouden Kust (u/d) Wonen op het water (on-line, permission granted 20/03/07 by image owner)
www.goudenkust.nl/verkoop/index.html Accessed 050307
Boscastle Flash Flood: Environment Agency(2005)
Heimaey eruption: USGS (u/d)

Table of Contents

Pag.

1. Natural Disasters and Spatial Planning

Collapsed buildings/rescue work

Natural disasters are typical examples of people living in conflict with the environment. The vulnerability of populated areas to natural disaster is partly a consequence of decades of spatial planning policies that have failed to take adequate account of hazards and risks in land use zoning and development decisions. Therefore it is critically important to develop more effective methodologies and tools for incorporating natural disaster reduction into spatial planning.

Spatial planning should always anticipate the consequences of planned actions. Through such anticipation uncertainty about future consequences can be reduced and confidence in the legitimacy of the respective democratic decision-making bodies can be increased. This is particularly relevant in the case of decisions about development in hazardous areas where lives, property and economic value is at risk.

Spatial planning authorities, which are in charge of making long-term decisions for specific geographic areas, have to consider all spatially relevant hazards and cannot reduce their focus to only one or two hazards like floods and landslides. The reason is that spatial planning is responsible for a particular spatial area (where the sum of hazards defines the overall spatial risk) and not for a particular object (as are, for example, sectoral planning institutions such as utility providers). Due to this fact spatial planning should ideally choose a multi-hazard or multi-risk approach in order to be able to deal appropriately with risks and hazards in this spatial context.

Flash Flood in Boscastle, UK, 2004.
Source Environment Agency (2005)

In contrast to this ideal - with certain exceptions in France and Italy - most current risk assessment approaches employed across the member states (and described in the Del. 1.1 document on the attached CD) tend to have a single hazard focus and/or a project orientated perspective.

Additionally, there is little harmonisation at the regional scale between the spatial planning procedures of member states. This is particularly a problem for the transboundary effects of hazards e.g. major-river flooding like that seen in the Labe / Elbe catchments in 2002. Accordingly, in order to increase the potential for broad scale sustainable hazard and risk management, especially in the light of the projections for impacts forced by climate change, the ARMONIA Multi-Risk Mapping project was financed under the Sixth EU Framework Programme for Research and Technological Development. It involved partners from seven countries and an international advisory group drawn from experts in the field and ran from October 2004 to March 2007.

The volcanic eruption on Heimaey,
Iceland 1973. Source: US Geological Survey

An artist's impression of a Floating House in
Waal, NL. Source: Gouden Kust (u/d)

2. The Aims of the ARMONIA Project

The overall aim of the research project ARMONIA (Applied multi Risk Mapping of Natural Hazards for Impact Assessment) was to develop a new approach to producing integrated multi- risk maps to achieve more effective spatial planning procedures in areas prone to natural disasters in Europe.

Harmonisation of existing hazard and risk mapping methodologies, data availability, technological tools and outputs, is seen as being increasingly important and would clearly benefit end users, achieving a practical result that can optimise the deployment of resources (financial, human, technological) and improve disaster mitigation and prevention. Amongst other things, the output of the ARMONIA project was conceived to harmonise:

- the methodologies for hazard and risk assessment for different types of potentially disastrous events; and
- the different processes of risk mapping in order to standardise data collection, data analysis, monitoring, outputs and terminology in a form useful to end users (multi-hazard risk assessment).

At European level it was expected that added value would come from the project's contribution to the discussion of a new European directive/guideline for the harmonisation of hazard/risk mapping.

The successful harmonisation of processes, methodologies, terms and information could lead to a better understanding by stakeholders operating in horizontal and vertical relationships. It could, therefore, improve co-ordination and cooperation in spatial risk management and promote more effective risk mitigation and reduction. In the horizontal dimension it helps to harmonise the understanding and actions of persons and groups that are operating on the same spatial level (e.g. city parliament, municipality, local public, local fire brigade etc.). In the vertical dimension, the communication and coordination between actors on different spatial levels (coordinating, administrative or political units on the EU level, state level, inter-state level, regional level or local/municipal level) would also be improved.

ARMONIA comprised the following steps:

1. Analysis of state-of-the-art for spatial planning and mapping of risk from natural hazards;
2. Development of a methodology for harmonised integrated maps;
3. Development of a harmonised knowledge base of terminology;
4. Integration of harmonised risk maps with spatial planning decision processes in the form of a decision support framework;
5. Implementation, integration and analysis of a case study simulation.

The project progressed through a series of work packages (WP), as follows:

WP1: Analysis of State-of-Art in Spatial Planning

WP2: Evaluation of current methodologies for risk map production

WP3: Proposal for harmonised integrated map and development of guideline for European standard for multi-hazard risk mapping

WP4: Development of harmonised Knowledge Base of terminology

WP5: Integration of harmonised risk maps with spatial planning decision processes; the creation of a conceptual Decision Support System (DSS)

WP6: Case Study: The application of the DSS to two study areas: the Arno River basin (Tuscany, Italy) and the UK

WP7/8: Dissemination, networking, on-line access, project management

3. Spatial planning and natural hazards: current practice in Europe (Del 1.1; 1.2; 1.3 on CD)

One of the first tasks of the project was to establish how spatial planning in different parts of Europe currently takes account of the risk of natural disaster when developing plans and making planning decisions. A particular concern was to examine how well the existence of multiple and potentially interacting hazards was incorporated into planning practice. An analysis of the approaches, norms and practices used in spatial planning for natural hazards in different European countries was therefore undertaken.

Spatial planning was defined in this context as the comprehensive, coordinated spatially-oriented planning undertaken at different spatial scales (from national to local). Sometimes this is also referred to as "land use planning". In contrast to the encompassing character of spatial planning, discrete sectoral planning authorities can be in charge of individual policy domains which have clear spatial implications (e.g. water management, geological survey, landscape conservation, transport planning etc.). These sectoral actors were, therefore, also taken into consideration within the project, because it is sectoral planning which is mostly responsible for hazard and risk assessment.

Due to the programmatic character spatial planning has on the national level, ARMONIA focused on the following more detailed spatial scales:

A. Regional Planning: Regional planning is the task of settling the spatial or physical structure and development by drawing up regional plans as an integrated part of a formalized planning system of a state. Regional planning is required to specify aims of spatial planning, which are drawn up for an upper, overall-level. The regional level represents the vital link between a state-wide perspective for development and the concrete decisions on land use taken at local level within the land-use planning of the municipalities. Its textual and cartographic determinations and information normally range across the scales of 1:50,000 to 1:100,000.

B. Land-use Planning: Creation of policies at local/municipal level guide land and resource uses (inside the administrative borders of a municipality, in charge of this task). Sometimes "urban planning" is used as a synonym. The main instrument of land-use planning is zoning or zoning ordinances, respectively. Land-use planning is situated below the regional planning level and consists normally of two stages: First a general or preparatory land-use plan (scale 1:5,000 – 1:50,000) for the whole municipality and second a detailed land-use plan for a small part of it, which is mostly legally binding (scale 1: 500 – 1: 5,000).

3.1 General findings

Multi-hazard approaches mostly do not exist: A spatial view of natural hazards needs to consider all kinds of hazards through a multi-hazard or multi-risk approach on all spatial levels (regional and local). With a few positive exceptions (see Figure 3.1) a multi-risk approach is not used because of the diverse responsibilities of sectoral planning divisions for different natural hazards.

Disaster driven process: The intensity of attention paid to natural hazards typically depends on the experiences from recent disastrous events rather than the occurrence of disastrous events in the more distant past or scientific hazard assessments. As a consequence, risk assessment and management focus more on frequent hazards (river floods, avalanches, forest fires) than on less frequent events. The result is a tendency to underestimate the hazard and thus the risk presented by extreme events.

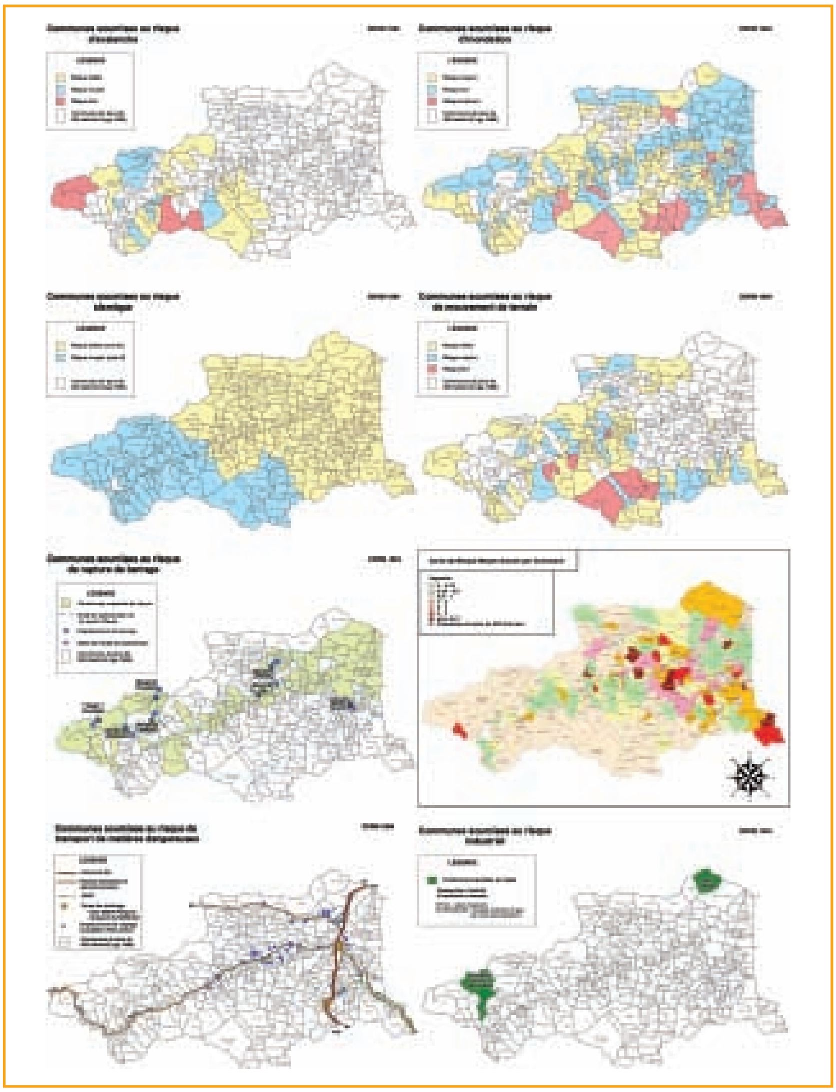


Figure 3.1: Risk maps about (a) avalanches, (b) flooding, (c) earthquakes, (d) landslides, (e) dam failures, (f) forest fires, (g) transport accidents with dangerous goods and (h) technology/major accidents (from upper left to lower right) (Del.1.1-B.III.-45)
Original Source: Prefecture de Pyrénées-Orientales 2005

Risk assessment is mainly a task of sectoral planning divisions: Spatial planning plays a minor role here across all of the countries. Further, it has become obvious that there is not a large difference between hazard assessments on different spatial levels. These assessments are mainly made at higher levels (due to the supra-local administrative responsibilities of the sectoral planning divisions) and then are just downscaled to the local level for, or by, municipalities.

Dominance of hazard assessment: Some countries focus only on hazard assessment. Little attention is paid to vulnerability. This means, that the assessment side is dominated by hazard assessment, whereas, a spatial risk assessment is found in only a few examples. The hazard assessment methods that are used are often only based on deterministic data.

Spatial planning presently plays only a minor role in risk management: On the regional level, the various responsible sectoral planning divisions are in charge of the management of natural risks. Regional planning has often only one supporting actor with the duty to implement measures, or to secure the implementation of measures that are carried out by sectoral planning divisions (structural mitigation). Only in the context of non-structural mitigation measures (keeping development away from threatened areas) is spatial planning important, in some countries, for the minimisation of damage potential. In contrast municipalities are a major actor at the local level. However they use land-use planning as only one of many other tools to reduce the risks within their area of responsibility.

Coordination is regarded as important: In all of the best practice examples special attention is paid to the coordination of the activities of all involved actors. This includes strategies to increase risk awareness at a local scale, as only those hazards and risks that are known can be mitigated. In contrast, ordinary practice is characterised by actors who are operating separately from each other.

3.2 Recommendations for improved integration of hazards and spatial planning

1. Standards for hazard mapping: In order to meet the requirements of spatial planning, minimum standards for hazard mapping are indispensable. In this context, the consideration of probabilistic data seems to be important. In addition, sectoral planning should indicate the areas, which might be threatened by different event probabilities (e.g. 1%, 0.5%, 0.1%). In consequence, the authority in charge of risk management (e. g. spatial planning) would be able to weigh-up the different threats with other interests in those areas where the spatial extent of a hazard and certain land-uses overlap.

2. Coordination of risk assessment and spatial planning activities: Often information, knowledge and activities exist parallel to each other without any linkages to sectoral planning authorities, spatial planning and emergency response. This is particularly important at the regional scale. Here, an authority that has a particular responsibility for risk assessment would be a clear strength.

3. Recognising multiple-risks in risk assessment: A multi risk perspective is not easily taken on by sectoral planning divisions who typically have a focus on particular forms of hazards. It can however be understood naturally as a task for spatial planning which is concerned about all potential threats to a given spatial area and their possible interaction.

4. Coordination of activities: Integrated risk assessment needs a coordinating actor. Due to the wide range of existing responsibilities, this task can mainly be taken by municipalities.

5. SEA directive as a common tool: A procedural framework for risk assessment will be indispensable for reaching the political goals of EU environmental policy. For that purpose, the directive 2001/42/EC ("Strategic Environmental Assessment") should be discussed. Given that SEA is relatively new and does not appear to be used to address hazard issues, it would be useful to emphasise the potential role of SEA to planning practitioners.

6. Guidelines and handbooks for risk management: Regional and local authorities should be provided with the know-how to conduct an effective risk management process.

7. Public awareness: A proactive involvement of the public is clearly helpful in order to influence individual householders. Means of information dissemination as well as methods to encourage active public integration (e.g. through the protection of individual buildings) should be implemented.

8. Integrative concepts: Best practice in risk management is based on integrative concepts. Those concepts cover structural and non-structural mitigation measures, preparedness and response elements.

9. Reorientation of funding policy – development of protection goals: Presently the funding of single projects aiming at risk management is typical. Normally, however, these projects are agreed without any operationalised protection goals as a basis. As a consequence, the fulfillment of certain goals cannot be guaranteed or even evaluated. The main idea behind the development of protection goals is to produce arrangements in combination with a quantitative output which can be financed by government but implemented and assessed at a regional or local level.

4. Current Practice in Risk Mapping in Europe (Del. 2.1 on CD)

In parallel to reviewing planning practice across Europe, it was also important to establish current practice in risk assessment related to risk mapping. Key findings of WP2 are discussed for each hazard in turn.

Floods

The methods generally used to estimate flood hazard are linked to the way in which flood risk is to be assessed. For example, if the flood risk to people is of concern then a flood hazard may need to be assessed in terms of flood depths and velocities. However, if flood risk is to be estimated in terms of economic damage to buildings then the flood hazard is usually established in terms of the floodwater depth and the duration of the inundation. This system is termed the Source-Pathway-Receptor-Consequence model (Figure 4.1).

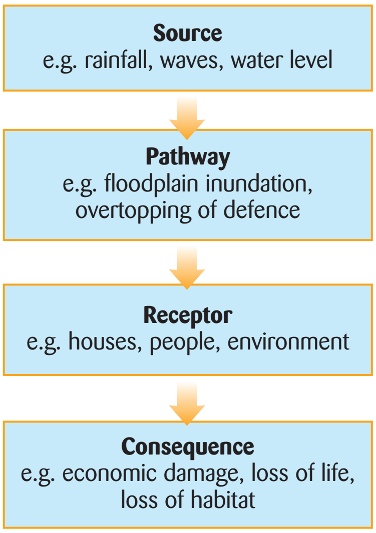


Figure 4.1: Source – Pathway – Receptor – Consequence conceptual model (Del. 2.1.1.1-B.I-7)

Economic damage is calculated by means of Annualised Average Damage curves. These are created through the estimation of the damage potential of flood effects with a range of probabilities (e.g. 20%, 10%, 4%, 1% and 0.5% chance of occurrence in any one year). A curve is shown in Figure 4.2.

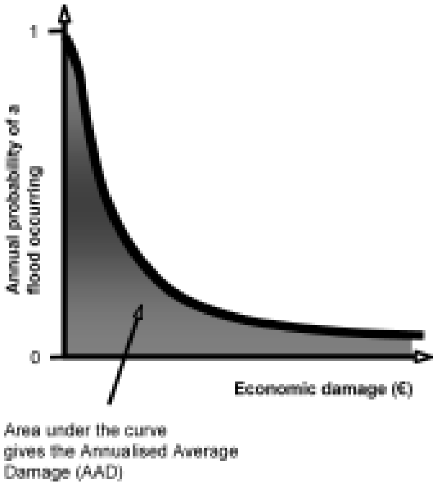


Figure 4.2: Annualised Average Damage curve (Del. 2.1.1.1- B.I-23)

Flood hazard and risk mapping is undertaken to different levels of precision throughout the EU, at national, regional and local scales. The current state of the art is represented by systems which combine Digital Terrain Model (DTM) technology with national property datasets within a Geographical Information System (GIS) to enable highly sophisticated mapping to be achieved (Figure 4.3).

Fig. 4.3: A local GIS-based flood risk map showing the economic damage for a flood that occurred in 1993 in Offenau in Neckar, Germany (Del.2.1.1.1-B.I-37)
Original Source: Buchlel et al. (2006)

Earthquakes

In order to map a seismic hazard one needs a certain amount of basic data:

1. A catalogue of recorded historical events. For each recorded event it is possible to find evidence in relation to e.g. the indicators of epicentral severity, epicentral intensity and magnitude.

2. Source zones. These are areas that can be considered geologically, structurally and kinematically homogenous. A seismic zone is defined through the probabilistic distribution of the epicentral intensities.

3. Attenuation model. For the evaluation of hazard it is necessary to know, in addition to the epicentral location and severity, how the phenomenon propagates from the epicentre and, as a result, the variation in:

- Intensity attenuation,
- Magnitude attenuation.

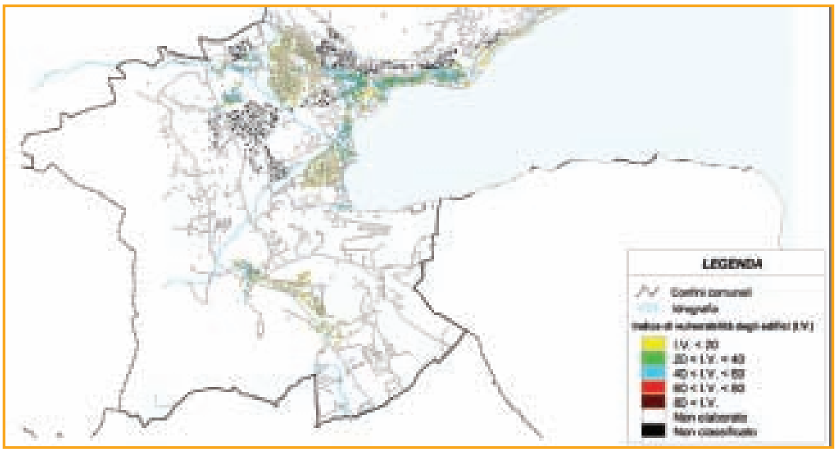


Fig. 4.4: Vulnerability map for buildings at local level for the municipality of Salò (Lombardia Region) (Del.2.1.1.1-B.II-57)
Original Source: ISTAT (census)

Vulnerability mapping also needs basic datasets. For example, the structural vulnerability of buildings to a seismic hazard is calculated by assessing (Figure 4.4):

- Construction class (brickwork and reinforced concrete) according to a structural typology;
- Age class i.e. four classes for brick buildings) (e.g. <1919, 1919-1945) and four classes for reinforced concrete (e.g. <1960, 1961-1971);
- Standard of maintenance (good and bad);
- Height class (i.e. two floors or more).

In Italy this data is increasingly being collected through the use of assessment cards which can be completed for each structure type and which categorise the structure's vulnerability on an A (good) — D (poor) scale.

Seismic risk assessment is carried out at three scales:

First level (territorial exposure): this is calculated in terms of the probability of a hazard affecting a territory.

Second level (damage scenario): This kind of evaluation can supply indicators about potential damage through modeling:

- the cost of buildings direct damages (physical and economic);
- the number of the buildings at risk of collapse (for planning emergency operations);
- the number of potential victims and wounded people (for estimating the impact of the event on the population).

Third level (local effects): These analyses can be made highly detailed through the use of the assessment card system.

Landslides

The recurrence of landslides can be assessed subjectively from general or qualitative information such as historical, geomorphological and geotechnical analyses. The direct analysis, using such information, in case of lack of historical data, can provide a probabilistic estimation on landslide occurrence.
The landslide inventory and landslide susceptibility maps are critically needed in landslide prone regions. These maps must be sufficiently detailed to support mitigation actions at the local level.
However, the quantitative definition of hazard or vulnerability requires analysis of landslide-triggering factors, such as earthquakes or rainfall, or the application of complex models. Hazard and vulnerability analysis is, therefore, extremely difficult when dealing with large areas. Consequently, the legends for most landslide hazard maps usually describe only the susceptibility of certain areas to landslides, or provide only relative indications of the degree of hazard, such as high, medium, and low.

Forest Fire

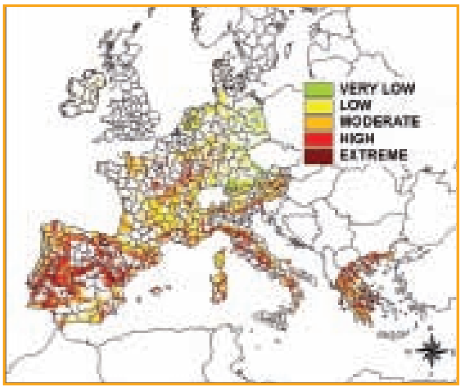


Fig. 4.5: Fire potential map from the European Forest Fire Information System (EFFIS) (Del.2.1.1.2-B.IV.14)
Original Source: http://inforest.jrc.it/effis

Forest fires are combustion processes that occur in the forest or, more generally, in the wildland which includes not only forests but also other natural vegetation such as shrublands or pastures. In other words all the vegetated lands which are not under agriculture. The triggering factors, the ignition sources of forest fires in Europe are in the large majority of cases of anthropogenic nature. Only a small percentage of fires are caused by lightning in dry storms or other even more rare events.

Two temporal scales are commonly identified with fire risk estimation:

- Assessment of Long-term risk assesses the fire risk that does not change, or changes very slowly over time e.g. fuel types, topography or climatic patterns;
- Short-term risk estimation requires daily or also hourly information on fuel moisture content, weather variables as temperature, relative humidity, wind, and precipitation.

In relation to spatial planning considerations long-term risk is the most appropriate scale of assessment. Relevant hazard mapping at regional and local scale is done in many countries (Figure 4.5). In relation to vulnerability mapping, however, there are hardly any global studies. This is due to the complexity and subjective nature of forest fire effects. Fire vulnerability is, however, beginning to draw an interest in the scientific community.

Volcanoes

All dangerous eruptive and posteruptive phenomena such as pyroclastic flows, wind-borne ash, lava flows, volcanic gases and lahars can be referred to as 'volcanic hazards'. Long-term forecasting of volcanic hazards is based on the assumption premise that a given volcano will generate the same eruption phenomena as in the past, if the structure of the volcanic system has not changed. Ideally, all 'live' volcanoes of the world should have a hazards map which reflects the long-term hazard forecast at that volcano, and which should be used by authorities, during times of quiescence, for risk mitigation and land-use planning. The ideal volcanic hazards assessment at a given volcano includes data from three main sources: geological investigations, volcano monitoring, and comparison with similar volcanoes.

The few European and international experiences which are focused on volcanic vulnerability assessment are developed at two main scales: territorial (Figure 4.6) and site scale. Risk assessment analysis metrics change across the scales with vulnerability regarded as being total in relation to regional assessments, improving to include methods which take into account time of day and warning lead time for local scale mapping. Well defined functions for full risk analysis are not currently available.

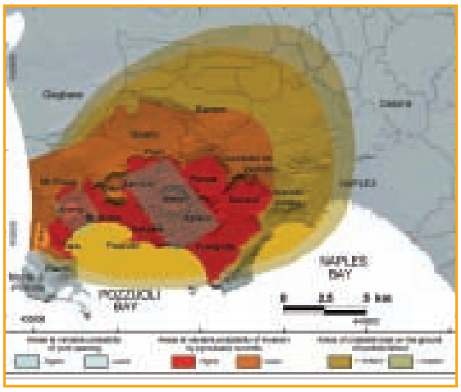


Fig. 4.6: Volcanic hazard map of the Campi Flegrei, It. (Del,2.1.1.2-B.V-14)
Original Source: Orsi G. et al. (2004)

Meteorological extreme events and climate change

Climate Change impacts and meteorological extremes are closely interconnected. However, although major progress in the understanding of climate has been made, there is still uncertainty as to how climate change affects local weather variability and the occurrence of extremes. Due to this, in climate change research the vulnerability concept is the most prominent for assessing climate related risks. It extends the one-dimensional focus on extreme events, e.g. whether we will have more heavy precipitation and subsequently floods expected in region X due to climate change or whether heat waves become more frequent in, e.g. Europe, and an additional question: are modern societies sensitive against these changes and if yes, are they prepared to cope with these changes? Vulnerability in relation to climate change is a function of system's sensitivity, exposure, and its adaptive capacity. As such, future vulnerability can only be assessed through the scientific understanding of climate, business, society, economy, institutions, and the environment (Figure 4.7).

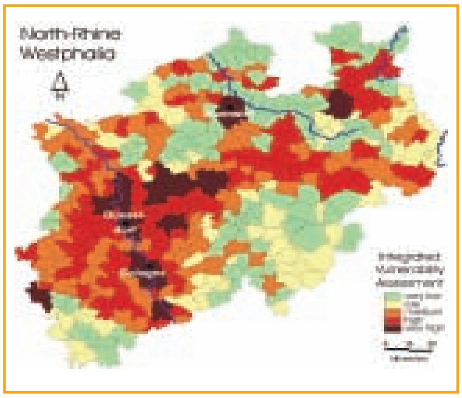


Fig. 4.7: An example of a climate change vulnerability map for 396 communities of North-Rhine Westphalia showing an explicit distribution of integrated vulnerabilities determined for climate risks at a community level (Del.2.1.1.2-B.VI-18)
Original Source: Kropp et al. (2005).

Due to the nature of this complexity future hazards and risk in relation to climate change are not predicted but projected by means of the computer modelling of various socio-economic scenarios. Although resolution is gradually improving in relation to the affects that different scenarios will have on the climate and weather, changes in extreme weather effects (e.g. flash flooding) at a local scale are still highly uncertain and will remain so.

Overall this review shows a range of different practices in hazard, vulnerability and risk mapping across the hazards. No one approach dominates the field.

5. Issues and approaches in the mapping of multiple risks (Del. 3.1; 3.1.1; 3.2 on CD)

The main goal of WP3 was to define a new harmonised methodology for integrated management of data from different risk analysis approaches and to set-up basic principles for an EU directive on harmonized risk mapping aiming specifically at spatial planning. While climate change, desertification and the hydrological cycle along with other natural hazards have contributed to environmental degradation in the European region in the twentieth century, human-induced demand factors (population growth, urbanization, agriculture/food demands) will increase pressure on the environment even more during the twenty-first century. These trends have impacted the vulnerability of urban centres to natural disasters in Europe.

Although spatial planners have a primary need for hazard maps (i.e. those which show the spatial extent and intensity of hazard effects), risk maps can be used by a wider stakeholder group and are specifically useful at three scales:

- at a local or maybe regional level, where vulnerability and risks may be so significant that clearing development and relocating people away from risky areas is considered as a policy option (very rare but does happen in some situations);
- where at a local level spatial planners are able to control or influence the use of existing buildings and can require or advise on mitigating/protective actions within the existing building stock (NB. the extent to which planners are able to do this is limited and does vary between member states);
- at a regional scale when broad decisions about development strategies are taken, it may be useful for planners to know about the overall levels and locations of vulnerability and risk (and direct future development/infrastructure accordingly); this may also be particularly relevant where future climate change scenarios are considered and different future development paths may lead to different future levels of risk and vulnerability under changed climatic/weather conditions.

In short, the primary goals of multi-hazard approaches and mapping are to reduce the loss of life and property, minimize suffering and disruption caused by various types of disasters, and better prepare the EU member states to address the consequences of natural hazard occurrence.

Multi-hazard and multi-risk approaches are particularly important in areas susceptible to different types of hazards, as regions in many of the member states are. In these regions and local areas a concentration on any one specific hazard effect can result in a counter-intuitive raising of physical or social vulnerability in relation to another type of hazard. For example, if a building development on a flood plain is approved because its structure includes an elevated and stilted ground floor, this could result in the structure being particularly vulnerable to the effects of an earthquake's seismic waves.

A review of the state of the art in existing multi-hazard and multi-risk methodologies revealed a number of systems in existence in Europe and globally, including the United States' FEMA organisation's Hazus-MH and the French Délégation aux Risques Majeurs (DDRM) systems. However, shortfalls were found in that none of analysed studies produce a rigorous multi-hazard scenario.

Useful findings were that:

- A rigorous multi-hazard approach cannot be simply based on superimposition of distinct hazard maps, since a multi-hazard analysis incorporates single hazardous events as well as their mutual interrelations and interdependence;
- It is widely accepted that any methodological approach, is strictly dependent on the scale of analysis and representation (local, regional, national scale) and should be structured and developed following scale and data resolution;
- Data sets should, if possible, be homogeneous, spatially representative, and continuous in terms of spatial and temporal series;
- All advanced methods tend to orientate toward development and implementation of a GIS-based DSS (specific software) for potential end-users and stakeholders;
- Complexity of approaches tends to increase with the number of hazard types considered;
- Multi-risk approaches rarely produce estimations in terms of money loss and damage.

In recognition of these points, and of the fact that a multi-hazard, multi-risk approach needs to consider cumulative consequences of different hazards affecting the same exposed element (e.g. landslides can be triggered by floods), it was agreed that the ARMONIA approach to multi-risk mapping should initially be guided by the following ideal methodology:

1. Individual hazards should be defined for the ARMONIA main spatial scales (strategic regional, local general and local site);
2. Vulnerability functions should be defined for any individual category of hazard, having as input the hazard intensity, hazard magnitude, hazard category and as output an average expected damage;
3. Fragility curves should be defined, when possible, for any individual category of hazard, obtaining the probability of damage (e.g. for seismic hazard the % of cracks in walls, the % of unsafe buildings, the % of collapsed buildings) for a given category of exposed elements defined by spatial planners;
4. Risk should be assessed for any individual category of hazard;
5. Different individual values of likely damage (risk), should be summarized in terms of fragility curves (probabilities of different damages for the same stock), for the same return periods (e.g. 1% or 0.1%).

Additionally, before the specific elements of a risk map could be elaborated the basic question had to be asked, who would be the end-user of hazard, vulnerability and risk maps?

Different users have different needs concerning the required data for their purposes — as Figure 5.1, from the Weißeritz-Regio initiative, shows in relation to the requirements of sectoral planning organisations and flood hazard information.

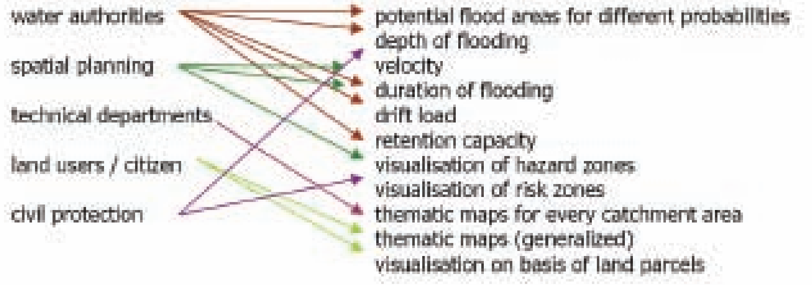


Fig.5.1: Different needs of different involved persons concerning contents of maps by the example of the Weißeritz-Regio mapping project. (Del.3.2-18)
Original Source: Walz 2005

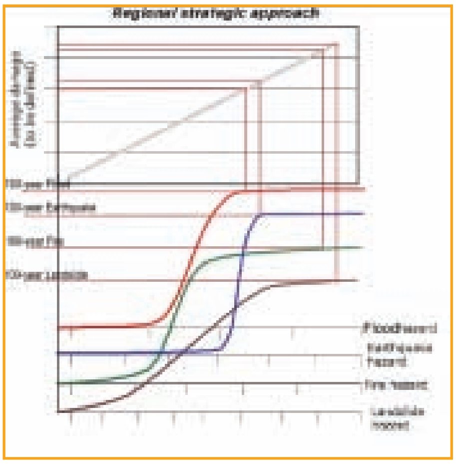


Figure 5.2: Average damage for each hazard assuming a 100 year return period (Del. 3.2-23)

This divergence of requirements by separate actors in risk management made it clear that a complete harmonisation of risk map information that feeds all needs is most likely not possible. However, a harmonisation of hazard mapping seemed to be possible (and necessary) to a certain extent. Figure 5.2 illustrates a starting point in the development of a multi-hazard, multi-risk approach, following the ideal approach listed above. Here, the illustration uses the average annualised damage for a series of 100 year return period events as a metric to show how different hazards can be shown to create greater or lesser risks of economic damage i.e. Landslide hazard (brown line) creates the highest and flooding (red line) the lowest potential losses. Risk categories are, however, classifications which are not necessarily quantifiable merely through the collection of empirical data relating to recent and historical events, for each type of hazard, which elicits the estimation of return periods; in some cases such data simply does not exist. Additionally, some climate-induced hazard effects are likely to be significantly influenced in the future through the non-stationarity of the climate which is projected in all the IPCC emissions scenarios. The ARMONIA methodology, therefore, recognises both that a more appropriate means to assess the probability of hazard events is through a scenario-based approach (discussed below) and that hazard classifications can be supplemented through a normative process of scientifically informed multiple-stakeholder deliberation designed to assist the prioritisation of mitigation / adaptation measures: Part of such a deliberation / scenario-based classification process would, of course, include the assessment of the multiple dimensions of vulnerability, through the application of vulnerability functions relevant to each hazard type. The development, for this purpose, of comprehensive vulnerability indices was carried out as part of WP5. Mapping risk as the effect of hazard intensity for an area of interest, in relation to the vulnerability of population, buildings, networks, nature and agriculture and other important elements of the area needs to be done in a way which is as informative as possible, without biasing decision-makers' perceptions: The colour red, for example, has been identified as being strongly affective. WP3 also, therefore, suggested that a two-parametric colour ramp could be used for the production of maps to indicate, through variations of colour and hue, both monetary and non-monetary risk (Figure 5.3).

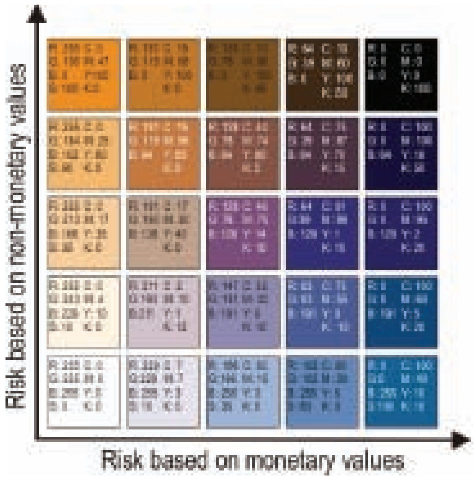


Figure 5.3: A colour scheme for a two-parametric risk assessment. (Del. 3.2-37)

6. Terminology (Del. 4.1.2 on CD)

Before proceeding to develop a harmonised approach there was a need in WP4 to create a harmonised glossary of terms. Following considerable consultation and deliberation this glossary was produced (as two versions: Del. 4.1.1 and 4.1.2). Although the complexity of the definitional requirements of the multiple disciplines meant that in many cases multiple definitions have been listed for a particular concept, the glossary has been positively received by a broad range of potential end users.

7. The assessment of multiple vulnerabilities: a differentiated approach (Del. 5.1 on CD)

In order to implement this type of study and this research a change of perspective becomes inevitable, in the sense that the disaster should not be considered as the result of the 'event' (earthquake, flood or other) but as the moment when vulnerable patterns and factors become apparent. Whilst the event (the hazard) is the triggering mechanism which discloses and reveals weaknesses of a given environment (Hewitt, 1997), the disaster occurs with the interaction of this force with physical, natural, social, economic and cultural systems. In effect, the vulnerability is already there, just looking for a triggering factor to become evident. So, using vulnerability as a measure of susceptibility, fragility or weakness, provides a qualification of exposed elements and systems. It also permits differentiation between one exposed element and another on the basis of the intrinsic characteristics of those elements at stake (e.g. buildings; people). It is therefore a rather powerful tool in the hands of planners, as it suggests the idea that risk may be increased or decreased in relation to the way cities, facilities, infrastructures are built; the policy is, therefore, no longer simply "yes or no". Recommendations and prescriptions to improve the quality of exposed elements and systems, thereby reducing their 'vulnerability', is a crucial point in addressing prevention through land-use planning and management. Vulnerability, however, is something that can be problematic to quantify across different scales. Some features, while rather evident when looked at from a short distance, fade away on a larger scale, but also, vice-versa, some patterns that may appear very clearly at a larger scale, lose their meaning when fragmented by a higher resolution: For example, the social vulnerability of the population within a single street is soon lost within data analyses of an affluent municipality, whilst the coping capacity of that same street could be underestimated if the social and community resources within areas at accessible distance were not taken into account.

Taking this into account it was decided that ARMONIA would recommend that for planning purposes vulnerability needs to be quantified at two scales:

- local, where local refers to municipalities;
- regional.

Furthermore, 'vulnerability' cannot be regarded as an expansive expression. As a term it does not mean the same thing to all people, or all disciplines (as is evidenced within the WP4 Glossary). For this reason it was decided that the several conceptions of the term would be needed to express vulnerability within the ARMONIA mapping methodology:

1. Physical vulnerability: Identifying how prone a building, structure or object is to damage when subjected to stress (a hazard effect);

2. Social vulnerability: Identifying social groups within a population, who will, according to the literature, suffer more strain if exposed to hazard effects e.g. the elderly;

3. Systemic vulnerability: accounts for spatial interdependencies by identifying weak points or elements within transport, health and emergency response infrastructure. It was found that seismic risk assessment has the longest history of the use of 'vulnerability' within the hazards disciplines, with literature reporting physical (structural) vulnerability in the form of 'fragility curves' created through the analysis of substantial survey data. However, fragility curves do not exist for hazard effects other than seismic so a more encompassing method needed to be found.

In appreciation of this and in agreement with the earlier work packages, a series of indices were created for use within a matrix-based ARMONIA methodology at regional and local scales. Using relevant literature these indices were developed in order to express not just the three types of vulnerability but also, explicitly, hazard specificity (e.g. to use an earlier example, a stilted building is physically vulnerable to seismic hazard but is highly resilient to flooding). They also accounted for the issue of mapping an area's coping capacity, by which is meant the vulnerability or resilience of an area which results from either the presence or absence of some particular facility or service (e.g. hospital) as well as the intrinsic vulnerability of that facility or service. The full versions of the vulnerability indices form the appendix to Del. 5.1. This work package also described a comprehensive set of intensity indices which can be used to quantify hazard effects uniformly at regional and local scales. A simplified example is shown in Figure 7.1.

Figure 7.1: A simplified ARMONIA hazard intensity index at regional scale (Del. 5.1-27) The more comprehensive indices intended for use with the DSS can be found in Del. 5.1-27-29

Natural Hazard	INTENSITY SCALES			
	Low	**Medium**	**High**	**Parameters**
Flood	<0.25	0.2 - 1.25	>1.25	Flood depth (m)
Forest Fire	< 350	350-1750	>1750-3500	Predicted Fire-line Intensity(*) (kW/m)
Forest Fire	< 1.2	1.2-2.5	>2.5-3.5	Approximate Flame Length (m)
Volcanoes	<5	5-10	>10	Intensity= Volcanic Explosive Index log10(mass eruption rate, kg/s) + 3
Landslide (fast and slow movements)	<5%	5 - 15%	>15 %	percentage of landslide surface (m2, Km2, ...) Vs stable surface;
Seismic	< 10 %g	10 - 30 %g	>30 %g	Peak ground horizontal Acceleration (%g)

8. A Decision Support System for Mapping Multiple Risk Scenarios (Del. 5.2 on CD)

A decision support system is a support tool for decision-making that is based on a methodology that can be followed to reach a final decision. In some instances the path is more important than the final solution as there could be numerous solutions depending on the initial input parameters.

The overall aim of this part of the project was to produce such a framework and decision support tool structure for risk informed planning. The specific objectives as laid out in the technical annex were:

- to produce a framework and decision support tool structure that will help ensure that planning decisions are fully informed about the multiple risks affecting particular areas of land, the vulnerability of different land uses and populations (taking account of main social factors) and the options that are available to mitigate the risks;
- to contribute to the central aim of the EU Environmental Assessment Directive (2001/42/EC) as this legislation and associated guidance currently pays little attention to natural hazard concerns.The purpose was not to produce a working DSS, but rather, in the context of the ambitious multi-risk objectives of the ARMONIA project, to undertake the essential conceptual and detailed design work before various elements of the recommended approach (described in Section 5 above) were tested out in a case study area in the final project phase.

8.1 The key features of the MURLUMSS DSS

The proposed Multi Risk Land Use Management Support System (MURLUMSS) DSS architecture has the following key features:

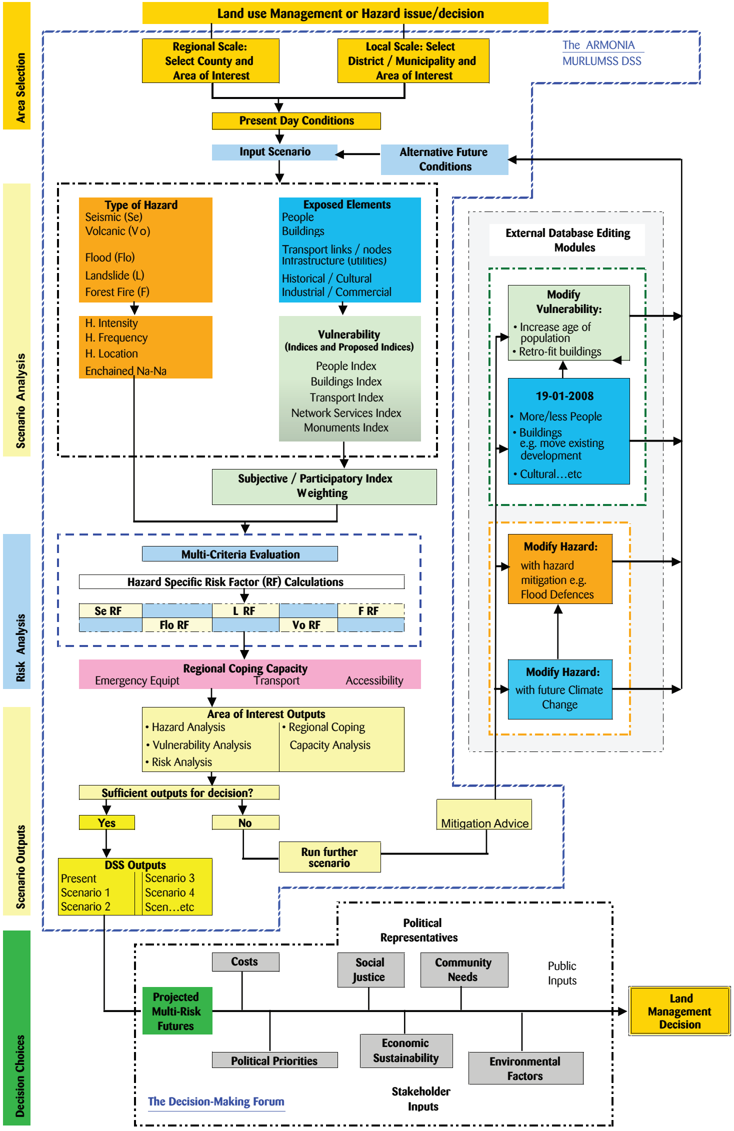
- It maps and visualises information on up to 5 different natural hazards and risks as well as different forms of vulnerability and coping capacity at both regional and local levels. These multi-scale, multi-risk and multi-vulnerability characteristics significantly extend current practice on DSS development for hazard and land use management;
- It enables different scenarios to be run which generate information about hazards, vulnerabilities and risks for specific areas of land that are of interest, so that different options for mitigating risks, reducing vulnerabilities or developing land can be compared through a system of Multiple Criteria Evaluation (MCE);
- It enables scenarios to be run which compare hazards, risks and vulnerabilities under different modelled climate change conditions;
- It provides a knowledge base on hazards, risk and vulnerabilities and on the various approaches that can be taken to mitigate risks through land use management decisions.

The conceptual staged decision support methodology was detailed by way of a flowchart (Figure 8.1) and an impression of its graphic functionality was created in the form of a Microsoft 'PowerPoint' presentation (Section 8.3).
It should be noted that only some of the elements of the 'ideal' multi-risk methodology developed in WP3 could be incorporated into the DSS which needed to be more pragmatic in its approach. In particular the use of fragility curves was not taken forward into the DSS due to these being unavailable across all of the forms of hazard.

8.2 Adapting and applying the DSS “in practice”

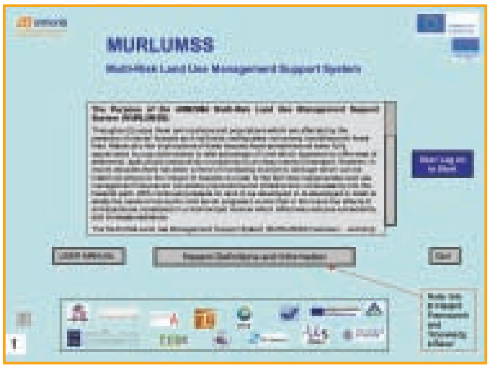
If operationalised MURLUMSS is envisaged to run through as a standalone application on an ESRI ArcGIS platform. Whilst the MURLUMSS DSS has therefore been designed to operate through the most common GIS platform - software which should be widely available across Europe - many other aspects of the system are likely to be far less constant between regions and localities: For example, there will be considerable disparity in the quality and availability of vulnerability data available at local and regional level across the member states. Despite these potential limitations it is suggested that an opportunity exists to use the DSS interactively, and to consider GIS as part of a participatory approach to decision making. There is an extensive literature on participatory GIS (e.g. Cinderby 1999, Elwood 2002) which sees the technology of GIS as a way of enabling both expert and non expert stakeholders to try out different scenarios and futures and evaluate them through visualisation, comparison and discussion. MURLUMSS could be utilized in this way with an open participatory stakeholder process determining the scenarios to be run through the DSS, the weighting factors to be applied in combining vulnerability indices and the comparative interpretation of the risk factors for different scenarios.

Figure 8.1: Flowchart depicting the structure of the MURLUMSS DSS (Del. 5.2-17)

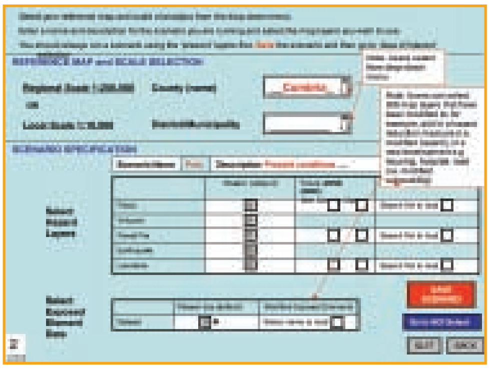


8.3 DSS Functionality

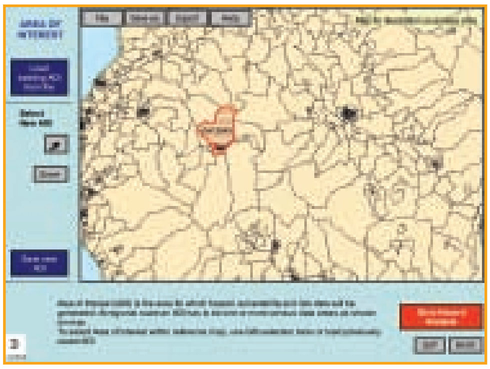
1. The title screen of the system explains the reasoning behind the system and provides links to a library of hazard information sources.



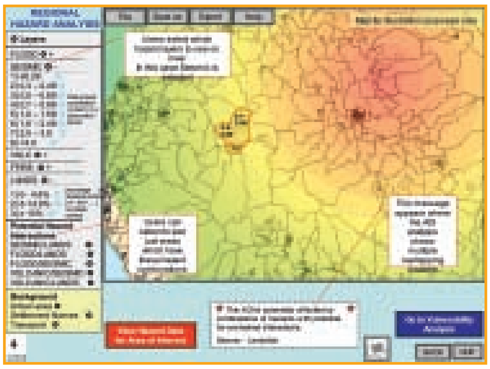
2. Having logged in the user selects the map and scale. Also the demographic and hazard data (from external datasets and models) is chosen: In this example a regional map has been selected for an analysis using 'Present conditions' i.e. no allowance has been made for population growth or climate change.



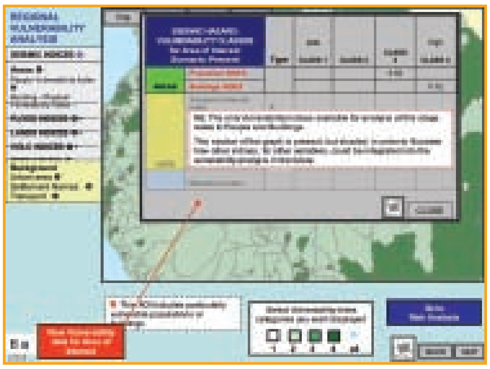
3. The user then selects an 'Area of Interest' (AOI).



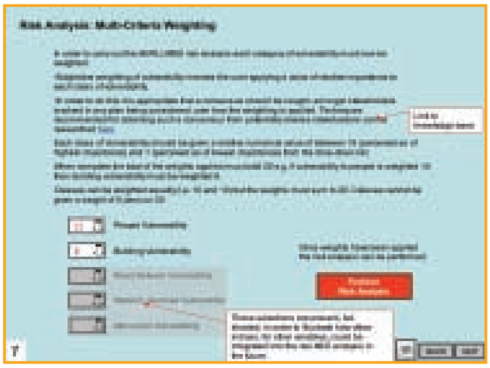
4. The GIS system then activates layers which depict potential intensities of up to five natural hazards which have been identified in the area: in this case Earthquake intensity has been visualized.



5. Once the hazardous areas have been defined the user progresses to a vulnerability analysis. Here indices are used to give a vulnerability 'score' for the people and buildings in the AOI.

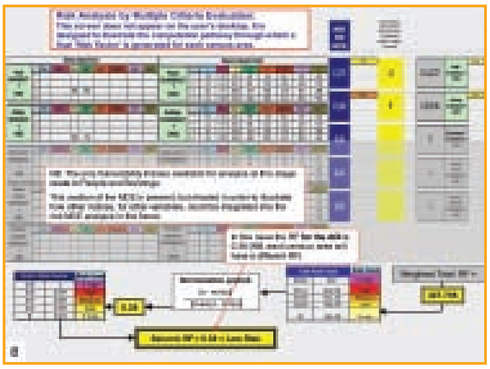


6. Once hazard and vulnerability levels have been calculated the user then commences a process of multiple criteria analysis (MCE) by subjectively weighting the area's vulnerability.

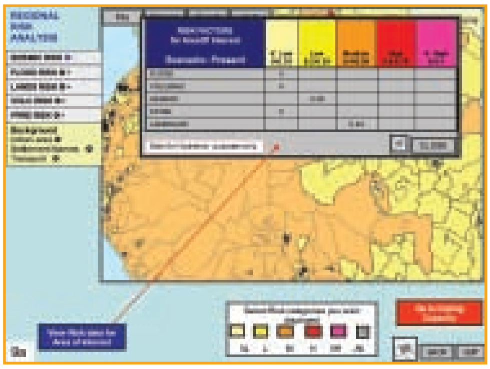


Risk Analysis: Multi-Criteria Weighting

7. MURLUMSS system of MCE applies an algorithm to the weights applied by the user/user group to the different vulnerabilities within the area of interest. In doing this a numerical 'Risk Factor' is produced for each hazard which affects the AOI. Although risk factors cannot be compared across hazards they can be directly compared between scenarios.



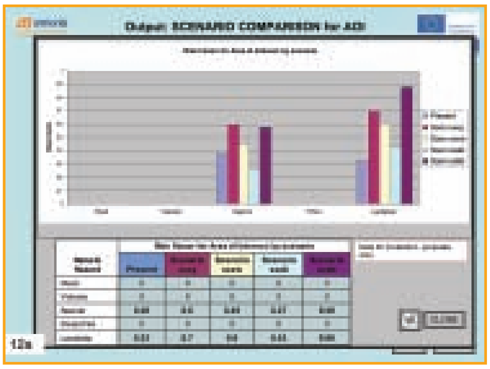
8. Once calculated within the system the 'risk factors' are mapped and visualized.



9. Once the Risk Factors have been calculated for one scenario the user is then given the opportunity to return to the start of the process in order to run another scenario. This second run could, for example, include the effects of placing more residential properties in the AOI (raising exposure), or the building of structural flood defences (adjusting the hazard). It is this capacity for running multiple scenarios that is MURLUMSS' strength. This is because the user is able to examine a number of possible 'risk futures' each created by notionally changing the environment in particular ways whilst also allowing for the process to be politically controlled through a process of multi-stakeholder deliberation i.e. the subjective vulnerability weighting process.

   Presenting multiple outputs to a user or user group assists in decision-making in two important ways:

   1. It allows the user to see how projections of different land use plans and policies could affect the risk levels in the area of study;
   2. It helps to communicate the nature of 'outcome uncertainty' inherent within any decision to develop in hazardous areas.



8.4 The DSS and Strategic Environmental Assessment

Although the SEA Directive is seen as being connected with a certain plan or programme this does not limit the potential for its effects on decision making processes to be complemented through the application of the MURLUMSS methodology. The DSS operates in a very similar fashion to SEA in that in both systems there are explicit stages through which each must progress; i.e. Initiation - Preliminary Analysis - Risk Estimation - Risk Evaluation - Risk Management – Monitoring. Such similarity of process lends itself quite naturally to the possibility of system integration.

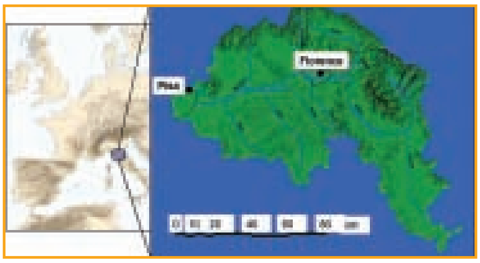


Figure 9.1: The Arno basin, Italy (Del. 6.1-40)

9. Case Studies (Del. 6.1 on CD)

In order to test the ARMONIA DSS methodology it was important to apply it in a case study context. Two such tests were devised with the aims of:

- validating and confirming the methods developed in WPs 3, 4 and 5;
- identifying gaps and limitations in the approaches and to suggest improvements;
- assessing the "usefulness" of the results using readily available data.

In order to achieve these aims the draft ARMONIA methodology incorporated in the DSS framework of WP5 was applied in the Arno River basin in Italy and at a national level in England and Wales.

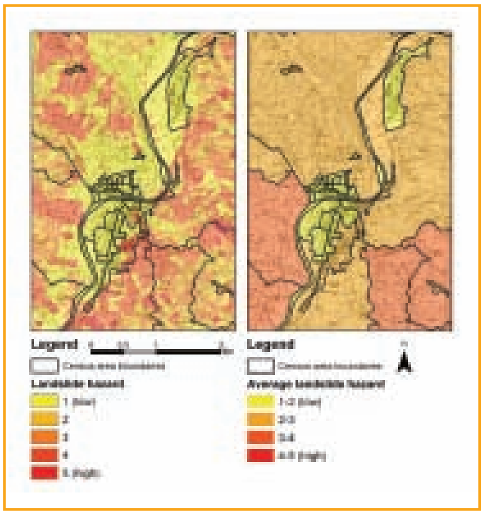


Figure 9.2: Left View: Raw landslide data
Right View: Averaged landslide data
(Del. 6.1- 62)

9.1 Mapping hazards and vulnerability in the Arno River basin (Case Study 1)

The Arno River basin is located almost entirely within the Tuscany region of central Italy. The river is 241 km long and drains a catchment with an area of about 8,228 km2. The catchment area is located within the mountainous region of the Northern Apennines. The location of the Arno River basin is shown in Figure 9.1. The Arno River basin includes 163 municipalities and has a total of some 2.6 million inhabitants.

The Arno River basin is subject to a number of natural hazards including:

- Floods;
- Landslides;
- Earthquakes;
- Forest fires.

Therefore, the basin lent itself to being studied in the context of multi-hazards, and multi-risks. For ease, three hazards were mapped (landslides, floods and forest fires) using the ARMONIA methodology.

9.1.1 Landslide hazard

The landslide data used in the pilot study took the form of a raster dataset with each pixel taking an integer value between 1 and 5; with a score of 1 representing minimum hazard. The average landslide hazard was calculated for each census area. This process loses some of the resolution of the hazard data. Figure 9.2 illustrates this point. However, if the landslide hazard is to be overlaid with vulnerability data which is stored at census level resolution, this generalisation was found to be unavoidable.

9.1.2 Flood hazard

The flood hazard maps took the form of a GIS shape file with four integer hazard classes. This GIS shape file covered the same areal extent as the landslide hazard layer. However, whereas the minimum landslide hazard class was 1, the minimum flood hazard is effectively zero since areas with flood hazard below category 1 were not mapped.

The flood hazard layer needed to be averaged over the census area. The results of this process are shown in Figure 9.3. It is important to note that large census areas which only cross a small portion of the floodplain are assigned a hazard value. For instance the large census area in the north-west corner of Figure 9.3 is assigned a uniform hazard score when in reality the only hazardous portion of that census area is along the floodplain margin.

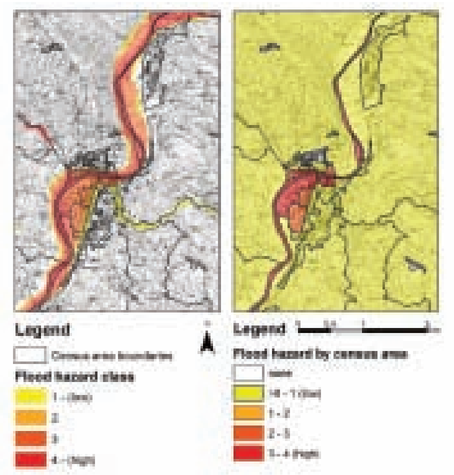


Figure 9.3: Flood hazard map averaged by census area and in its raw form (Del. 6.1-63) Left view: Flood hazard in its raw form Right View Flood hazard averaged over census area

9.1.3 Forest Fire

The forest fire hazard map does not strictly require aggregation at the census level since it does not use any census data. The receptors are the forest areas and the vulnerability is a function of whether the forest is in a protected area. However, census units were used in this hazard mapping exercise (Figure 9.4) so that comparison could be drawn between all the hazard and risk maps.

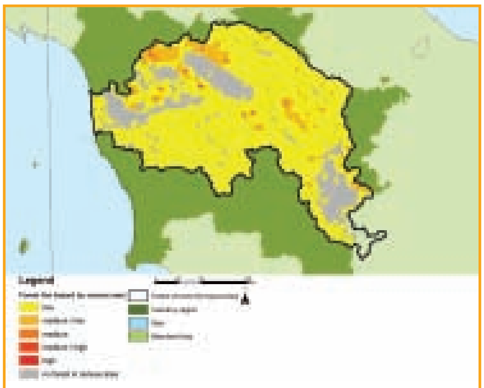


Figure 9.4: Forest fire hazard by census area (Del.6.1-67)

9.1.4 Data Availability

The vulnerability and consequence indices used in the draft ARMONIA methodology require a wide range of census data, especially to assess the indices related to buildings. The lack of a harmonised census data collection system across Europe at present hampers efforts at producing pan-European vulnerability and consequence indices. It is possible, however, that the harmonisation of census data collection in the future (including such variables as building fabric) may make European scale vulnerability analyses possible.

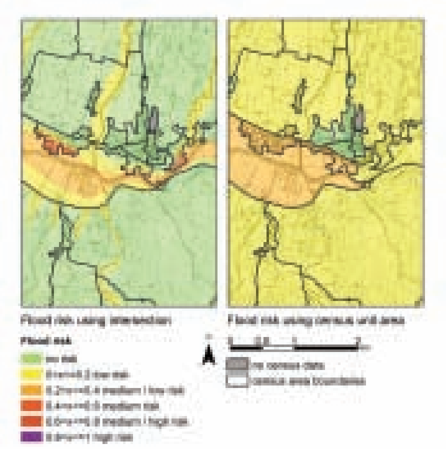


Figure 9.5: Left view, risk mapped as hazard intersection. Right view, risk mapped to census area (Del. 6.1-86)

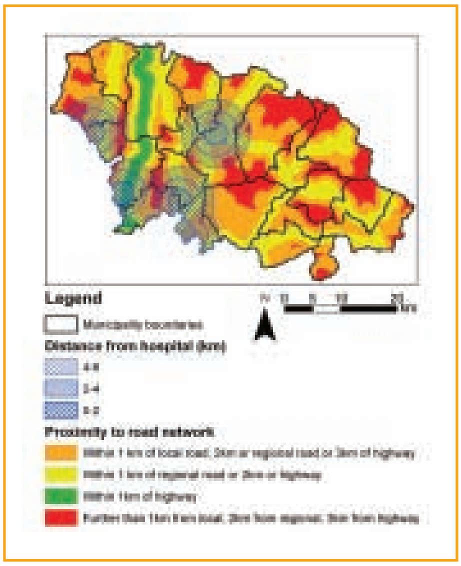


Figure 9.6: Coping capacity mapped as proximity to critical infrastructure (D.6.1-90)

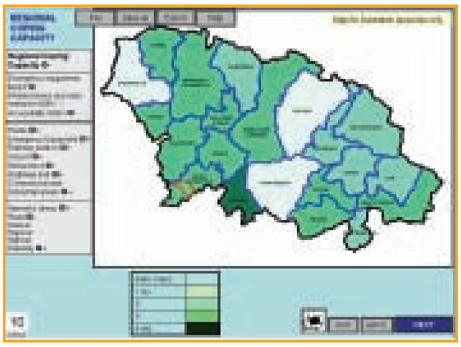


Figure 9.7: Coping capacity based on the road and railway network infrastructure density for the Mugello Region (Del. 6.1-100)

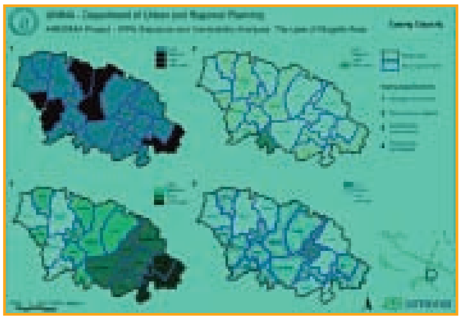


Figure 9.8: Coping capacity for the Mugello Region using accessibility as a proxy 1) Strategic equipment 2) Road and rail networks 3) Accessibility (road) 4) Accessibility (rail) (Del. 6.1- 103)

9.1.5 Implementation of the draft ARMONIA methodology in the Arno River basin

The draft ARMONIA methodology employed by the conceptual DSS was implemented for all the census areas in the Arno River basin which contained census and hazard data. Of the 2479 census areas covered in the flood and landslide hazard data 2263 were used since the remainder did not possess census data. The forest fire data encompassed a larger area, a total of 17,318 census areas, although only 4007 contained forest. Although the conceptual DSS provides a tool for integrating hazard, vulnerability and exposure it is only as precise and accurate as the input hazard and consequence indices and the weightings given to each consequence index by end users. Having discussed a number of techniques through which data could be presented using the ARMONIA methodology an adaptation was proposed whe-

ARMONIA Project – WP6

UNINA - Department of Urban and Regional Planning

00

Area Of Interest: Urban Fabric

Municipality: Sesto Fiorentino

Planning Forecast

Planning Tool: Provincial Coordination Plan of Florence

Land use option: Conservation

Impacts of planning choices on present risk conditions

Hazard increase ☐

Vulnerability increase ☐

Decrease of urban coping capacity ☐

Earthquake

Floods

Landslides

Chained events

Acceptable with mitigation

Coping capacity of the Municipality

Guide-lines for planning

Figure 9.9: Example land use planning table (multi-risk) based on the urban area of Sesto Fiorentino (Del. 6.1-105)

reby population quartiles rather than 'equal interval' data are used and hazard data is used to intersect census areas. Using these methods adds substantial clarity to risk levels (Figure 9.5). The case study analyses also highlighted the importance of applying normalisation to data at specified resolutions as it was found that this process tended to reduce levels of risk if applied at regional rather than local scale.
Coping capacity was found to be best projected graphically by weighting distance from critical infrastructure. This method reduced edge-effects by including the distance of infrastructure outside the area of interest in the analysis (Figure 9.6).

Vulnerability and coping capacity were mapped in more detail for just the Mugello region of the Arno basin. Figure 9.7 illustrates the capacity of the region's road and rail network as a function of its density and Figure 9.8 shows an example of how multiple factors of coping capacity could be mapped.
Additional work was also undertaken to develop a method of presenting detailed site specific information on multi-risk for planning authorities (Figure 9.9). This shows the need to move from general broad assessments to case specific information for particular planning situations.

9.2 Impacts of climate change in the Arno River basin

To complement the Arno basin case study the Potsdam Climate Institute (PIK) ran their CLIMBER-2 intermediate complexity climate model in order to project a range of possible climatic futures for the Tuscany region using four SRES emission scenarios . The results indicated that:

- The coast of Tuscany is threatened by the sea level rise impacts of human-induced climate change. Considering the number of people living in the hazardous zone it might be necessary in the future to relocate coastal buildings, at least in the low-lying coastal regions;
- Summers and winters will become hotter at the end of the twenty first century;
- The summer seasons will be hotter and drier;
- Regarding planning issues; it will be the responsibility of administrative bodies to develop strategies suitable to cope with the reduced water availability. Other strategies could involve developing new building codes to cope with the extreme summer temperatures;
- Estimates for design flood values could be too.

These findings are very useful from a multi-risk planning perspective as they provide important information with which to apply adaptive management principles. Whilst projections are in no way predictions they do give planners and risk managers the ability to assess how the different parts of society could be strained if particular emissions paths are followed. Figure 9.10 and 9.11 illustrate the temperature anomalies which are projected for Tuscany under the A1F1 (fossil fuel intensive) and A2 (most populous) emissions forcing scenarios. These anomalies represent summer mean temperature increases in some regions of 11°C to 12°C (A1F1) and 9°C to 10°C (A2). Figure 9.12 illustrates the projected annual rainfall anomaly for the region under the A2 scenario (the yellow to red ramp indicates a 0 to -120mm reduction in precipitation). If integrated into the DSS methodology projections such as these would not completely eliminate uncertainties about the future but they could assist decision-makers to consider the effects that the climate may have on any development they authorise.

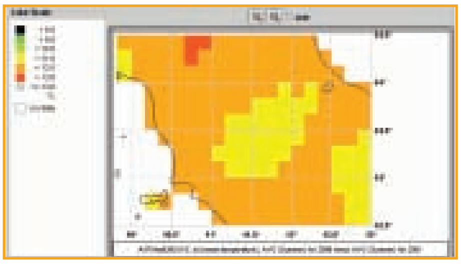


Figure 9.10: Difference between 2001 and 2099 for June, July, August mean temperature. Seasonal summer average temperatures for the Arno River basin for the A1FI scenario (Del. 6.1- 114)

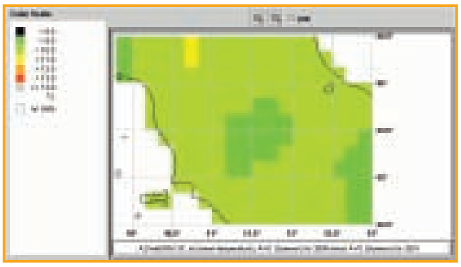


Figure 9.11: Difference between 2001 and 2099 for June, July, August mean temperature Seasonal summer average temperatures for the Arno River basin for the A2 scenario (Del. 6.1-122)

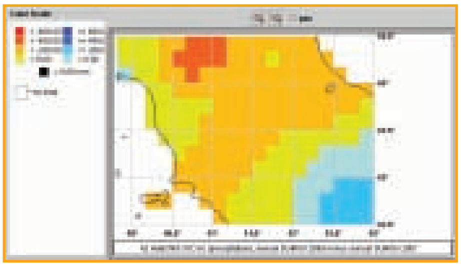
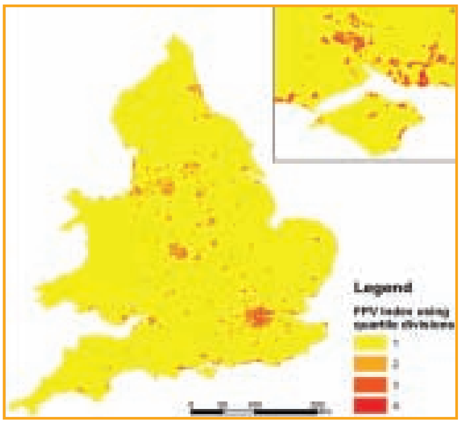


Figure 9.12: Difference between 2001 and 2099 for annual precipitation. Annual sum of precipitation in the Arno catchment for the A2 scenario (Del. 6.1-125)



NB: FPV is the consequence index for people

Figure 9.13: Consequence index for people calculated using quartile divisions (Del. 6.1- 138)

9.3 Mapping vulnerability in England (Case Study 2)

As well as piloting the draft ARMONIA methodology in the Tuscany Region of Italy it has also been piloted in England and Wales using readily available data sets. This allowed the methodology to be tested at a national scale as well as a regional scale. Data on the following natural hazards were available:

- Floods;
- Seismic activity;
- Landslides.

Although the draft ARMONIA methodology provides indices for receptors like buildings and roads this case study used people as the sole receptor due to fact that many of the variables used to create the buildings and roads indices are not collated within England and Wales as they are in Italy. Human vulnerability and risk indices were developed using census 2001 data.
Figure 9.13 shows how the quantile division of the national population data provides a relatively useful vulnerability index using just the <5 and >64 age variables. Calculating risk was also carried out using the national dataset and was applied to the city of Manchester (Figure 9.14).

In using the ARMONIA methodology for risk mapping in England and Wales a series of challenges were identified:

1. The methodology tended to exaggerate the risk from seismic hazard in the countries. On a global scale seismic hazard in the UK is low and flooding demands far greater resource allocations;
2. Other indices which have been created in the UK in order to map people vulnerability produce more useful results than the ARMONIA indices (e.g. the Social Flood Vulnerability Index (SFVI) by Tapsell et al 2002);
3. Decision makers in the UK tend to be interested in risk to natural hazards being defined in terms of direct economic damage and/or loss of life. It was uncertain how useful the ARMONIA methodology's output of a risk factor could be used by decision-makers more familiar with these other methods. Notwithstanding as noted earlier the fragility curves which are used to inform economic damage/loss of life calculations do not yet exist for a number of the hazards studied.

Following its application in all the case studies it was suggested that the ARMONIA consequence indices were limited in their predictive power in relation to mapping the vulnerability of people, buildings and network infrastructure.

Suggestions were made that could potentially increase the efficacy of these indices (e.g. through including a variable which describes the aggregation of buildings in order that apartment blocks are registered as more vulnerable than single isolated farm buildings). The application of some social variables which are collected throughout the EU states to bolster the draft use of just age variables for people vulnerability was also suggested (e.g. educational attainment and employment status are two useful variables collected in at least 15 European countries).

Recommendations and conclusions

The following represents the main conclusions and recommendations that resulted from the case study work:

- The draft ARMONIA methodology requires further validation in areas where quantifiable risk metrics such as economic damage and loss of life are available for a number of different hazards;
- Alternative multiple risk mapping methods that are not as data specific as the draft ARMONIA methodology need to be investigated further;
- Many decision makers require risk metrics that are quantifiable (e.g. economic damage, potential loss of life) in order to plan sustainable hazard mitigation measures. More work is required on vulnerability curves for a number of exposed elements and hazards to allow risk metrics to be quantified;
- In appreciating the importance of participative governance there needs to be greater research into what the end users of risk maps actually require. Although spatial planners in many European countries only currently use hazard maps, other decision makers, responsible for implementing hazard mitigation measures, need to know specific information in the form of quantifiable risk metrics in order to assess whether the proposed mitigation measure is sustainable from both an environmental and economic point of view.

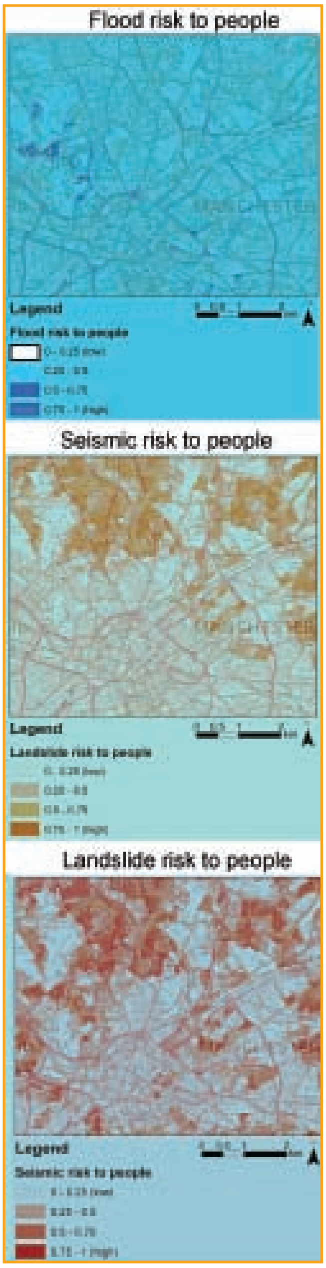


Figure 9.14: Risk mapped using the ARMONIA methodology in the centre of Manchester (Del. 6.1-142)

10 Recommendations for European Policy (Del. 3.3 on CD)

At the culmination of all the work packages, which defined state-of-the-art in spatial and land-use planning policy; hazard mapping; vulnerability mapping and risk mapping; the production of a draft decision support system and the testing and improvement of the methodology for that system in two European case study areas, the ARMONIA Project concluded by issuing a proposal for a:

European Parliament and Council Directive on the implementation of multi-risk analysis into land use planning and management for the reduction of natural disasters.

This proposed Directive would lay down a framework for the reduction of risk to human health, the environment and economic activity associated with natural hazards vs. land use planning and management in the European Community.

It would recognise that planners need to act on several risk-related factors, including: the hazard component; exposure and the vulnerability of exposed systems as well as, to a certain extent, on the overall risk. It would point out the consequential need for a much improved integration among evaluations and analyses that are produced by various disciplines. Pointing out that a single-hazard approach should be avoided and consideration should be made to the potential enchainment effects among different threats and the other relevant component of risk; that is, the vulnerability of exposed systems.

It would recognise:

- the need for the integration of scientific evidence with the perspectives and aspirations of agencies and with different branches of public administrations in charge of various preventative actions;
- the relevance of space and time factors in the consideration of risks, that are dynamic components of modern societies;
- the apparently more technical issue of multiple land ownership regimes, the control of which determines the type and quality of prevention that can be achieved across the different states.

The proposal recommends that tools be developed that would:

- allow the purchase and 'retirement' of exposed land parcels from the planning process;
- the relocation of existing exposed developments;
- the influence of the market mechanism (through economic incentives such as insurance) in order that it would become more profitable to develop in safe rather than exposed areas.

In relation to multi-risk mapping the proposal suggests that the impact and consequences of natural events which have national and trans-national effects would be reduced if common approaches and formats were applied.

Such multi-risk analyses should involve:

- Analysis at three main spatial scales (strategic regional, local general, local site);
- The mapping of hazards including: the site/area of the event; intensity/ severity/magnitude of each natural event through parametric scales; return time of events related to potential triggering factors and/or maximum expected event;
- The identification and analysis of exposed elements at risk where possible using a fragility chart where the probability of damage and typology is a function of the intensity, for any individual exposed elements or category. Vulnerability should consider different parameters in the different geographical scale of analysis, (i.e. physical vulnerability, urban coping capacity, social coping capacity, socio-economic coping capacity), as well as building and network vulnerability;
- The analysis of risk for all individual categories of hazard. Risk is given in terms of probability of expected losses or damage, for a given asset or engineering constructions and typology, for a given return period. Two main methods can be used to carry out such analysis such as vulnerability curves or damage matrix approach;
- Areas of land at risk from enchained hazards;
- Harmonisation of individual values of damage (risk) and maps derived from each hazard analysis, for the same return period expressed in the same unit. A multi-layered hazard map, without aggregating hazards, can be produced by overlaying single hazard maps, using a GIS environment.

Under the Aarhus Convention all these maps would be accessible to all organizations involved in risk management and to members of the public.

Scientific partners

T6 Società Cooperativa

Staffordshire University, Institute for Environment and Sustainability Research, Faculty of Health and Sciences

Geological Survey of Canada, Natural Resources, Terrain Sciences Division, Canada Landslide Project

Ceske Centrum pro Strategicka Studia, Water Management Department

Università degli Studi di Napoli Federico II, Department of Urban and Regional Planning and Earth Sciences

Geologian tutkimuskeskus, Espoo Unit, Geology and Environment

HR Wallingford Ltd, Department of Water Management

Universität Dortmund, Institute of Spatial Planning, Faculty of Spatial Planning

European Commission - DG Joint Research Centre, Institute for Environment and Sustainability - Land Management Unit

Potsdam Institut fuer Klimafolgenforschung, Departement Integrated Systems Analysis

Politecnico di Milano, Department of Land Use and Urban Planning

Algosystems SA, Research & Development Department

Lancaster University, Department of Geography

www.wizardcomunicazione.eu

Web site for further information:
www.armoniaproject.net

armonia

The project involved 13 partners from Czech Republic, Germany, Greece, Finland, Italy, United Kingdom and Canada.
ARMONIA started on 1 October 2004 and ran until 31 March 2007.

Contacts: **T6**
Via Genova, 30 - 00184 Rome - Italy
Tel. +39 06.47823286 . Fax +39 06.47882798
E-mail : info@t-6.it Website : www.armoniaproject.net