

INTERREGIONAL
RESPONSE
TO NATURAL
AND MAN-MADE
CATASTROPHES
SIPROCI



5

RISK MAPPING

A PROPOSAL FOR A COMMON EUROPEAN
METHODOLOGY



 PROJECT PART-FINANCED
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North East South West
 INTERREG I I I C

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www.siproci.net

RISK MAPPING A PROPOSAL FOR A COMMON EUROPEAN METHODOLOGY

*"Europe will not be made all at once,
or according to a single plan.
It will be built through concrete
achievements which first create
a de facto solidarity."*

*Schuman Declaration
9 May 1950*



SIPROCI is an EU-funded project that helps local and regional authorities to better forecast, prevent and respond to natural and man-made disasters.

Thanks to SIPROCI, 13 partner organisations from 7 European countries exchanged best practices, simulated different emergency situations and developed new joint methods and tools for disaster management.

These include a glossary of Civil Protection (CP) for EU citizens, minimum standards for local CP plans, good practices of using information and communication technologies in CP, a proposal for a common European risk mapping methodology and European strategies for CP communication to citizens.

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INTRODUCTION

This handbook has been realised in the framework of the European Project SIPROCI - "Interregional Response to Natural and Man-made Catastrophes", promoted by the Province of Macerata (Italy) in partnership with various Civil Protection authorities and organisations in Europe. The aim of this project is to improve local and regional response to catastrophes and disasters through interregional collaboration across Europe.

13 Civil Protection authorities coming from the Czech Republic, Germany, Greece, Hungary, Italy, Poland and Spain have closely collaborated in four different thematic Working Groups to exchange, develop and transfer methods and good practices for improved solutions to natural and man-made catastrophes.

One of the Working Groups (Working Group 3) analysed and compared "methods, techniques and instruments for how to monitor and map risks" among different countries. Focus has especially been put on methods for risk mapping.

The Working Group members have selected and proposed one best method, mainly based upon the one already successfully applied in the Province of Macerata (Italy). The method has been improved by further studies, considerations and analysis of the various processes used in other European and non-European countries. As such, this method constitutes a proposal for a best practice for risk mapping and reflects the necessity of having guidelines, preferably common to all EU countries.

This handbook is an extract from a more extensive report which summarises the proposed best method for risk mapping selected by the Working Group.



Disaster simulation exercise in Spain (earthquake) - SIPROCI project

ADVANTAGES OF A COMMON METHOD FOR RISK MAPPING

The advantage of the adoption of a common methodology provides greater ease in confronting and exchanging information and data between experts and technicians operating in the civil protection field.

In fact, the use of a common risk classification and a common terminology would allow for uniform forecasting and prevention of risk activities and emergency management. In addition, exact knowledge of the expected consequences would be possible in a certain risk area after the calamity if the risk scenario were referred to in common standards.

The existence of a common risk classification could make it possible to have an almost objective criteria for the distribution of funds to different countries, regions, provinces (or districts) and cities, giving priority to areas characterised by higher risk levels.



In addition, this way of proceeding could be the basis for having common strategies for risk mitigation in areas with the same level of risk, even if belonging to different countries.

The proposed methodology for risk mapping deserves further study and European diffusion. Actually, the value and efficiency of this data collecting system would be of greater importance if it was not limited to local situations, but rather spread out to the governments of each country, regardless of budgets and political ideas.

The method described in this document has been analyzed in each partner's different country in the hope of ensuring the adoption and the usefulness of these implantations. The main difficulty for implantation of such methodology is that each country already has its own methodologies, software, databases and mapping systems, so that it might not be easy to adopt a unified method because of social, economic and political aspects within different countries. For this reason even if the countries participating in this project are obviously the potential primary target groups for transfer and implementation, discussion at a European scale should be launched to lay the basis for a more unified method for risk mapping.



HVA PROCESS (hazard vulnerability analysis) GENERAL CRITERIA

PREMISE

Risk mapping is the process of identifying areas at different levels of risk. In other terms it is the representation of the results of risk assessment on specific maps, showing the levels of expected losses which can be anticipated in specific areas, during particular disaster hazards.

It is generally acknowledged that methodology for risk mapping should be drawn up for each type of risk. However, once a methodology has been established for a given risk it can be extended and adapted to other risks, providing all necessary analysis is carried out considering the peculiarity and distinctiveness associated with a certain event.

It should be remarked that a full understanding of all kinds of risks requires the development of a complex methodology which also includes the use of statistical and numerical analysis. Sometimes it may not always be possible to adopt a complete probabilistic approach because of the difficulties in its application, especially considering the aim to have expeditious risk mapping in those countries where it has never been applied. In such cases a qualitative approach is needed, mainly based on past experiences.



Educational tool used in the Czech Republic - SIPROCI project

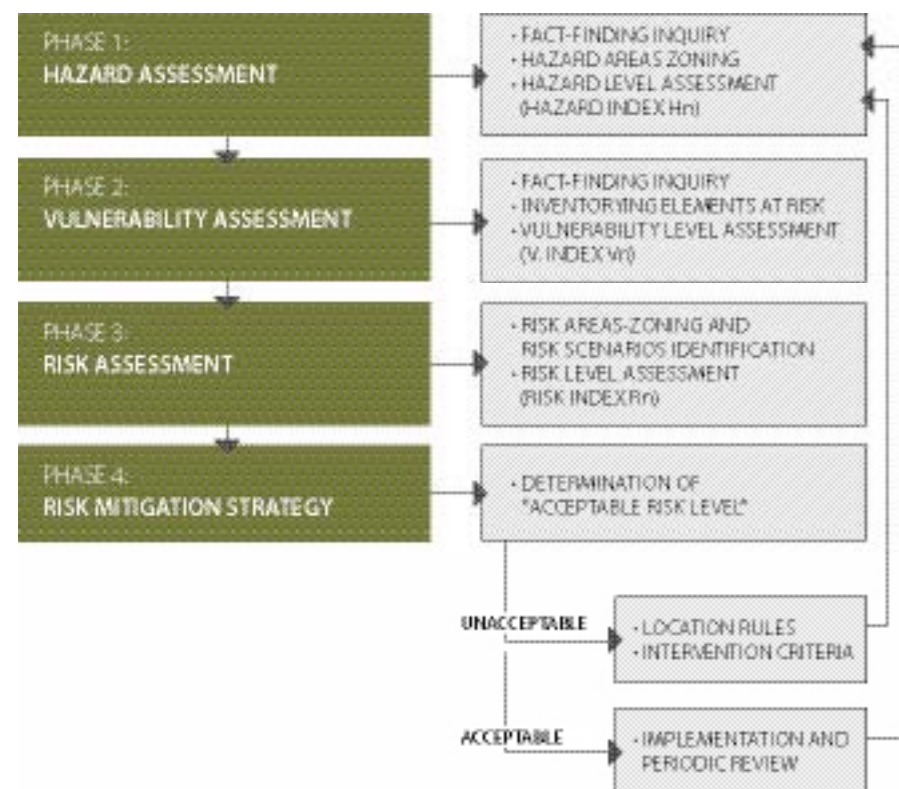
PHASES OF THE METHODOLOGY

HVA (Hazard Vulnerability Analysis) is the process of evaluating risk associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude and severity, exposure and consequences.

When conducting a hazard-vulnerability analysis one identifies, using current knowledge or some degree of existing building stock, those structures and areas that are vulnerable to hazards. In addition, a community growth plan or flat map superimposed on the hazards map will help you identify areas vulnerable to natural hazards. Vulnerability identification determines the facilities at risk and to what degree they might be affected, as well as how they might affect other surrounding structures.

The aforementioned process allows decision-makers to anticipate losses, evaluate potential impacts, and facilitate effective emergency planning and hazard risk management.

In agreement with HVA process, methodology for risk mapping should be divided in two main groups of phases:



The first main "group of phases" should define risk scenarios by analysing each risk and its implication in terms of hazards and vulnerabilities:

- 1) phase 1: hazard assessment
- 2) phase 2: vulnerability assessment
- 3) phase 3: risk assessment

The second main phase should concern the planning strategies for risk mitigation:

- 4) phase 4: risk mitigation strategy

The flowchart (on the left) depicts the mentioned HVA process, showing its application as various options are assessed and an optimal solution with acceptable risk is attained. It requires an assessment of what level of risk is acceptable, given that it is not generally possible to reduce risk to zero. The acceptability of certain risks may vary both in different countries and in time.

ELEMENTS AT RISK

The proposed list of elements at risk, to be understood as those things adversely affected by destructive events should include, as follows:

- population;
- buildings (urban and rural settlements);
- productive areas and primary resources: economic activities, such as industrial and productive areas, including areas housing technological plants, but in general, areas housing particularly dangerous factories at high risk of chemical and industrial accidents;
- infrastructural networks;
- technological networks;
- cultural heritage;
- environmental resources.

RISK DEFINITION

In the consolidated existing literature, risk should be the result of the interaction among three main factors:

- **hazard (H)**: defined as "the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon of a given magnitude".
- **vulnerability (V)**: defined as "the level of loss to a given element or sets of elements at risk resulting from the occurrence of a damaging phenomenon of a given magnitude", meaning "the percentage of the lost value of a given physical system exposed to a given destructive event or the sensitivity of a given system to be damaged or to resist when exposed

to a certain destructive event of a given magnitude".

• **value of the elements at risk (E)**: defined as "those elements adversely affected and similarly damaged by the same type of risk". The value does not refer only to a mere economic calculus.

The most acknowledged expression of risk in literature defines risk as the product of the previously mentioned factors:

$$R = H * V * E \text{ (risk equation)}$$

According to the risk equation, risk in the acceptance of "total risk" (R) means "the expected losses (numbers of lives lost, people injured, damage to properties, or disruption of economic activities) due to a particular damaging phenomenon".

Since hazard (by this definition) is always a frequency, it is always potentially measurable. As a consequence, risk depends on probability and consequences of the event, so that safety is based on a quantitative measure for risk.

However, more complex definitions should be based on different indicators related to vulnerability and hazards and their interactions including the following parameters:

- the probability that a given event might occur at a given time;
- measures of risk prevention/reduction/remediation.

Because of the difficulties in determining hazard and vulnerability in proba-

bilistic terms, and in determining the value of the elements at risk, it is often preferred to adopt a user-friendly definition of risk to allow a more expeditious risk mapping. So risk, to be understood as "specific risk" (R_s), means "the expected level of loss due to a particular damaging phenomenon":

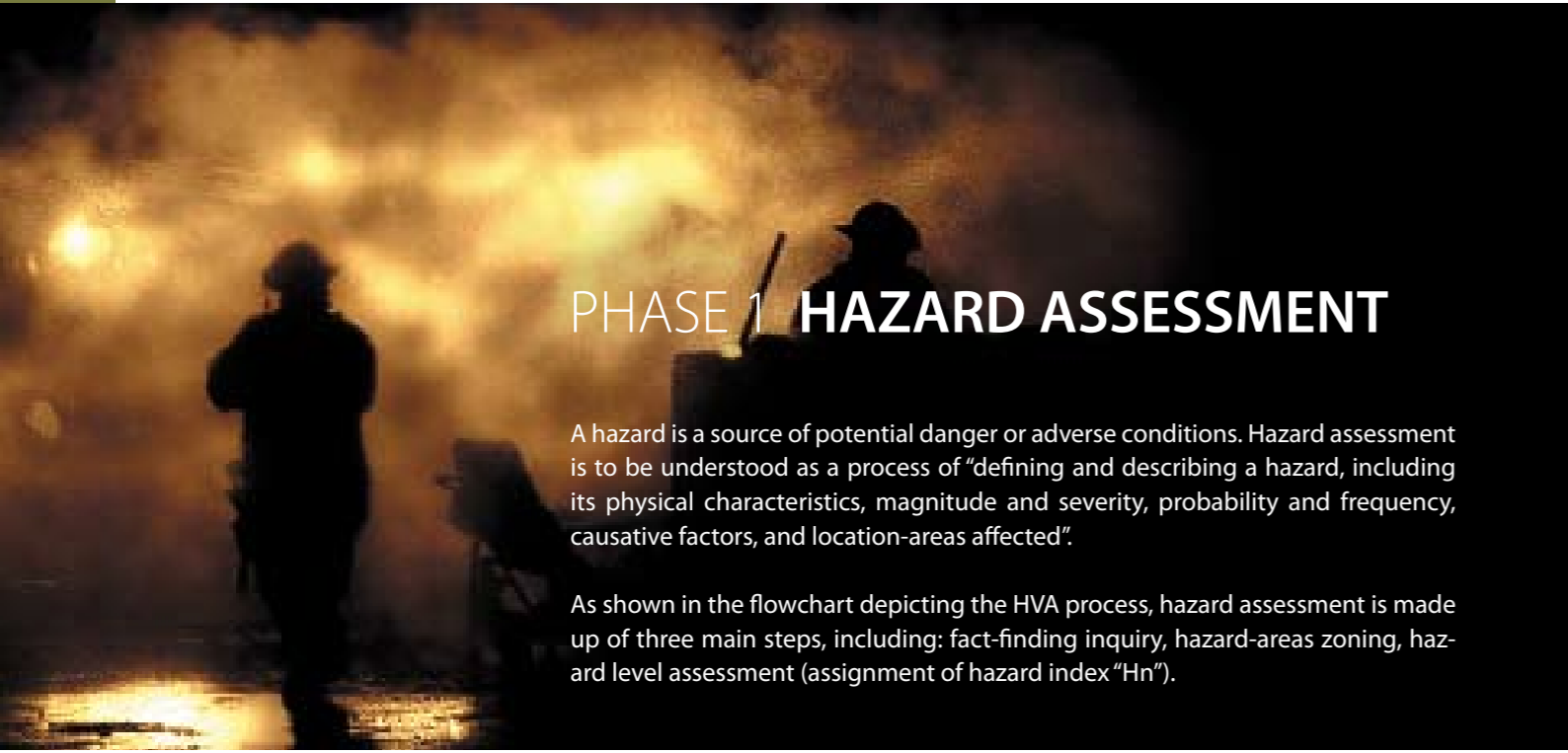
$$R_s = H * V \text{ (simplified risk equation)}$$

Total risk (R) is function of specific risk (R_s) through the expression: $R = R_s * E$

For simplicity, in the present work specific risk is indicated by "R" and not by "R_s".



Disaster simulation exercise in Germany (industrial accidents) - SIPROCI project



PHASE 1 HAZARD ASSESSMENT

A hazard is a source of potential danger or adverse conditions. Hazard assessment is to be understood as a process of “defining and describing a hazard, including its physical characteristics, magnitude and severity, probability and frequency, causative factors, and location-areas affected”.

As shown in the flowchart depicting the HVA process, hazard assessment is made up of three main steps, including: fact-finding inquiry, hazard-areas zoning, hazard level assessment (assignment of hazard index “Hn”).

FACT-FINDING INQUIRY

A comprehensive knowledge of the physical territory should be compiled, making use of all existing data, analyses and technical studies and of further studies eventually needed. In particular the following main factors should be investigated, concerning a possible *threat* present in a certain area:

- **extension**, in relation to land morphology and intrinsic vulnerability;
- **magnitude** in terms of energy produced;
- **return period**, in terms of probability of recurrence.

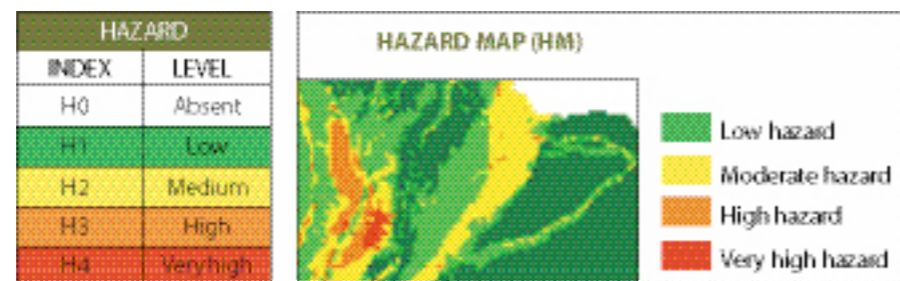
HAZARD-AREAS ZONING

An expeditious zoning of areas threatened by a potential hazard is made possible by the acknowledgement of the extension of the threat.

It makes it possible to produce a map referring to a specific hazard, briefly named “*Hazard Map*”, useful for marking the different hazard zones. Such cartographies can be better developed on GIS platforms, permitting the digitization of cartographic phenomena and their geo-references.

HAZARD LEVEL ASSESSMENT (HAZARD INDEX “Hn”)

Thanks to specific numerical and statistical analysis based on the remaining mentioned factors, such as magnitude and return period, it is possible to associate a hazard index “Hn” to the corresponding hazard zone. The proposed classification of hazard includes five impact indicators (hazard indices: H0, H1, H2, H3, H4) corresponding to hazard levels (absent, low, medium, high, very high), as shown in the following table:



The current indicators can certainly be replaced by different and more appropriate indices developed within further advanced research and studies about a certain kind of hazard.

PHASE 2 VULNERABILITY ASSESSMENT

As shown in the flowchart depicting the HVA process, vulnerability assessment is made up of three main steps, including: fact-finding inquiry, inventorying elements at risk, vulnerability level assessment (assignment of vulnerability index “Vn”).

FACT-FINDING INQUIRY

The acquisition of information about vulnerable elements is useful for characterising the anthropic system and is an important task in the construction of appropriate risk scenarios.

INVENTORYING ELEMENTS AT RISK

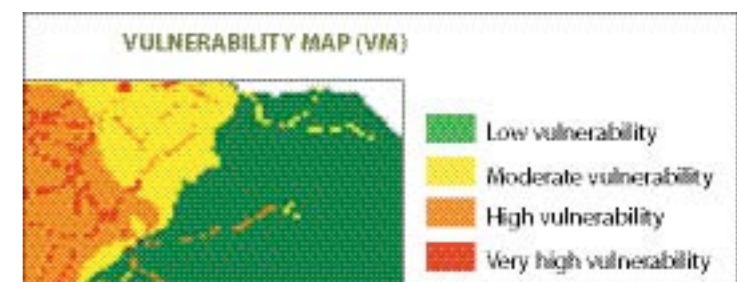
The procedure involves making maps referring to the elements at risk, briefly called “*Vulnerability Map*”. Such maps should contain the exact localization of vulnerable elements through their geo-references. The use of GIS platforms should allow one to associate the database to cartographies.

VULNERABILITY LEVEL ASSESSMENT (VULNERABILITY INDEX “Vn”)

Thanks to specific numerical analysis and/or mere reflections upon the anthropic system, it should be possible to associate a vulnerability index “Vn” to the corresponding zones including elements at risk.

The proposed classification of vulnerability includes five vulnerability indicators (vulnerability indices: V0, V1, V2, V3, V4) corresponding to different vulnerability levels (absent, low, medium, high, very high), as shown in the following table.

VULNERABILITY		ELEMENTS AT RISK						
LEVEL	INDEX	PEOPLE	BUILDINGS	PRODUCTIVE AREAS	CULTURAL HERITAGE	INFRASTRUCTURE NETWORKS	TECHNOLOGICAL NETWORKS	ENVIRONMENTAL RESOURCES
ABSENT	V0	absent	absent	absent	absent	absent	absent	absent
LOW	V1	low density	very high quality/ low quantity	minor activities	absent	LN of limited interest	TN of limited interest	absent
MEDIUM	V2	medium density	high quality/ medium quantity	medium activities	absent	LN of local interest	TN of local interest	absent
HIGH	V3	high density	medium quality/ high quantity	major activities	minor CH	secondary LN	secondary TN	minor ER
VERY HIGH	V4	very high density	low quality/ very high quantity	major activities at high risk of accident	major CH	primary LN	primary TN	major ER





Disaster simulation exercise in Germany (industrial accidents) - SIPROCI project

The accuracy of the vulnerability index depends on the quality and quantity of collected information and on the way such parameters (elements at risk) are compared and combined (see paragraph "Calibration of the methodology: a possible approach").

It is also important to have information on the emergency task force team (local police stations, fire stations, and hospitals) useful for determining possible difficulties during rescue operations, clearly increasing vulnerability.

So, the context in which the disastrous event happens is very important. The classification should follow a more realistic approach taking into account a wider number of other factors emphasizing, among others, the physical peculiarities of the territory or the special needs

posed by emergency management. As an example, risk scenarios related to population exposed to a given hazard will take into account not just "urban concentration" but also the following factors:

- people's distribution (i.e. urban centres, scattered houses, etc.);
- easy access to emergency facilities;
- easy access to damaged sites;
- children and aged population involved;
- others.

Collected data about elements at risk, such as population and the number of important businesses or industries will always be in a state of dynamic change. This dynamic change will eventually cause the database created to be null and void; therefore, it will be necessary to periodically update it.

PHASE 3 RISK ASSESSMENT

As shown in the flowchart depicting the HVA process, risk assessment is made up of two main steps, including: risk-areas zoning and risk scenarios identification; risk level assessment (assignment of risk index "Rn").

RISK-AREAS ZONING AND RISK SCENARIOS IDENTIFICATION

First, the process of risk assessment requires the identification and characterization of risk scenarios. Risk scenarios are the full representation of those phenomena which somehow interfere with life in a given territory causing loss and damage.

The identification of risk areas is made possible through the overlapping of Hazard Maps and Vulnerability Maps (from phases 1 and 2 respectively). It is deemed necessary not only to limit the identification of the risk levels in

quantitative terms (for example the subdivision of the risk levels that come from the hazard and vulnerability levels), but to identify the different risk scenarios in relation to the specific characteristics of the territory, its strengths and weaknesses, and realistic emergency management possibilities.

Risk scenarios are fundamental in forecasting and prevention activities, constituting the essential data of a civil protection plan in particular and of a civil protection system in general. Identifying risk scenarios and their implications in terms of hazards and vulnerabilities should be the main objectives and contents of the Emergency plan.

Another aim is to make a useful instrument for identifying the indispensable interventions for the safety of the territory. This operation can be adequately done

only through detailed knowledge of the causes and the effects of phenomena and in all of their possible manifestations.

RISK LEVEL ASSESSMENT

(RISK INDEX "Rn")

The possible scenarios derive from the interaction of the classes of hazards (H0, H1, H2, H3, H4) with the classes of vulnerability (V0, V1, V2, V3, V4) described in the previous paragraphs.

So risk can be classified into the following five classes:

- **R0** (no risk): the risk is absent;
- **R1** (low risk): the risk is negligible;
- **R2** (medium risk): the risk is socially tolerable without prevention activities;
- **R3** (high risk): the risk is not always socially tolerable and prevention activities are previewed;
- **R4** (very high risk): the risk is not socially tolerable and prevention activities are needed.

RISK			VULNERABILITY				
			V0 absent	V1 low	V2 medium	V3 high	V4 very high
HAZARD H	H0	absent	R0	R0	R0	R0	R0
	H1	low	R0	R1	R1	R1	R1
	H2	medium	R0	R1	R2	R2	R3
	H3	high	R0	R1	R2	R3	R4
	H4	very high	R0	R1	R3	R4	R4

For each combination of hazard classes and vulnerability classes an output risk class could be assigned through the matrix on the left, which constitutes just a proposal.



Disaster simulation exercise in Hungary (earthquake) - SIPROCI project

In agreement with risk equations, risk is null (R0) only if at least one of the multiplying factors (**H or V**) is zero, that is when a certain threat cannot cause losses (e.g. a strong earthquakes in a desert with no elements at risk exposed) or when no threats exist in an area characterized by a very high-level of vulnerability (e.g. no earthquakes in a crowded town).

The following table shows the possible consequences or damages to the elements at risk in relation to the risk indices. It shows the existence of a correspondence between risk indices and the possible risk scenarios.

VULNERABILITY		ELEMENTS AT RISK						
LEVEL	INDEX	PEOPLE	BUILDINGS	PRODUCTIVE AREAS	CULTURAL HERITAGE	INFRASTRUCTURE NETWORKS	TECHNOLOGICAL NETWORKS	ENVIRONMENTAL RESOURCES
LOW	R1	safety not bound to fail	marginal damage	marginal damage	marginal damage	marginal damage	marginal damage	marginal damage
MEDIUM	R2	safety not bound to fail	minor functional or aesthetic damage without evacuation	minor damage without activities interruption	minor functional or aesthetic damage	minor damage without evacuation	minor damage without interruption of services	minor damage
HIGH	R3	possible problems of safety	significant functional damages and consequent evacuation	significant damage with temporary interruption of activities	significant damage	significant damage and consequent evacuation	significant damage with temporary interruption of services	significant damage
VERY HIGH	R4	possible loss of lives and severe injuries to people	severe damage and consequent evacuation	severe damage with interruption or destruction of activities	severe damage	severe damage and consequent evacuation	severe damage with interruption or destruction of services	severe damage



PHASE 4 RISK MITIGATION STRATEGY

Risk mitigation strategies are made up of analyses and studies, also represented graphically, which are enough to determine how to act in order to mitigate or avoid the risk, to plan the possible financing of the structural and non structural measures for risk mitigation and lastly, to define territorial restraints such as possible relocation of settlements and correct land-use.

This phase should include geological and geotechnical study to achieve planning criteria and monitoring.

As shown in the flowchart depicting the HVA process, risk mitigation strategy is made up of three main steps, including: determination of "acceptable risk level"; identification of "location rules"; identification of "intervention criteria".

ACCEPTABLE RISK LEVEL

Before determining planning strategies for risk mitigation, it is necessary to evaluate "acceptable risk level". Acceptable risk is the level of risk which is acceptable to society, an enterprise or an individual. Acceptable risk can be expressed in quantifiable terms by gauging the elements contained in a risk assessment, or by taking a qualitative approach.

There is no single level of risk that is acceptable in all cases. The acceptance of risk is an important decision that will vary due to a large number of circumstances. The acceptable risk level strictly interacts with the idea of absolute safety. Experience demonstrates that absolute safety, which means a condition of an absence of risk, is impossible to be reached due to the unforeseeable, or unconsidered risks and human error. Therefore, the idea of safety has to be considered in relative terms. In fact, if a high level of safety corresponds to a low level of risk and vice versa, then absolute safety corresponds to a null risk.

It is necessary to live with a rationally acceptable risk level, minimized by a common safety strategy. The acceptability of risk, as well as the perception of risk may vary from subject to subject. Furthermore, they are both strictly subjective and interact with perceived probability, which differs from the real level of probability. For instance, if we consider a worker in an industrial plant, thanks to his job duties, job proficiency and the information that his job gives him, his acceptable risk level is different from that of the rest of the population. For frequent events, which have a high probability of



occurring, the perception of risk often coincides with the real level, for less frequent events the real level of risk tends to be mistakenly exaggerated by the public, whereas for rare events the real level of risk is often underestimated by the public. For instance, the perception of risk and the risk acceptability regarding an earthquake are quite different for the Japanese population, accustomed to daily seismic activity, and European inhabitants, subject only to desultory seismic tremors.

It has also been shown that some factors can create a low perception of risk in the population, such as in the case of actions undertaken on a voluntary basis, personal control over the risk, the lack of consequences for future generations, up-to-date technologies, the tendency to quickly forget about past disasters



Disaster simulation exercise in Italy (forest fire) - SIPROCI project

and the involvement of only one or few social classes. It is also evident that, according to different kinds of society, the real risk may or may not coincide with the perceived risk. "Acceptable risk" is a product of the society where it is perceived and involves consideration of social, economic and political factors.

As a result, the acceptable risk level does not necessarily represent the "safe level" but rather a point of reference. The real level of risk should, of course, be lower than the level of risk considered "acceptable", which again, is a point of reference.

The knowledge of such levels makes it possible to identify the priority for interventions aimed at risk mitigation and the decisions regarding risk management.

LOCATION RULES

Location rules aim at the mitigation of vulnerability or exposure to risk through "non structural measures", i.e. a correct planning of the activities allowed in the areas exposed to risk.

INTERVENTION CRITERIA

Intervention criteria aim at the mitigation of hazard through "structural measures", which should be straightforward actions such as environmental safety, recovery and reclamation, consisting of direct interventions (e.g. in the case of floods, plumbing works), in intervention-reducing acting forces (e.g. in the case of landslide: risk, drainage, re-profiling and reduction of slopes), and/or in interventions increasing resistant forces (e.g. in the case of landslide: anchorages and strengthening).

CALIBRATION OF THE METHODOLOGY: A POSSIBLE APPROACH

It is clear that an area classified at very high risk on an urban level could be at moderate risk on a regional level. This shows the necessity of calibrating the proposed methodology: first the calibration depends on the level (national, regional, provincial, urban) upon which we conduct the analysis. Such level will be hereafter named "area level".



The "Vulnerability level" is the main factor influencing the final "Risk level", because of the possibility that it could change based on the "area level" investigated. Areas with the highest population, important industries and businesses, important infrastructural and technological networks and with more cultural heritage and environmental resources will be considered the most vulnerable. The level of vulnerability of each area at risk, depending on the above-mentioned attributes, such as the elements at risk (see paragraph "Phase 2 - vulnerability assessment"), should be determined on a point scale. Since the values of each attribute are so different, it would be extremely difficult to compare them to one another.

To resolve this problem, values of attributes for each "area level" should be normalised. This could be done by dividing each value of each "area level" by the largest value in that particular attribute. This process will give us a value between 0 and 1, allowing a comparison also taking the area level effect into consideration. Once the values of the attributes have been normalised, the order of importance of the attributes should be determined, associating a corresponding weight to each attribute. A numerical vulnerability index is now calculated thanks to the following equation:

$$V.I.(i) = \sum_j w_j * a_{ji}$$

where "j" is the attribute, "i" is the "area level", "w" is the weight, and "a" is the normalised value of that attribute.

The correspondence between the "numerical vulnerability index" (V.I.) so obtained and the proposed vulnerability indices (V0, V1, V2, V3, V4) should be given through an appropriate scale.

Similar consideration could be made for hazard assessment.

In conclusion, the importance of good calibration of the methodology in such numerical approaches is evident: it clearly deserves further studies to obtain a general methodology applicable on different levels and in different countries.



Disaster simulation exercise in Germany (industrial accidents) - SIPROCI project

FURTHER READING, PROJECT INFORMATION AND CONTACT DETAILS

6 booklets have been realised in the framework of the SIPROCI project. They can be downloaded in 8 language versions at www.siproci.net



Other useful information and website links:

Home page of the Interreg IIC Programme • www.interreg3c.net

European Commission's homepage for Regional Policies • www.ec.europa.eu/regional_policy/index_en.htm

European Commission's homepage for Civil Protection • www.ec.europa.eu/environment/civil/index.htm

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