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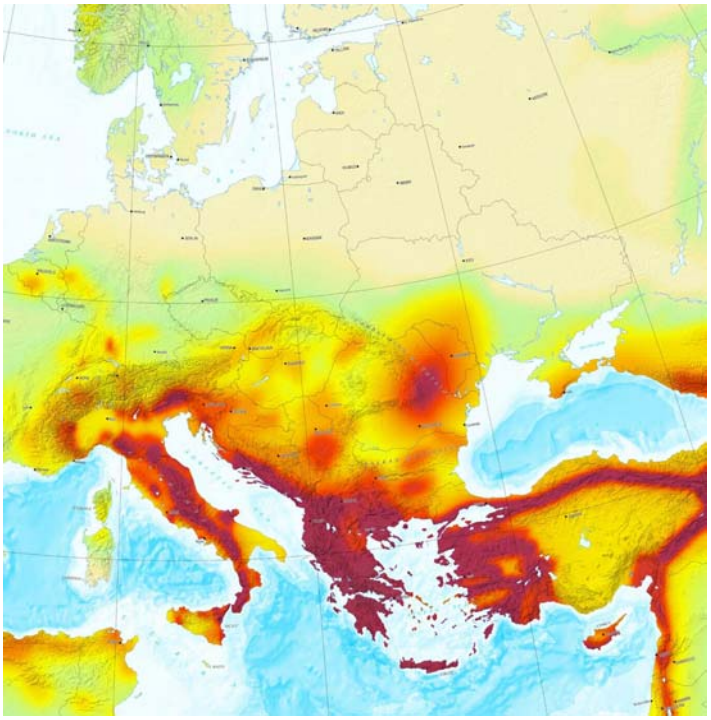
Risk Mapping of Earthquakes in New Member States

by

Boyko Ranguelov, Róbert Jelínek, Maureen Wood and Javier Hervás



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The Institute for the Protection and Security of the Citizen provides research-based, systems-oriented support to EU policies so as to protect the citizen against economic and technological risk. The Institute maintains and develops its expertise and networks in information, communication, space and engineering technologies in support of its mission. The strong cross-fertilisation between its nuclear and non-nuclear activities strengthens the expertise it can bring to the benefit of customers in both domains.

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1. INTRODUCTION

1.1 Earthquake hazard mapping

Earthquakes have a powerful destructive potential. In Europe there are many countries prone to this hazard, mostly Greece, Portugal, Spain, Italy and partially UK, Belgium, France and Germany. From the PECO countries (see Figure 1). According to the opinion of national experts summarized in Wood & Jelínek 2007, earthquakes represent high risk in Bulgaria, Romania and Slovenia, a medium risk in Cyprus, and low risk in the Czech Republic, Estonia, Hungary, Lithuania, Poland and Slovakia. For Latvia, earthquakes were not considered as a priority hazard. Figure 2 and Figure 3 show and examples of destructive earthquakes from Bulgaria and Romania, respectivelly.

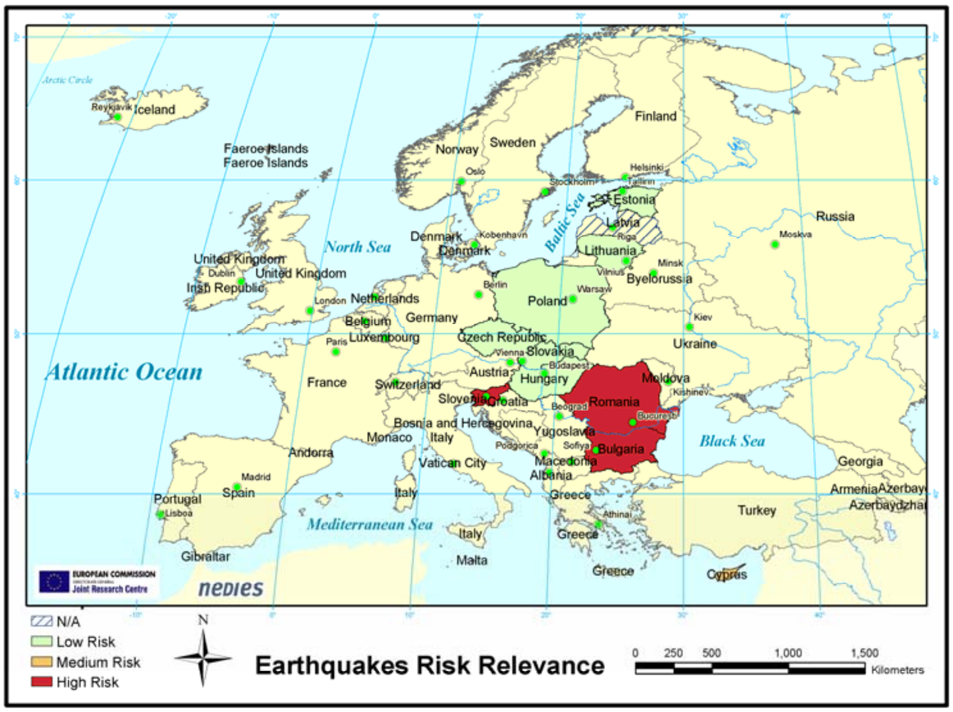

Figure 1: Risk relevance to earthquakes in the surveyed countries according to the opinion of national experts

Seismic hazard mapping is standardized in Europe with the implementation of the new EUROCODES system. This system requires that buildings are designed and constructed in accordance with a harmonized and unified approach. The desire for harmonization also motivated an international team of European specialists to create the unified Seismic Hazard Map of Europe (Jiménez et al., 2001) using a scale of 1:5,000,000 for the expected Peak Ground Acceleration (PGA) for 10% exceedance in 50 years (475-year return period), that was published in 2003 (http://wija.ija.csic.es/gt/earthquakes/). The Unified Seismic Hazard Map of Europe (illustrated in Figure 4) is a very good example of how to achieve a unified methodology for seismic hazard mapping across European regions. Indeed, both time-scale parameters, 50 years and the 475 year-return period[1], are recommended by EUROCODE 8.

[1] The return time, or more properly the average return time, of an earthquake is the number of years between occurrences of an earthquake of a given magnitude in a particular area.

Figure 2: Destructed church after the 1928 earthquakes in Bulgaria (M7.0 and 6.8)

Figure 3: Partially collapsed reinforced concrete frame and masonry wall office and apartment buildings in Bucharest, Romania after March 4, 1977 earthquake. *Photo by C. Rojahn 1977, U.S. Geological Survey Photographic Library,*

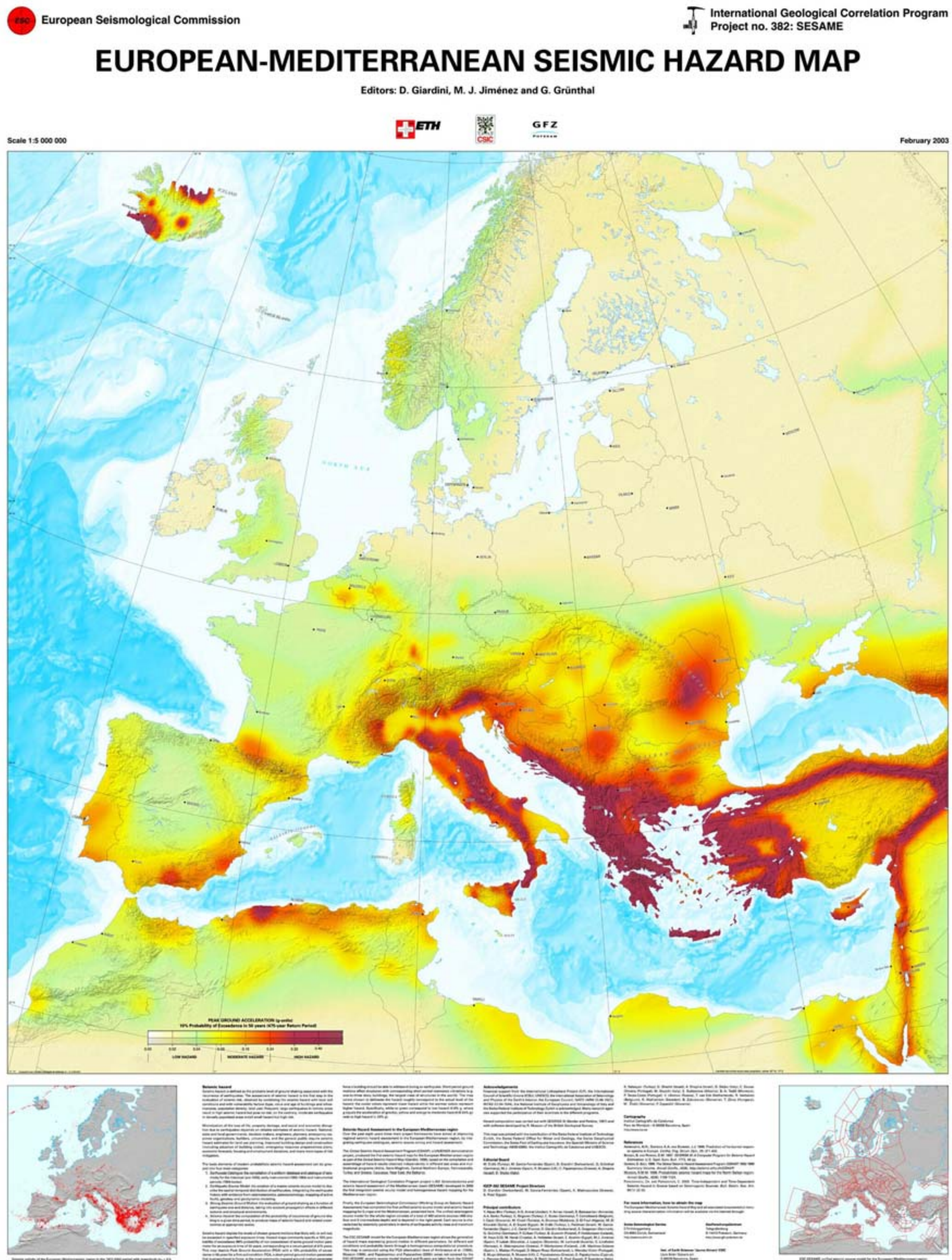

Figure 4: The seismic hazard map of the European-Mediterranean region

In addition, the same approach could be applied to unify practices associated with mapping natural hazards and the risk levels and vulnerability to exposure associated with them. This effort could be of significant value in particular when one considers that very frequently the contours of the respective isolines of earthquake activity (intensity, acceleration, etc.) do not coincide with national or regional boundaries. However, such an effort would require collaboration on a large scale and significant resources.

The essential data and information needed to produce seismic hazard maps are:

- Epicentral maps (inventory)
- Seismotectonic maps
- (Surface) geology maps
- Active fault maps (inventory)
- Earthquake catalogues – to establish the recurrence periods (sometimes the paleoseismological data are used for such purposes)
- Attenuation[2] laws (for intensities and/or accelerations)

As a result of this data processing, the so-called seismotectonic sources can be outlined. Taking into account the relevant mapping information and applying the respective methodology (for example, McGuire, 1993, Cornell, 1968, etc.), the seismic hazard maps may be produced and constructed as:

(1) Expected intensity maps[3] for a certain period of time (the old methodology) or as

(2) Expected acceleration maps[4] for a certain return period (the new methodology), which are more useful for design engineering purposes. Usually the maps are produced taking into account the average soil conditions.

If soil conditions are already mapped for different purposes (seismic safety studies for certain sites, high risk objects such as nuclear power plants, dams, Seveso II installations, etc.), a microzonation study[5] has to be performed (for example, as described in Tiedeman, 1992).

Finally, it should be noted that secondary earthquake effects can frequently lead to more negative consequences, such as surface ruptures, aftershocks, floods, mudflows and landslides generation, tsunamis, etc., but these impacts are usually not taken into account in most earthquake maps.

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[2] Attenuation is the degree to which the amplitude of a seismic wave is reduced with time or distance traveled.

[3] Intensity is a measure of the effects at a particular place produced by shaking during an earthquake.

[4] Acceleration in this context is defined as the time rate of change of velocity of a reference point during an earthquake.

[5] Microzonation is the identification of separate individual areas having different potential for hazardous earthquake effects.

1.2 General description of the project

In 2003 the Joint Research Centre performed a survey of mapping practices in eleven (11) countries for eight (8) major hazards. This activity was funded as part of the project entitled "Management of Natural and Technological Risks" under the JRC Enlargement action within the Sixth Framework Programme (6FP) for Research and Technological Development (RTD). This project was a continuation of an activity supported by the JRC Enlargement action programme within the Fifth Framework Programme (5FP) RTD aimed at the 10 "PECO" countries.[6] The two activities were designed to support the efforts of new Member States and Candidate Countries in the creation of compatible regional and national central information systems for supporting authorities in the management of risks and emergency situations due to natural and technological hazards. The 6FP project was expanded to include Cyprus[7].

Under the 5FP project experts from the PECO countries agreed on ten priority hazards as important concerns for the region, as follows (Wood et al. 2003):

Natural hazards	**Technological Hazards**
▪ Floods	▪ Industrial installations
▪ Forest fires	▪ Transport of dangerous goods
▪ Storms	▪ Contaminated lands
▪ Landslides	▪ Pipelines
▪ Earthquakes	▪ Oil-shale mining

The 6FP project aimed to investigate risk mapping practices and policy for priority hazards in these countries. The aim of this activity was to:

- Examine the existing situation, in each surveyed country for mapping of priority natural and technological hazards
- Compare methodologies used in the different countries for hazard to inform guidelines for establishing compatible national mapping systems
- Provide a basis for defining a pilot project that would test feasibility of different approaches to harmonizing aspects of mapping practices in regard to specific hazards

Moreover, it was determined that these objectives could be best fulfilled through the administration of a questionnaire on risk mapping practices and policy for priority hazards to the target countries (Di Mauro et al. 2003).

The 6FP project selected eight of priority hazards from the 5FP project as the subject of the questionnaire, excluding oil-shale mining and pipelines for practical reasons[8]. The survey

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[6] PECO countries refer to the 10 Member States in central and Eastern Europe (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia). The acronym is derived from the French translation of "Central and Eastern European Countries" ("Pays de l'Europe Centrale et Occidentale").

[7] The 6FP project could also include Cyprus and Malta (although 5FP was only targeted to PECO countries). Yet for mainly practical reasons, Malta was not included in the 6FP phase of this project, although some bilateral expert exchanges on natural and technological hazards took place.

[8] In the case of oil-shale mining, interest in this hazard was not widespread and it was determined that most respondents would not have a mapping programme aimed at this activity. On the other hand, in many countries the competent authority that manages pipelines and pipeline mapping is quite distinctly apart from those that handle other technological hazards or natural hazards. Therefore, it was considered impractical to include this hazard in the survey based on the additional extra effort that might be required to gain the support and co-operation of these authorities.

and its main results are fully described in the document, “Risk mapping in the New Member States (Wood and Jelínek, 2007).

1.3 Survey Methodology and Content

This section describes the survey process including the background as well as practical and technical considerations that determined its focus and approach.

Method for Soliciting and Verifying Questionnaire Responses

Survey responses were collected over the course of a 10-month period between November 2003 and July 2004. The initial survey was sent to project focal points nominated by the countries. They were not required to respond to the questionnaire on every hazard; rather, they were requested to complete a questionnaire for only those hazards that they identified as priority hazards. For this reason, there is not a complete set of questionnaire responses for any one hazard. For information on which countries provided information on particular hazards, please see the document, “Risk mapping in the New Member States” (Wood and Jelínek, 2007).

The JRC then organized a meeting in each participating country to discuss the answers to the questionnaires with the responding authorities. This meeting offered an opportunity to clarify questions and responses, gain more comprehensive information, and improve consistency between responses across hazards and respondents.

Following the meeting the survey was revised and reviewed, and through an iterative exchange between respondents and the JRC, the responses were finalized and accepted as complete.

Content of the Full Questionnaire

Each questionnaire encompassed eight separate sections, and each one focused on a particular hazard. Moreover, the questions applied the same methodology for each hazard. In essence, the questionnaire aimed to identify state-of-the-art mapping practices, priorities, and similarities and differences in mapping practices for each hazard. The data identity and availability based on the questionnaire encompassing more than 35 questions grouped into six categories: earthquake hazard maps, earthquake hazard data, elements at risk to earthquakes, earthquake vulnerability maps and earthquake risk maps. Each questionnaire was divided into six sections:

- General description of hazard maps
- Data and data collection
- Identification of elements at risk
- Vulnerability mapping and classification
- Risk mapping
- Final considerations (use and accessibility)

Description of the Earthquake Hazards Questionnaire

The earthquake hazard mapping questionnaire is the subject of this report. Its contents can be summarized as follows:

General description of hazard maps

This section deals with the availability of official earthquake hazard maps (i.e., maps made by a government entity, such as a ministry, mapping agency, the army or other) in a particular country. Additionally, the existence of any other types of earthquake hazard maps is investigated. Standard map parameters such as coverage, scale, projection, format, icon and symbol used, issuing authority, date of origin and the latest updates are also requested.

The second part of this section asks respondents to identify the standard components of official maps, that is, whether objects such as topography, hydrological catchments, land use, water bodies, administrative boundaries, population, roads, railways are regular features of earthquake maps.

In the third part of this section, the respondent is asked to specify how earthquake hazard maps are used, degree of accessibility to such maps to the public and their availability via Internet.

The final part requests information on existing legislation covering earthquake mapping practices in the surveyed countries.

Data and data collection

This part of the questionnaire describes information on earthquake hazard data sources and related collection process. The section starts with questions in regard to reference authorities for collecting information about earthquake hazard sources and its related management.

The second part asks for information on official mechanisms for collecting earthquake hazard data. The respondents were allowed to specify the type of information collected (e.g., seismology, geology, earthquake events) parameters and units used, and how data is collected. Furthermore, information was also requested about the area covered by the data, the time period covered, the frequency of updates and whether the data are maintained in digital or paper form.

This section also asked questions about the specific way in which data are used in the surveyed countries and the degree of accessibility of data or constraints on their use.

Identification of elements at risk

This section explores how respondents classify elements ("objects") exposed to earthquake hazard and the level of importance assigned to each category (from very low to very high) for the elements selected.

Vulnerability mapping and classification

The first part of this section asks about the availability of official earthquake vulnerability maps in the surveyed countries and how different levels and types of vulnerability are classified in the country. Respondents are also asked to indicate whether certain types of damage (e.g., to people, to property) are considered reversible (temporary) or irreversible (persistent) in the respondent country.

Risk mapping

This part of the questionnaire aims to determine whether earthquake risk maps are produced in the country and, if so, what the standard features of these maps are. It also seeks information on how earthquake risk is represented in such maps, public accessibility and how the maps are used.

Use and accessibility (final considerations)

The final part of the questionnaire describes general questions related to a harmonized approach to define risk maps and ask about potential benefit of those integrated risk maps in the surveyed countries.

2. ANALYSIS OF RESPONSES TO THE EARTHQUAKE SURVEY

As is shown in Table 1, the following six out of the 11 countries completed responses to the earthquake hazards survey:

- Bulgaria
- Czech Republic
- Cyprus
- Romania
- Lithuania
- Slovenia

Estonia, Hungary, Poland and Slovakia did not provide any data. Nor did Latvia provide data since it had already indicated that risk of an earthquake is negligible in that country. The majority of the experts responding to the survey were from geological or geophysical institutions and one respondent was from a university. Responses were generally very comprehensive with many useful comments, therefore the response quality is considered very high.

Table 1: Respondents and focal points for earthquake mapping questionnaire

Country	Address
Bulgaria	Geophysical Institute - BAS Sofia 1113, Acad., G.Boncev Street, Block.3 1113 Bulgaria www.geophys.bas.bg
Czech republic	Institute of Rock Structure and Mechanics, Academy of Sciences V Holešovičkách 41, Prague 8, 182 09 Czech Republic www.irsm.cas.cz
Cyprus	Geological Survey Department 1, Lefkonos Str., Nicosia, 1415 Cyprus www.moa.gov.cy
Lithuania	Lithuanian Geological Survey Konarskio 35, Vilnius, 03123 Lithuania www.lgt.lt
Romania	Ministry of Agriculture and Rural Development B-dul Carol I, Nr. 24, Sector 3, Codul Postal 020921, Oficiul Postal 37, Bucharest, Romania http://mapam.ro/
Slovenia	Environmental Agency of the Republic of Slovenia (Seismology Office) Dunajska 47/VII, Ljubljana, 1000 Slovenia www.arso.gov.si

2.1 Earthquake Hazard Maps in Surveyed Countries

There are several kinds of maps in use in the surveyed countries. The most common types of maps are intensity maps and acceleration maps described as follows:

> ***Intensity maps:*** This type of map presents isolines or different colors of the expected intensities for a certain return period.
>
> ***Acceleration maps:*** These maps feature isolines or different colors to represent the probability that the expected Peak Ground Acceleration (PGA) will be exceeded for a certain return period.

Table 2 presents data on the current state of earthquake hazard maps and their parameters in the surveyed countries. (It should be noted that different countries may apply different methodologies to produce their maps. However, the survey was not designed to identify or analyse the different methodologies applied to hazard mapping in the different countries).

Types of maps

Official seismic hazard maps (maps made by a government entity, such as a ministry, a mapping agency, the army or other) are currently required under law in all of the respondent countries, namely Bulgaria, Czech Republic, Cyprus, Lithuania, Romania and Slovenia. The law usually requires earthquake hazard zonation maps. An example of such map can be seen in Figure 5, page 20. However, all of the countries also use other types of earthquake maps besides the official maps except Slovenia.

Scale, coverage, projection and format of maps

- The scales of the seismic hazard maps vary between 1:400,000 and 1: 1,000,000. The scale depends in large part on each country's size, and in fact, almost all maps use different cartographic projections. This variation suggests that homogeneity could be an important consideration for harmonizing maps across borders.
- In all countries, seismic hazard maps are developed at national level.
- The maps are available in paper form in all countries but also in digital form in Slovenia, Cyprus and Lithuania.

Data created and last updated

Results indicate that earthquake hazard maps in the surveyed countries have been created during the 1990's and early 2000's. Cyprus records the most recent earthquake maps. Moreover, some of the maps were upgraded recently (between 1998 and 2000 in several countries), but a few countries also still use maps created using older methodologies in the late 1980's.

Table 2: Availability of earthquake hazard maps

Country	Maps Produced Format – Digital (D) or Paper (P)	Coverage/ Scale	Date Created/ Last Updates	Legal Act Foreseeing Earthquake Hazard Maps
Bulgaria	Zoning (P) Other	National 1:1,000,000 Local 1:1,000,000	1987/updated in 1987 1990-2000	Ministerial decision for the seismic zonation map of Bulgaria (1980)
Czech Republic	Zoning (P)	National, scale ns	1997-1998/ ns	National Code CSN 73 0036 Seismic loads of buildings (1997) Czech Technical Code ICS 91.080.00, 91.040.00, CSN P ENV 1998-1-1
		Regional, scale ns	since 1981/updated in 2002 (5-10 yrs)	
		Municipal, scale ns	1978/ with respect to NPP safety regulations	
	Other	Coverage of Central Europe, scale ns	1999/ ns	
		CZ-PL-SK	2000/ ns	
Cyprus	Zoning, microzoning (D, P)	National 1:500,000 and 1:25,000	1983/ updated in 1994	Yes, Seismic Code of Practice
		Municipal 1:25 000	2003/ ns	
	Other	European coverage 1:500,000	2003/ updated in 2003	
Lithuania	Zoning (D)	National: 1:400,000	1998/ Not updated	No
	Other	Regional Belarus & Baltic Regional Belarus & Baltic 1:1,000,000	1995/ ns 1998/ not updated	
Romania	Zoning (P)	National 1:1,000,000	2001/updated after changes	Law No. 575/2001
		Regional 1:1,000,000		
		Provincial 1:25,000		
		Municipal 1:5,000		
	Other	National 1:1,000,000	1998/ updated after changes	
Slovenia	Zoning (D, P)	National 1:500,000 National 1:1,000,000	2001/2001 1987/1987	Legal act UL RS 32/93 (Environmental protection law) Legal act UL RS 30/01 (Changes and supplements to the law of the organisation and fields of work of the Ministries) Legal act UL SFRJ 31/81 (Regulations for constructing buildings on seismic areas)

Legend: D- digital, P- paper, ns- not specified NPP- nuclear power plant

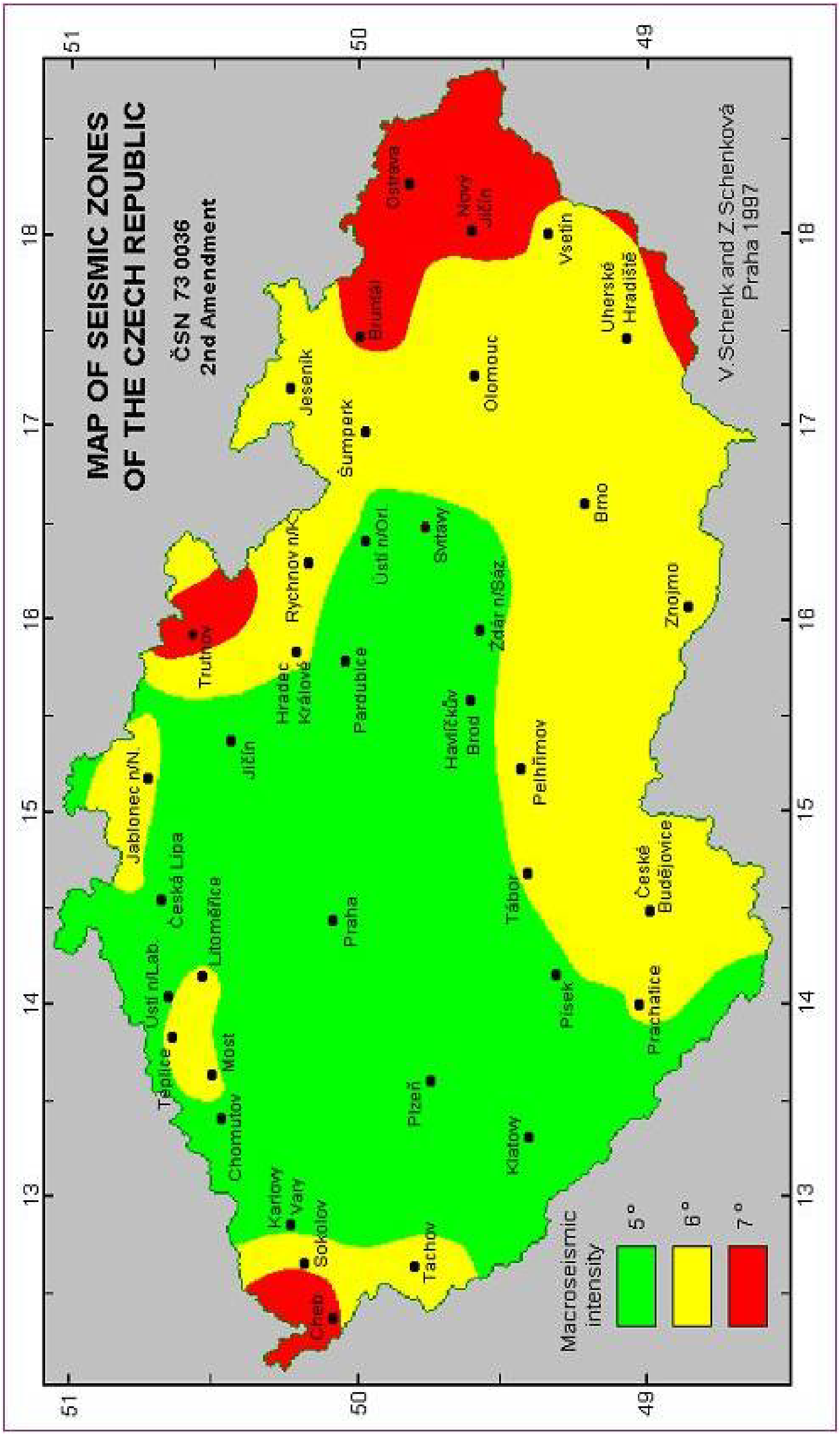

Figure 5: Map of the seismic zones in the Czech Republic

Legislative framework

Respondents were asked to describe any legal instruments that mandate or guide official mapping of earthquake hazards. Almost all countries have some legislation in this regard, however, it tends to focus on seismic design codes rather than mapping. For example, Romania has produced a sophisticated digital map of expected acceleration for seismic zones in the country, but it is not recognized as an official map in the legislation.

Representation of earthquake hazard areas on maps

Survey results indicate that some countries use a variety of maps to represent earthquake hazards as summarized in Table 3. In Bulgaria contour frequency and magnitude are used to delineate and describe earthquake hazards. In the Czech Republic (Figure 6) and Slovenia, other methods (intensity, PGA) are used to illustrate earthquake hazards.

Table 3: Representation of earthquake hazard on maps

A topographical map showing faults	Cyprus, Lithuania, Romania
Contour frequency and magnitude describing the earthquake hazard potential	Bulgaria, Cyprus, Romania
Areas where historical earthquake events have occurred	Cyprus, Lithuania, Romania
Other	Czech Republic (in macroseismic intensities and PGA), Romania, Slovenia (Design ground acceleration in rock or firm soil, intensity in MSK – 64)

Legend: PGA- Peak ground acceleration

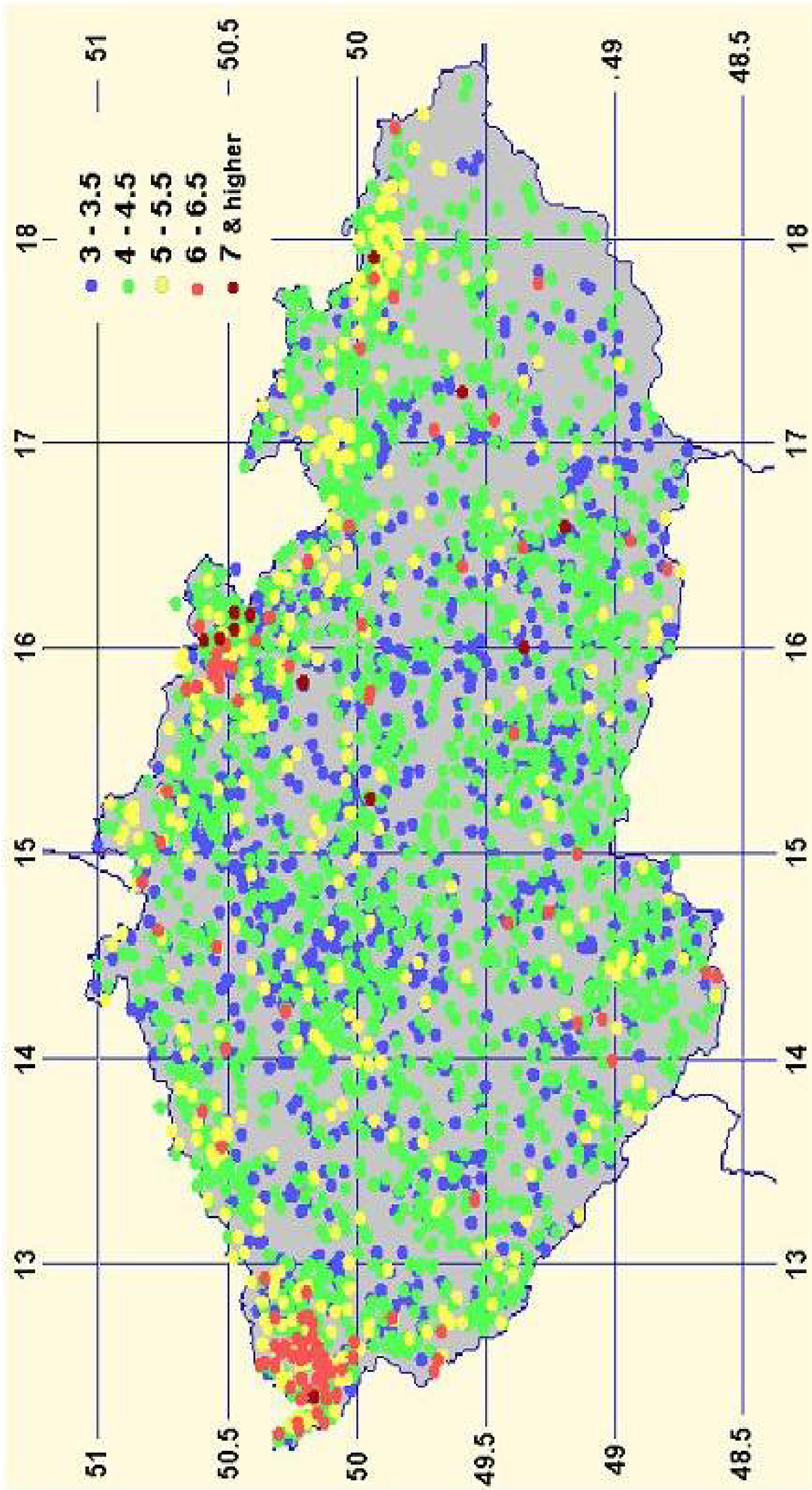

Figure 6: Map of the maximum macroseismic intensities observed in the Czech Republic

Map features or symbols and background information on earthquake hazard maps

In all of the surveyed countries, background information generally consists of administrative boundaries, water bodies, roads and railways. Typical earthquake-related features displayed on maps are intensity and PGA. The responses of each country are summarized in Table 4.

Table 4: Map features and background information used in seismic hazard maps

Country	Standard Earthquake Map Features or Symbols
Bulgaria	**Earthquake-related:** Intensity **Background:** Hydrological catchments, administrative boundaries, roads, railways
Czech Republic	**Earthquake-related:** Intensity, PGA **Background:** Land use, administrative boundaries
Cyprus	**Earthquake-related:** PGA, degree of hazard **Background:** Topography, hydrological catchments, land use, administrative boundaries, roads
Lithuania	**Earthquake-related:** Intensity **Background:** Water bodies, administrative boundaries, roads, railways
Romania	**Earthquake-related:** Intensity **Background:** Topography, land use, water bodies, administrative boundaries, population, roads, railways
Slovenia	**Earthquake-related:** Intensity, PGA **Background:** Topography, hydrological catchments, water bodies, administrative boundaries, population, roads, railways

Use of earthquake hazard maps and their degree of accessibility

As can be seen from Table 5, seismic hazard maps in the surveyed countries are used for a variety purposes. The use of the maps is mainly associated with application of national building codes and rules. The experts also indicated that the maps were useful for land use planning, and disaster prevention and protection.

In general earthquake hazard maps are widely available to the public and decision makers, with some exceptions for maps created in support of the civil defence action plans and the military purposes. In Romania, access to maps is granted only on a limited basis to individuals or entities outside the government.

Table 5: Use of earthquake hazard maps and their degree of accessibility

Use of Earthquake Map	Bulgaria	Czech Republic	Cyprus	Lithuania	Romania	Slovenia
Targeted Information Communication to the Public	Public/ Restricted	Public	Public	No	Restricted	Public
Targeted Information Communication amongst Decision-makers	Public	Public	Other	Public/ Other	Restricted	Public
Land Use/Spatial Planning	Public	Public	Public	NS	Restricted	Public
Territorial Management	Public	Public	No	Public	Restricted	No
Emergency Response Plans for Civil Protection	Restricted	Restricted	Restricted	No	Restricted	Public
Targeted Allocation of Resources	No	No	No	No	Restricted	No
Scientific Research	Public	Public	Restricted	Public	Restricted	Public
Military Purposes	No	No	No	No	Restricted	No
Visualization of Information only	NS	No	No	No	Restricted	No

Legend: "No" = earthquake maps not typically used for this purpose)
NS = not specified

2.2 Seismic Hazard Data

Seismic hazard data are generally based on higher magnitude seismic events and their consequences. The main parameters derived from the processing of seismic data from these events are:

- the time and date of origin,
- epicenter coordinates,
- magnitude,
- depth, and
- fault plane solutions[9].

There are several European centers that collect and process similar data such as *the European-Mediterranean Seismological Centre (CSEM*, http://www.emsc-csem.org/), *the Observatories and Research Facilities for European Seismology (ORPHEUS*, http://orfeus.knmi.nl/) and *the International Seismological Centre (*ISC, http://www.isc.ac.uk/). At these facilities strong motion instruments record the acceleration pattern of individual seismic events. These observations are very useful in case of near strong seismic events, and for verifying predictive models. Sometimes such lower magnitude events are necessary for a more precise understanding of the seismic

[9] A fault plane solution is a way of showing the fault and the direction of slip on it from an earthquake, using circles with two intersecting curves that look like beach balls.

environment, including delineation of the active faults, the assessment of defused seismicity, the definition of seismotectonic boundaries and other important parameters. Detailed descriptions of the effects within the macroseismic field (i.e., the impact zone of a severe earthquake) such as the number of deaths and injuries, impacts on affected lifelines and other critical infrastructure, can also be very useful. These data can be used to make vulnerability assessments, as well as social and economic impact assessments and emergency planning.

According to the survey, in all of the countries, except the Czech Republic, a national authority is responsible for collecting information on earthquake hazards. Seismic hazard data normally collected in the surveyed countries are presented in Table 6.

Table 6: Seismic hazard data information

Country	Seismology (Collection Method)	Surface Geology	Collection of Information on Specific Events	Format Area Coverage Geo-Reference Metadata/Standard
Bulgaria	Intensity, ground acceleration, magnitude (automatic/manual)	Lithology, stratigraphy, stress/strain	Intensity, ground acceleration, magnitude, other (no data)	Paper, some digital National, regional Geo-referenced: Yes Metadata used
Czech Republic	Intensity, magnitude (standard procedures)	Not collected	Intensity (questionnaire)	Digital & paper National, regional, provincial Geo-referenced: Yes Metadata: No
Cyprus	Intensity, ground acceleration, magnitude (automatic/manual)	Lithology, stratigraphy	Intensity, ground acceleration, magnitude, surface ruptures (questionnaire/ automatic)	Digital & paper Coverage: All levels Geo-referenced: Yes Metadata used
Lithuania	Magnitude (automatic)	Lithology, stratigraphy	Macroseismic investigations were carried out only recently, after the Kaliningrad earthquakes in 2004.	Digital National, provincial Geo-referenced: Yes Metadata used
Romania	Intensity, ground acceleration, magnitude, other (automatic)	Not collected	Intensity, ground acceleration, magnitude, other (automatic)	Digital Coverage: All levels Geo-referenced: No Metadata: No
Slovenia	Not collected	Not collected	Intensity, ground acceleration, magnitude (mapping/questionnaire/automatic)	Digital & paper National Geo-referenced: Yes Metadata: No

Seismology

National seismic surveys in respondent countries generally collect seismological information using the following data sources:

- instrumental (seismograms and accelerogrames),
- descriptive (notes, visual observations),
- questionnaires for the felt events and their consequences,
- old historical descriptions (and paleoseismological studies).

All seismic-prone countries have their own seismic data collection systems. They usually consist of a seismic stations network, and a data processing centre (and also sometimes a visualization survey).

Most of the countries rely on old records in paper form and process seismic data manually. The main outputs are seismic bulletins and catalogues which are produced on paper and sometimes also in digital form. The main parameters reported for individual events are generally the epicenter location, magnitude, depth and intensity (in the case of a felt event). All of the national data collection bodies make a posteriori surveys (after the felt seismic events) of the macroseismic fields using developed questionnaires. Many of the countries' seismic data centers institutions are still in search of the old chronics and historical descriptions of the historical seismic events.

Most of the national seismic data centers are highly concentrated scientific bodies, except in Romania and Bulgaria where two national institutions exist separately for the seismic data and for the strong motion data. Nonetheless, the results of collection activities are more or less compatible, regardless of whether activities are unified or split between national organizations, because procedures for processing data have been standardized by *the International Association of Seismology and Physics of the Earth's Interior* (IASPEI, http://www.iaspei.org/). European harmonization efforts in this area are now directed towards improving cooperation for the field studies. An international team for Rapid Intervention Field Investigation (FITESC, http://fitesc.8m.com/) has been created to lead this activity within the European Seismological Commission (EMSC, http://www.esc.bgs.ac.uk/).

Geological Setting and Conditions

Usually geology mapping and related topics are not incorporated in the responsibilities of the seismic centers. In all countries the geological data and mapping are collected and processed by other institutions dealing specifically with this subject area.

Events

According to the survey, information on events are collected using a questionnaire and/or automatic monitoring in all countries, except Lithuania.

Additional observations

All of the countries have geo-referenced information related to seismic hazard data (except Romania). In Bulgaria, Cyprus and Lithuania metadata are standardly used. The advantage of using a metadata standard is that data sets will interoperate with other sets that use the same standard. The majority of the countries retain the data in digital form.

Use of seismic hazard data

The seismic hazard data are intended for specific uses in all of the surveyed countries. The use of seismic hazard data in the surveyed countries and its availability are summarized in Table 7.

Table 7: Use of seismic hazard data and their degree of accessibility

Use of Earthquake Map	Bulgaria	Czech Republic	Cyprus	Lithuania	Romania	Slovenia
Targeted Information Communication to the Public	Public	Public	Public	Public	Restricted	Public
Targeted Information Communication amongst Decision-makers	Public	Public	Restricted	Public	Restricted	Public
Land Use/Spatial Planning	Public	Public	Public	No	Restricted	Public
Territorial Management	Public	Public	No	No	No data	Public
Emergency Response Plans for Civil Protection	Restricted	Restricted	Restricted	No	Restricted	Public
Targeted Allocation of Resources	Public	No	No	No	Restricted	Public
Scientific Research	Public	Public	Restricted	No	Restricted	Public
Military Purposes	Restricted	No	No	No	Restricted	Public
Visualisation of Information only	No	No	No	Public	Restricted	Public

Legend: "No" = data are not typically used for this purpose.

Similarly as for the earthquake hazard maps, the earthquake hazard data are restricted in Romania. For the other countries, the data are available to the public.

Experts were also asked if available information is sufficient for defining a national seismic hazard map. All of the respondents were of the opinion that they have enough data to produce seismic hazard maps.

2.3 Earthquake Vulnerability Maps

Usually the seismic vulnerability functions are derived through analysis of the data from previous events particularly in relation to observed impacts on buildings. There are only a few examples within the surveyed countries of vulnerability assessments addressing potential impacts on the human population. Preparation of seismic vulnerability maps requires a considerable amount of data from different sources and thus, it is a rather complex and labour intensive task. A number of highly technical operations are involved including data base organization and management, cadastre creation (which does not exist in several countries), and other highly specialized analytical work. For this reason funding and human resource requirements are normally quite high for this type of exercise. Efforts to integrate or facilitate sharing of data from different sources, e.g., national cadastres, seismological surveys, digital maps, etc by the various institutions responsible for them could be somewhat useful in reducing these resource requirements.

Level of importance of the elements at risk exposed to earthquake hazards

Respondents were also asked to rate the importance of various categories of typically vulnerable objects to earthquake risk management in their countries, on a scale of very low to very high. In general, respondents did not indicate whether the importance rating was based on the element's perceived value to society or alternatively, on perceptions surrounding potential for exposure and resilience. Rather, the responses provide a simple indication of how such objects are prioritized for mapping seismic hazards in each country. The elements at risk and their importance according to the experts' opinion are presented in Table 8.

Table 8: Level of importance of the elements at risk exposed to earthquake hazard

Country	Humans as Indivi-duals	Humans as Social Targets	Infrastruc-ture	Cultural Heritage	Private Property	Natural Resour-ces	Ecology
Bulgaria	VH	VH	VH	H	M	VH	M
Czech Republic							
Cyprus	M H	VL L	M	M	M	VL	VL
Lithuania	VL	VL	L	VL	L	VL	L
Romania	H	VH	H	H	H	M	M
Slovenia							

Legend: **VH**: Very high; **H**: High; **M**: Medium; **L**: Low; **VL**: Very low

A graphical comparison between the elements at risk to earthquake hazard is presented in Figure 7. This figure clearly indicates that Romania and Bulgaria are the countries with the total highest level of importance of risks to earthquakes. On the other site are the Baltic countries, as illustrated by example from Lithuania.

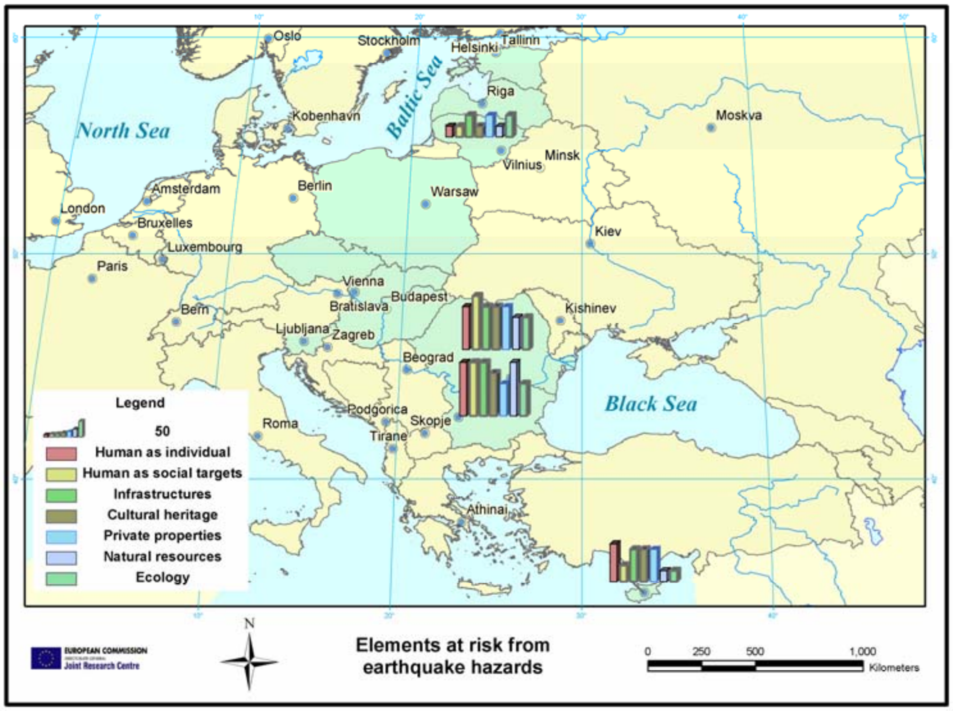

Figure 7: Elements at risk from earthquake hazards

In reality no official classification of "vulnerable elements" for earthquake hazards exists in any of the surveyed countries. However, comments from various surveyed experts indicate that it is current practice in most countries vulnerable to seismic activity to consider population and infrastructure as high or very high elements at risk. The vulnerability of cultural heritage is also commonly of high concern. On the other hand, there is a tendency to underestimate the potential severity and importance of ecological damage (e.g., release of pollutants, habitat destruction and other impacts on biodiversity, etc.). Frequently, private property is estimated as a risk of only medium concern in the face of an earthquake (Ranguelov, 2004). More research is still needed to confirm these observations and obtain deeper understanding of current perceptions and practices for estimating vulnerability to earthquakes.

Classification of damages

Most of the experts noted that the terminology of "reversible" and "irreversible" damage is used in everyday practice but not at the official level. Survey responses indicated that there is general agreement among the experts about which types of damages should be classified as reversible and irreversible and the damage classification to which they belong. The data obtained from four countries are presented in Table 9.

Table 9: Classification of damages as reversible and irreversible in Bulgaria, Cyprus, Lithuania and Romania

Country	Reversible Damage	Irreversible Damage
Bulgaria	**Human**: Injury, epidemic, economic loss **Infrastructure:** Severe damage, loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss, loss of accessibility **Private property:** Economic loss, loss of functionality **Natural resources:** Loss of resources	**Human**: Death, chronic health effects, disability **Infrastructure:** Destruction, uneconomical recovery **Cultural heritage:** Cultural loss, economy **Private property:** Economic loss **Natural resources:** Loss of resources
Cyprus	**Human**: Injury, acute health effects, epidemic, economic loss **Infrastructure:** Severe damage, ,loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss, loss of accessibility **Private property:** Economic loss, loss of functionality	**Human**: Death, disability **Infrastructure:** Destruction, uneconomical recovery **Cultural heritage:** Cultural loss, economy **Private property:** Economic loss
Lithuania	**Human**: Injury, acute health effects, epidemic, economic loss **Infrastructure:** Severe damage, loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss, accessibility **Private property:** Economic loss, loss of functionality **Natural resources:** Economic loss, loss of resource **Ecology:** Loss of biodiversity	**Human**: Death, chronic health effects, disability **Cultural heritage:** Cultural loss, economy **Natural resources:** Economy
Romania	**Human**: Injury, acute health effects, epidemic, economic loss **Infrastructure:** Severe damage, loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss, loss of accessibility **Private property:** Economic loss, loss of functionality **Natural resources:** Economic loss, loss of resource **Ecology:** Loss of biodiversity	**Human:** Death **Ecology:** Loss of biodiversity

2.4 Earthquake Risk Maps

In principle seismic risk maps represent the combining of earthquake hazard maps with associated vulnerability estimates for zones of potential impact. These risk maps normally aim to present the possible consequences of a strong seismic event taking into account all seismically vulnerable elements (i.e., building stock, population, environment, lifelines and other critical infrastructure, etc.). Scenarios are frequently developed to estimate the potential consequences from events of a different magnitude. The, FEMA project HAZUS (http://www.hazus.org/) and the project UN RADIUS (http://www.geohaz.org/contents/projects/radius.html), for example, both implemented this approach.

However, another very different approach is also widely used for earthquake risk mapping, the so-called "near real time seismic damage assessment". The aim of this approach is to assess the range of possible negative consequences (usually physical damage and deaths and injuries in the human population), often along with an estimate of the necessary response resources, immediately after any strong seismic event occurs in the world (for example the systems of: EMERCOM, Japan, Israel, ETH, EC-JRC - http://disasters.jrc.it/).

A limited number of methodologies have been developed for seismic risk mapping at European level. One approach has been developed in Germany that more or less associates potential physical damage with different zones of seismic risk (Wahlstrom et al., 2004). An approach originating in Spain applies statistical data on earthquake deaths and injuries worldwide to estimate risks for a particular seismic area (Samarjieva & Badal, 2002). These approaches could also provide useful input for future development of this topic.

According to the data collected by the questionnaires there are no seismic risk maps developed in the new Member States and Candidate Countries, with some minor exceptions. In Bulgaria some models and publications have been created to support prediction of potential physical damages, human fatalities and injuries, and economic losses based on certain scenarios (Christoskov & Solakov, 1994).

Almost all countries expressed a desire for a harmonized approach to seismic risk mapping, recognizing that this type of development could produce several benefits including unification of the methodology, more easily readable maps, and other practical applications). However, available funding would have to be considered before any of the countries could agree to participate in such a standardization activity.

3. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The key findings in the surveyed countries concerning earthquake risk mapping according to the questionnaire are summarized as follows:

- **Earthquakes are perceived as a high risk in Bulgaria, Romania and Slovenia, a medium risk in Cyprus, and a low risk in the Czech Republic, Estonia, Hungary, Lithuania, Poland and Slovakia.** Notably, six out of eleven countries (Bulgaria, Czech Republic, Cyprus, Lithuania, Romania and Slovenia) provided information on earthquake mapping. Latvia did not consider earthquakes a priority hazard. Estonia, Hungary, Poland and Slovakia did not provide any information on this topic.

- **Official seismic hazard maps are currently available in all of the respondent countries**, namely Bulgaria, Czech Republic, Cyprus, Lithuania, Romania and Slovenia. Those maps are usually earthquake hazard zonation maps.

- **National hazard maps are usually used in association with seismic design codes and rules and to facilitate their practical implementation.**
- **Earthquake hazard maps and data are generally available to the public in the majority of countries** (except Romania).
- **All countries are well prepared in regard to data collection and seismic hazard mapping.** Most of the maps are in paper form; some are digital.
- **Most common collected earthquake-related parameters are** epicenter location, magnitude, depth and intensity.
- **Geo-referenced information is available in all of the surveyed countries** (except of Romania). Metadata are standardly used in Bulgaria, Cyprus and Lithuania.
- **No seismic vulnerability maps have been developed in any of the countries**, with some minor exceptions (some approaches have been used for strong earthquakes consequence scenarios).
- **Romania and Bulgaria appear to have the most concern about the potential consequences of an earthquake, based on the number of elements that are considered highly or very highly important to the overall risk.**
- **Four countries reported having classification of potential damages as reversible or irreversible** but not at the official level.
- **None of the surveyed countries is currently producing official earthquake risk maps.** However some unofficial risk maps have been reportedly produced in Bulgaria.
- **No special legislation targeted to seismic risk mapping** has been established in any of the surveyed countries.

Recommendations

The following recommendations are also proposed on the basis of the survey responses:

- **It is recommended that seismic risk mapping should be an important focus of ongoing research on risk mapping at European level.** The significant risk associated with earthquake hazards in some PECO countries (notably Bulgaria and

Romania) suggests that tools to facilitate improved risk and vulnerability mapping of earthquake hazards in these countries would be welcomed**.**

- **A pilot project to study the applicability of current risk mapping methodologies in Europe has already been recommended and should include seismic hazards.** Since common methodologies already exist for seismic hazard assessment, as well as an easy and unified data set, and much previous experience among European experts, fast progress could be achieved in adapting risk mapping techniques to seismic hazards.

- **The combination of currently available seismic hazard maps with modern mapping and cadastre technology (GIS environment), development of more efficient and precise approaches to vulnerability assessment may also be possible.** Work in this area could also be incorporated into a risk mapping pilot project.

- **It would also be extremely useful to develop a guideline for seismic risk mapping to facilitate the establishment homogenous practices for data collection and processing in Europe, software usage, mapping methodology, etc**. Common approaches are particularly important for earthquake hazards when one considers that very frequently the contours of the respective isolines (intensity, acceleration, etc.) do not coincide at the both sides of the state boundaries. Examples of common methods for such activities as data processing and quality assurance already exist in IAEA requirements for seismic safety assessment of nuclear power plants. (Procházková & Šimúnek, 1998).

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Abstract

In 2003 the Joint Research Centre conducted a survey of mapping practices in eleven (11) new Member States (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) for eight (8) major natural and technological hazards such as floods, forest fires, storms, landslides, earthquakes, industrial installations, transport of dangerous goods and contaminated lands. This activity was funded as part of the project entitled “Management of Natural and Technological Risks”.

One fundamental project objective was to examine the existing situation in each of the surveyed countries, and compare different mapping methodologies in order to define guidelines for establishing compatible risk mapping systems, in particular multi-hazard risk mapping. This report describes the results of the earthquake section of the risk mapping activity. Responses to the survey provide important information about the current status of earthquake hazards and risk mapping in different countries and advantages and obstacles to developing a common methodology for multi-hazard risk mapping including this hazard in each country.

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