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THE EUROPEAN RISK-UE PROJECT : AN ADVANCED APPROACH TO EARTHQUAKE RISK SCENARIOS

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SUMMARY

Several European teams and 7 eastern and western European cities, in particular, have combined their knowledge of the earthquake phenomenon and its effects on buildings and populations, with the aim of submitting the RISK-UE project to the European Commission in the context of the 5th PCRD: "An advanced approach to earthquake risk scenarios, with applications to different European towns". The duration of the project is 3 years (2001-2004). The main objective is to achieve a plausible assessment of the direct and indirect damages, following a scenario earthquake, and the consequences resulting from those damages in order to increase awareness within the 7 cities so that the "Plans of Action" necessary to effectively reduce the risk of an earthquake can be carried out.

INTRODUCTION

The European RISK-UE project [1] was launched in 1999, at the end of the International Decade for Natural Disaster Reduction (IDNDR), and commenced in January 2001. The project will come to a close at the end of 2004.

The project itself involves the assessment of earthquake scenarios based on the analysis of the global impact of one or more plausible earthquakes at city scale, within a European context. The primary aim of these scenarios is to increase awareness within the decision-making centres of a city, of the successful appropriation of the problems caused by a seismic risk and of the implementation of *Management Plans* and P*lans of Action* to effectively reduce this risk.

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Similar programmes were also proposed between 1990 and 2000, i.e. HAZUS (1999) [2], in the US, RADIUS (1999) [3], worldwide, for developing countries, and GEMITIS [4], in France, applying to both the West Indies and Nice.
However, no such global programme was launched in Europe and this has now proved to be an urgent requirement, particularly in light of the political impact (at the end of 1999) of the earthquakes in Izmit, Turkey, in Athens, Greece and in ChiChi, Taiwan.

Structured around 7 eastern and western European cities, the RISK-UE project will, first and foremost, develop a *Modular Methodology* for creating earthquake scenarios concentrating on the distinctive features of European cities with regard to current and historical buildings, as well as on their functional and social organisation in order to identify weak points within the urban system.

This approach is currently applied to the following 7 European cities: Barcelona, Bitola, Bucharest, Catania, Nice, Sofia and Thessaloniki (Figure 1).

At a final summit in Nice scheduled for the end of March 2004, the different results will be compared and the various problems highlighted by the scenarios will be discussed.

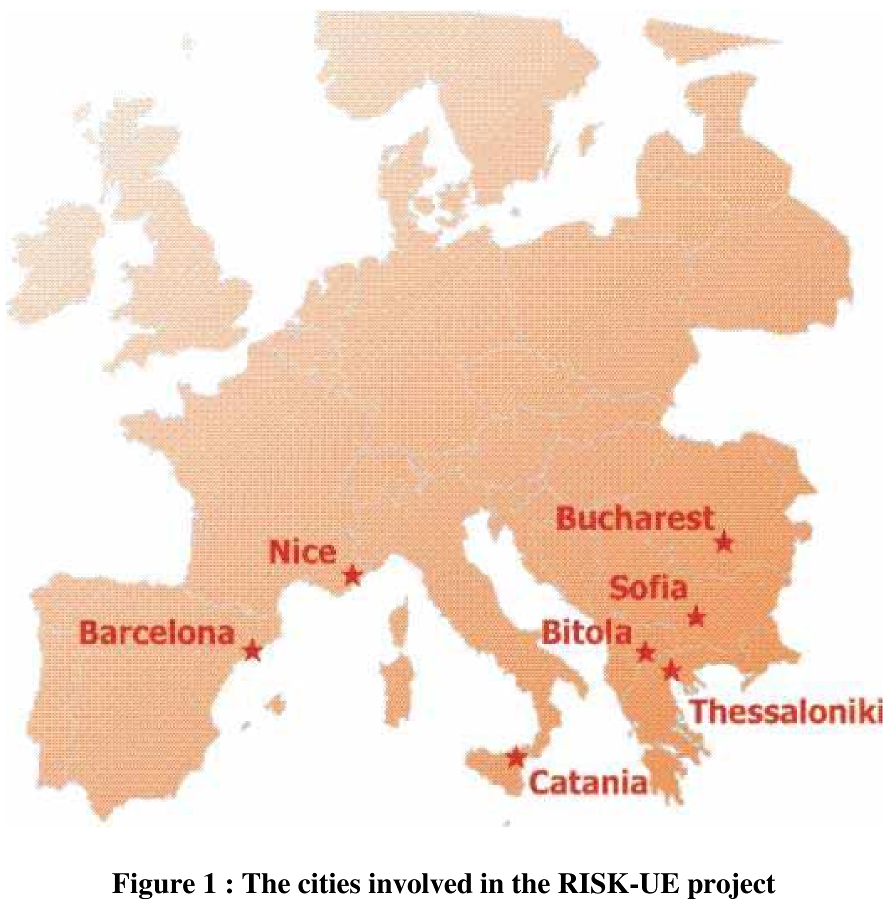


Figure 1 : The cities involved in the RISK-UE project

OBJECTIVES OF THE PROJECT

The *strategic* objectives of the RISK-UE project are:

- To create earthquake scenarios, validated by the decision-makers within each city, and enabling the direct (in terms of cost and victims) and indirect (in terms of failure of services within the city) consequences to be assessed.
- To develop, with this aim in view, the most comprehensive database possible, enabled within a GIS, and structured around the following key subjects: Natural phenomena (hazards) and the elements at risk (stakes, vulnerability and impacts). This database will be completely integrated into the standard GIS for the city.
- To introduce, by means of a web site, all the stages involved in implementing the different earthquake scenarios: www.risk-ue.net, which will be available to all those concerned.
- To create synergy enabling a network of Euro-Mediterranean cities to be established, particularly in the Balkan region and Africa.

The *scientific* objectives are as follows:

- To establish a modular approach for creating earthquake risk scenarios on the consensus of several European institutions specialised in the field of seismic risk.
- To highlight the distinctive European features of the various urban systems including: urbanisation, old town centres, different building types, among them: monuments, lifeline facilities, and the general organisation of the city and its response to an earthquake.
- To homogenise the work already undertaken in other European projects.
- To apply the methodology to several European cities, in partnership with the various public services involved in planning, construction and national security.
- To validate this methodology in conjunction with other experts, in particular at the final summit taking place in Nice in 2004.

ORGANISATION OF THE RISK-UE PROJECT.

Work Packages

The general organisation is shown in table 1. In response to the objectives described above, 7 work packages (WP) have been drawn up in order to implement this methodology:

WP01: European distinctive features, Geographic Information System inventory (GIS), database and building typology;
WP02: Seismic hazard assessment, at both regional and local level;
WP03: Urban system analysis. Highlighting weak points under normal conditions, during crisis and recovery periods;
WP04: Vulnerability assessment of current buildings;
WP05: Vulnerability assessment of old town centres, historical monuments and buildings;
WP06: Vulnerability assessment of lifeline facilities and essential structures;
WP07: Seismic risk scenarios.

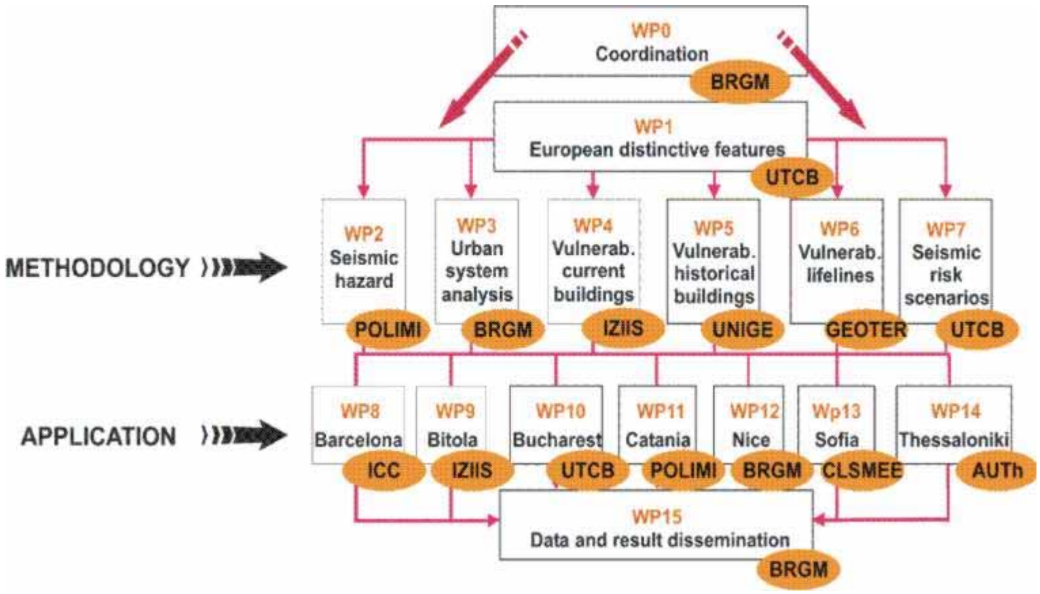


Table 1: Organisation of the RISK-UE project: Work packages.

There are 7 additional work packages (WP08 to WP14) relating specifically to the 7 cities concerned, to which the previous methodology will be applied. Finally, there are 2 further work packages concerning the coordination of the project (WP0) and the dissemination of results (WP15).

Organisations

10 scientific and technical organisations are taking part in the RISK-UE project, along with the 7 cities implicated in the methodology (see table 2).

BRGM	Land use Plan. and Natural Risks - Orléans - Marseille
GEOTER	Geology, tectonics, environment and risks - Roquevaire
POLIMI	Politecnico - Structural Eng. Dept. - Milano
UNIGE	Univ. of Genoa - Structural Eng. and Geotecnics Dept.
UTCB	Technical Univ. of Civil Eng. - Bucharest
ICC	Cartographic Institute of Catalunya - Barcelona
AUTH	Aristotle Univ. of Thessaloniki
IZIIS	Institute of Earthquake Eng.and Eng. Seismology - Skopje
CLSMEE	Lab. for Seismic Mechanics and Earthquake Eng. - Sofia
CIMNE	Int. Center for Numerical Methods in Eng. - Barcelona
CITIES	Ajuntament de Barcelona
	Comune di Catania
	Ministry of Public Works, Transport, Housing - Bucharest
	Ville de Nice
	Municipality of Sofia
	Town of Bitola
	Organization of Thessaloniki

Table 2: Partners of the RISK-UE project

MAIN INTERMEDIATE RESULTS

WP01: European distinctive features.
This led to the completion of a preliminary document highlighting the *distinctive European features*. This principally involves all of the elements at risk within the urban system, its organisation in times of crisis and recuperation, the impact of previous earthquakes, data relating to the natural, geological, geophysical and geotechnical systems, and the development of the application of earthquake resistant codes and building types.

In addition, the analysis of different building types has led to the proposal of a matrix (BTM) of 23 building types; the most current and those common to all European and Mediterranean countries: see table 3.

Label	Description of building type	Label	Description of building type
M	***Masonry structures***	***RC***	***Reinforced concrete structure***
M1	Load-bearing masonry walls composed of :	*RC1*	Support beams / columns
1.1	*Rubble*	*RC2*	Structural concrete wall
1.2	*Freestone*	*RC3*	Support beams / columns with unreinforced brick-lined wall:
1.3	*Ashlar*	*3.1*	*Even brick-lined structures*
M2	Crue	*3.2*	*Uneven structures (i.e., uneven support beams, uneven brick lining, flexible level)*
M3	Load-bearing unreinforced masonry walls:	*RC4*	Compound structure of reinforced concrete (portico and concrete walls)
3.1	Hardwood flooring	*RC5*	Prefabricated concrete walls
3.2	Masonry arches	*RC6*	Prefabricated concrete walls with structural concrete walls
3.3	Floors with metal and masonry joists	***S***	***Steel structures***
3.4	Reinforced concrete floors	*S1*	Steel Support beams / columns
M4	Load-bearing reinforced masonry walls	*S2*	Cross-braced steel structure
M5	Structures made completely of reinforced masonry	*S3*	Steel Support beams / columns with unreinforced brick-lined wall
		S4	Steel Support beams / columns with structural concrete wall cast in-situ
		S5	Steel and reinforced concrete components
		W	***Wooden structure***

Table 3: Matrix of typology of selected structured European buildings

WP 02: Seismic hazard assessment.
The primary purpose of this work package is to provide basic tools for estimating the earthquake ground-shaking hazards and some related effects in urban areas in Europe and elsewhere, and for producing suitable map representations. Such estimations and maps are intended as a basic input for developing relatively detailed earthquake damage scenarios for cities. These scenario earthquakes are defined based on 2 approaches: probabilistic and deterministic.

These lead to the preparation of spectral parameter maps for acceleration or velocity for different response times. These maps are primarily needed to be able to respond to the Level II requirements proposed for the assessment of the vulnerability of buildings (refer to WP 04).

These approaches are based on the consideration of the magnitude-distance-site conditions, by an appropriate mitigation law, such as the Ambraseys et *al.* [5] law.

The assessment method used in the probabilistic approach is a standard one; it enables the spectral parameters to be produced within a model, whilst taking account of the site conditions on the basis of a unique programme. (CRISIS 99 [6]).

In addition to meeting the level I requirements, to assess vulnerability, the deterministic approach is also produced in terms of intensities. A comparison of the 2 approaches is shown below in figure 2.

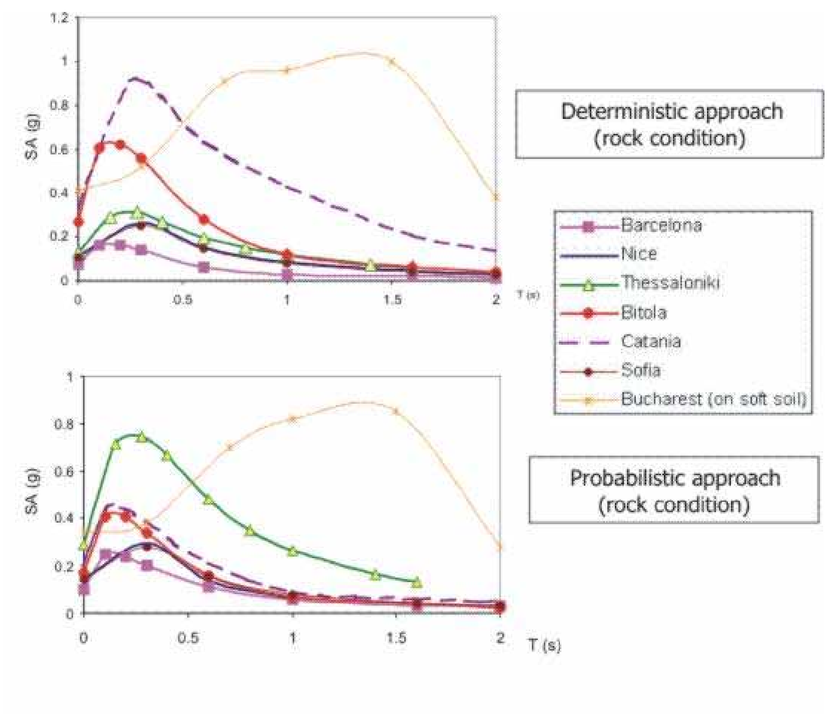


Figure 2: Comparison of the deterministic and probabilistic approaches (T = 475 years)

Some results of the application of the defined methodology for the city of Nice is shown in figure 3 [1]. In this case, the seismic zonation is derived from a 3D geotechnical model based on geological data combined with geotechnical and geophysical data [7]. By combining the seimic zonation with the PGA map, we obtain the PGA values taking into account the soil condition in the city area.

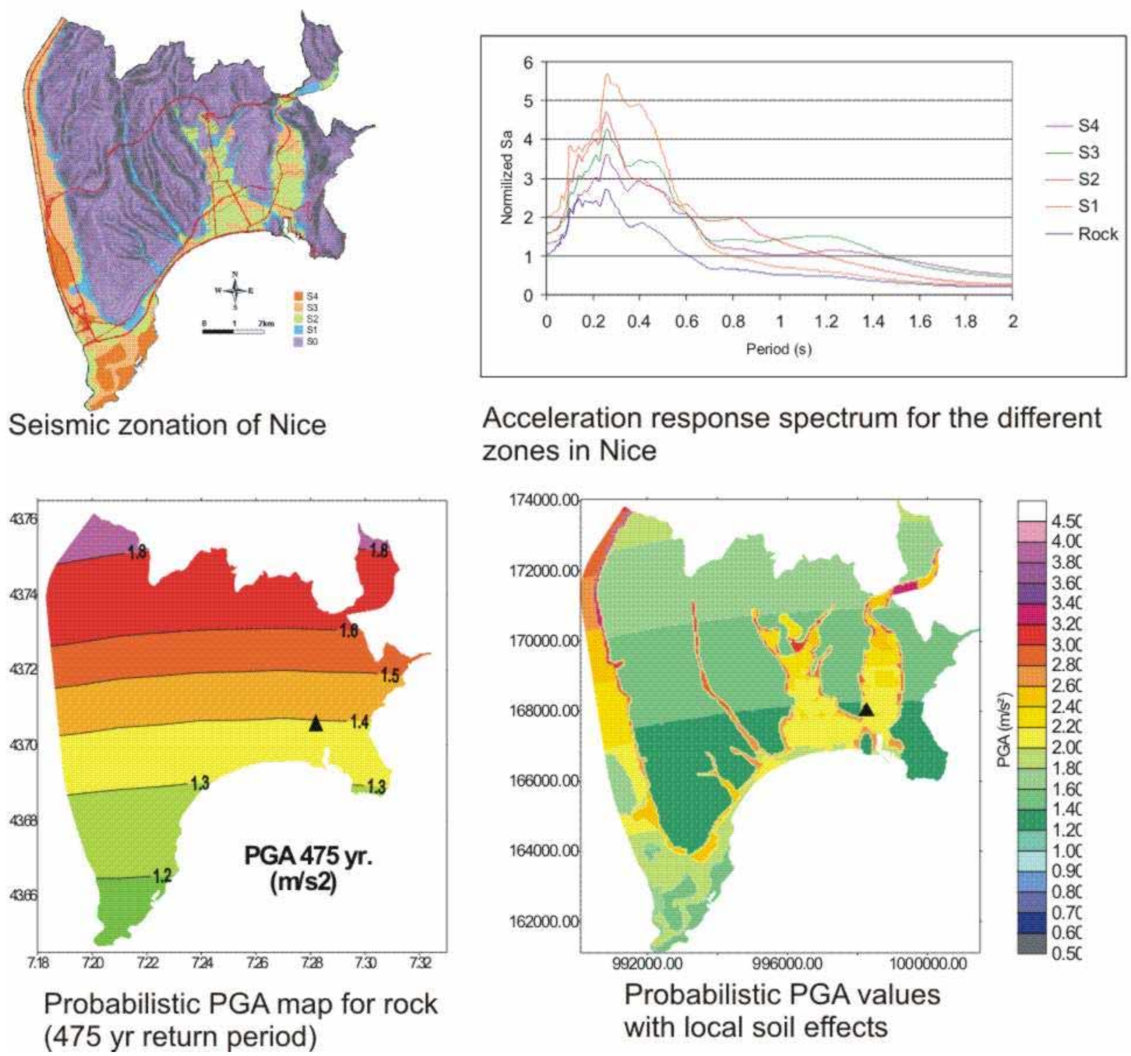


Figure 3: WP02 results for Nice : seismic zonation and probabilistic earthquake hazard [1].

WP 03: Urban system analysis.

In addition to analysing the physical vulnerability of buildings and lifeline facilities, it is also important to analyse the vulnerability of the actual system affected by an earthquake, i.e. the town or agglomeration. To do this, the functioning of the system must be analysed in order to be able to:

- determine the most important buildings which may be the subject of a more detailed vulnerability analysis.
- analyse the scenario results in terms of a system failure.

For example, if the health system of the city studied is only serviced by one individual, large hospital, then this health system will be extremely vulnerable since the hospital could easily be put out of service by the earthquake, causing the entire health system to break down. On the other hand, if several well-equipped hospitals are able to provide a service, the system will consequently be less vulnerable.

We have defined two levels of analysis: The first is purely qualitative and requires the definition of the different services within the system studied (emergency services, health, tourism, economy), a hierarchy of the different buildings belonging to each of the services, the definition of the major interactions between the services (e.g. the health service requires the services of the electricity companies). The second level introduces a quantitative hierarchy of buildings and seeks to define the interactions at building level (for example, location of the transformer supplying the largest hospital).

The urban system exposure analysis is made depending on the period considered. The indicators for the global value assessment of various elements at risk for the three reference periods (normal, crisis and recovery) were defined. These elements are comprised of *Polygons:* residential and commercial area, building stock areas, free space area. *Points:* isolated buildings (administrative, educational, emergency, medical etc) and lifeline building facilities (Tanks, Pumping stations, M/R stations, CO etc). *Lines:* water, wastewater, gas and telecommunication system. Maps in GIS format were produced, illustrating the main issues for these elements at risk for each period. An example is given in figure 4. It concerns the trade zones in the central area of Thessaloniki [1]. The importance of commercial buildings in the urban system varies from the normal period to the recovery period.

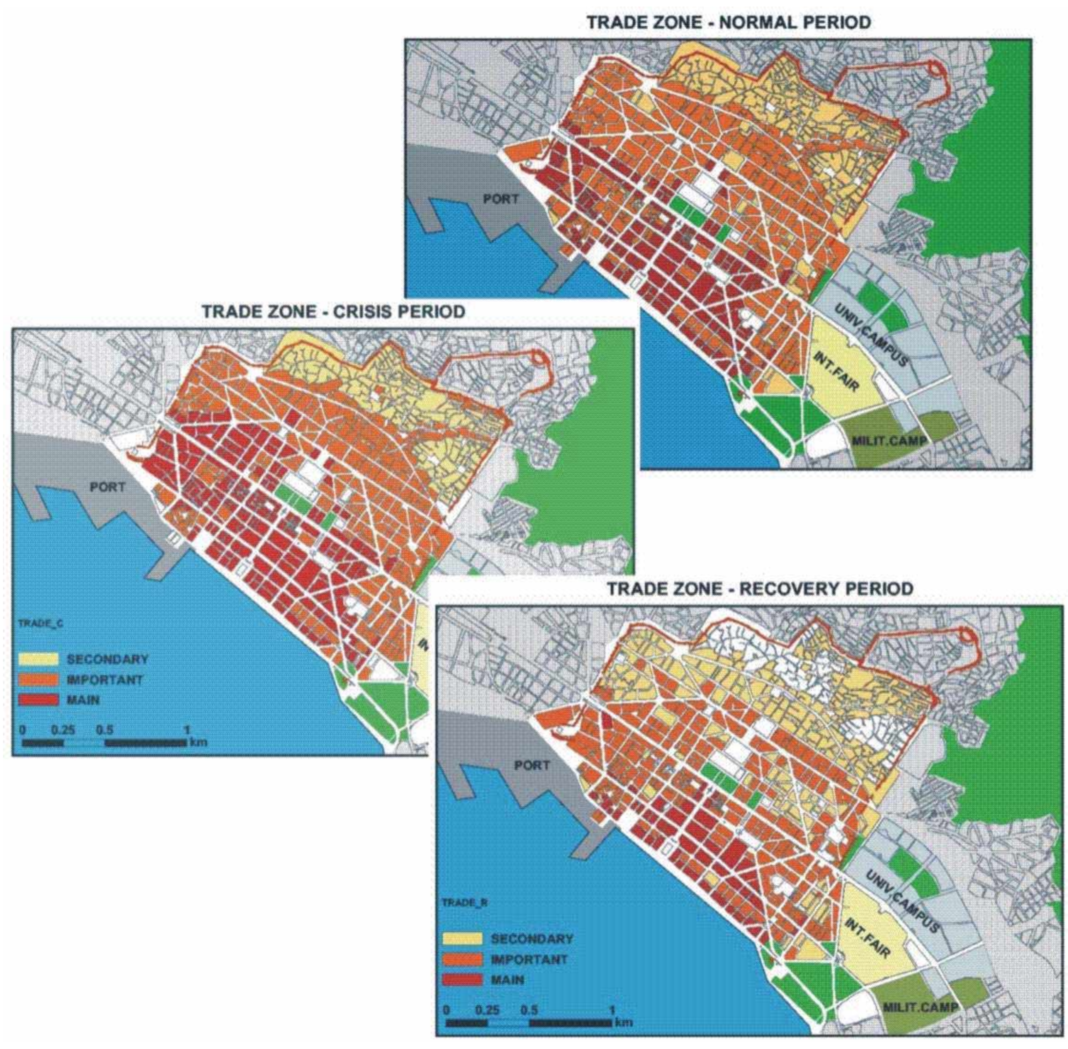


Figure 4: WP03 results for the city of Thessaloniki : analysis of the commercial zones in the center town [1].

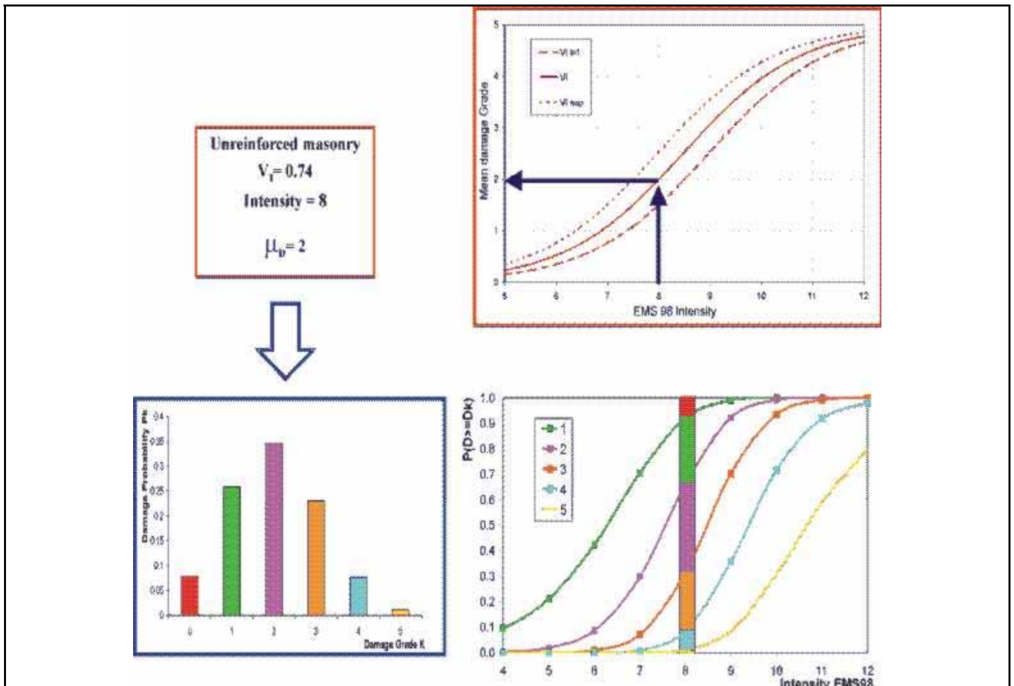
WP 04: Vulnerability assessment of current buildings.

This takes into consideration current buildings for which 2 levels of approach have been proposed:

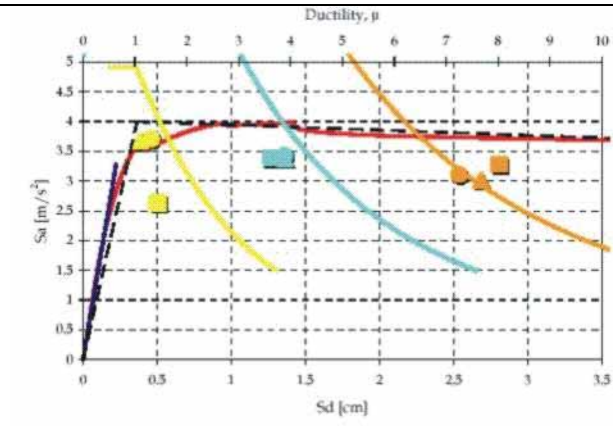
- Level I, using traditional, so-called “macroseismic" or "statistical" methods based on a large number of samples retrieved from previous earthquakes, particularly those in Italy, Greece, Romania and the former Yugoslavia.

  These methods are based on the assessment of the V*ulnerability* Index, V_I, by building type, enabling a V*ulnerability Curve* to be chosen (damage to/ or dependent on the macroseismic intensity or the maximum acceleration), followed by the choice of *a Fragility Curve*, showing the spread of damage according to the 5 classifications of the EMS 98 scale (D1: minor damage, to D5: collapse).
- Level II, using modern, so-called “mechanical” methods, based on behavioural analyses, so-called "displacement analyses" by assessing the destructive "performance" and whose main development was proposed in the ATC 40 (1996) [8] and the HAZUS (1999) [1] project.

These analyses were implemented principally by IZIIS (Skopje), UNIGE (Genoa), AUTH (Thessaloniki), and UTCB (Bucharest) for a fundamentally European context, based on the typologies defined in table 3. UNIGE have also proposed a non-iterative simplified method, enabling the “performance point” and the corresponding spectral displacement to be directly obtained. UNIGE has also carried out a comparison of the approaches of levels I and II; it obtained comparable results for both masonry constructions and those of reinforced concrete (see EGS 2003, Nice). The general methodology being carried out by IZIIS is now completed since end 2003.



Level I “macroseismic or statistical” method, based on the determination of a Vulnerability Index, Vi, and Fragility Curves. According to Giovinazzi *et al* [9].



Level II "mechanical" method, based on the ATC 40 methodologies, on the basis of a simplified assessment of the Performance Point and on the basis of comparisons with 3D dynamic modelling of masonry constructions. According to Lagomarsino *et al* [10].

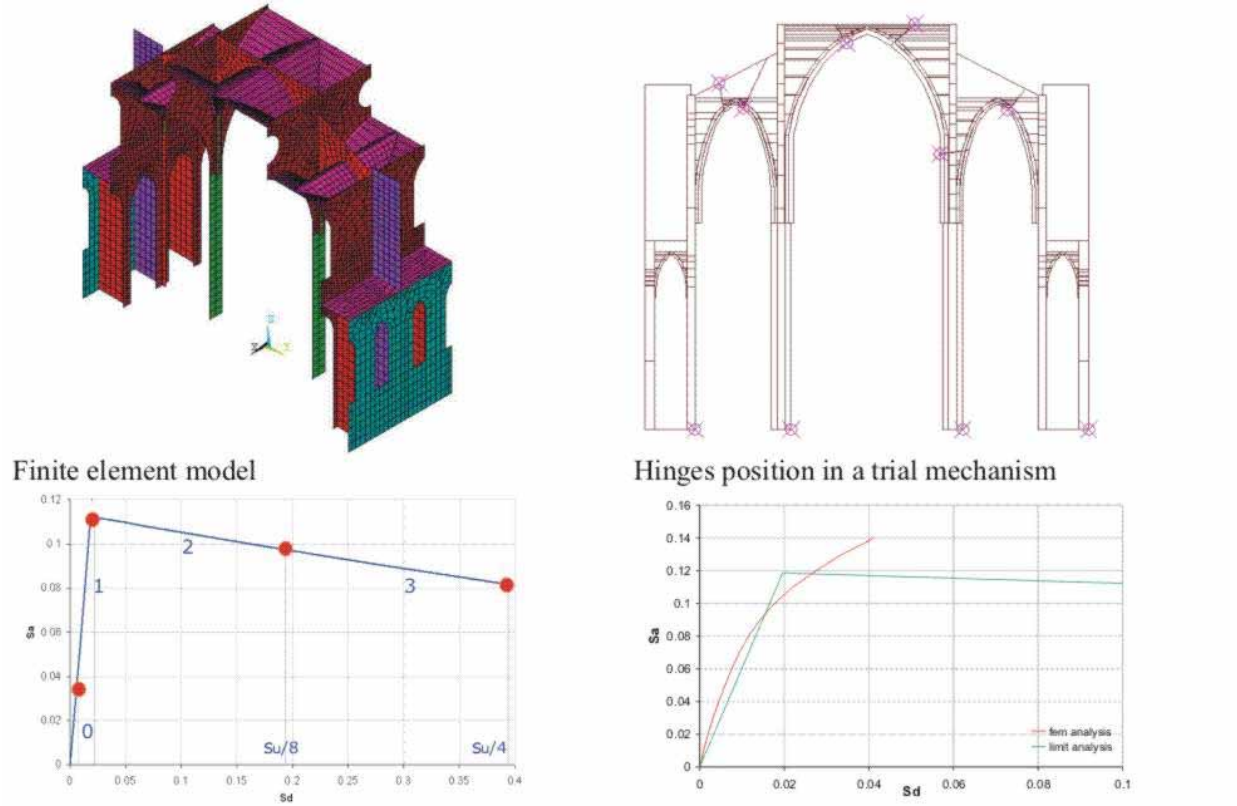
Figure 5: Methods of levels I and II to assess building vulnerability [1].

WP 05: Vulnerability assessment of old town centres, historical monuments and buildings.
This involves building aggregates, comprising old town centres, as well as certain historical monuments, particularly notable for being the representative image of the town.

Only the level I "macroseismic or statistical" method has been proposed by UNIGE for building aggregates. This allows the vulnerability index, V_I, to be modified for a building considered to be 'isolated', depending on its location in relation to its neighbouring buildings.

With regard to monumental heritage, the original methods of levels I and II have been developed by UNIGE, specifically within the framework of the RISK-UE project.

For example, the Santa Maria del Mar Church and the Saló del Tinell were selected as representative monuments for the city of Barcelona. Starting from plans, drawings, photos, etc from the representative monuments and in collaboration with the UNIGE team, began the vulnerability analysis of the Santa Maria del Mar Church [1]. By means of the limit analysis technique, the collapse mechanisms of the church are being analized. In this way, both the lowest level of acceleration in which the church might collapse and the capacity curve of the structure can be determined.



Finite element model

Hinges position in a trial mechanism

Capacity curve (unit of g/m)

Comparison between capacity curves by FEM and limit analysis

Figure 6: Vulnerability assessment of Santa Maria del Mar church in Barcelona [1].

WP 06: Vulnerability assessment of lifelines facilities and essential structures.

This relates to the whole of the lifelines network, in particular water, sanitary, electricity and gas, communications and infrastructures, etc. as well as critical and strategic constructions, corresponding, for example, to classes C and D of the French earthquake-resistant building regulations.

For these, there is little past European experience to draw from, but GEOTER and AUTH have proposed an assessment method which takes into account the most appropriate level I and II.

The first step of the risk assessment of lifelines consisits in the inventory of these constructions in a GIS. Indeed, the water network system of Greater Sofia Municipality is considered critical among the supply systems and data were gathered during the project.

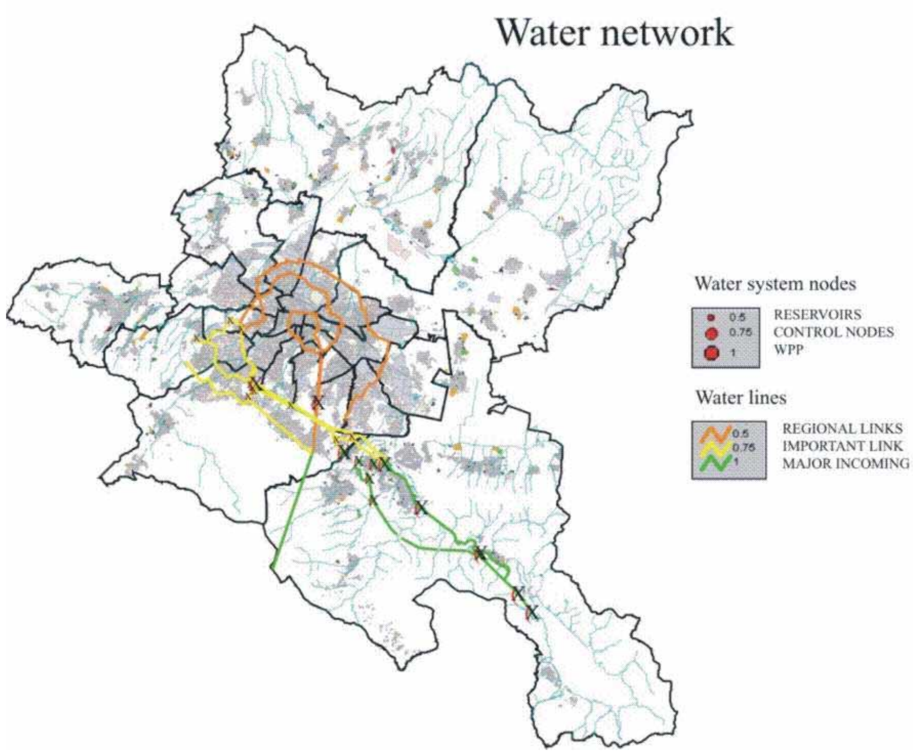


Figure 7: Water network in the city of Sofia [1].

WP 07: Seismic risk scenarios.

This involves the implementation, in the strictest sense of the word, of earthquake scenarios with the following main phases:

- Assessing direct damage, by combining data relating to seismic hazard and that relating to the physical vulnerability of buildings.

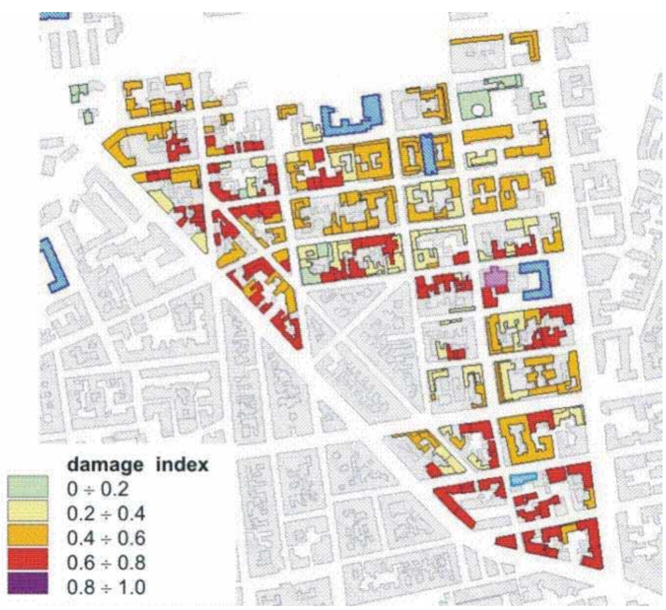


Figure 8: RISK-UE level I damage assessment in central area of Catania [1].

- Determining the number of victims (deaths, minor injuries, severe injuries), including those corresponding uncertainties.
- Assessing the direct and indirect economic impact (particularly, loss of companies).
- Estimating the potential number of persons rendered homeless and the problems resulting from this.
- Assessing network and infrastructure recovery times.

The methodology was developed by UTCB, with contributions from all partners.

IMPACTS OF THE RISK-UE PROJECT

The wide differences in earthquake hazard exposure, local geological and geotechnical characteristics and urban and construction features of the 7 cities has made it necessary to adopt at each step approaches sufficiently flexible to account for the basis factors in the different situations. For various reasons, but mainly due to the results of extensive previous projects and investigations, the work done differs from one cities to another. For instance, some cities like Catania and Thessaloniki benefit of previous study concerning detailed analysis of earthquake ground-shaking hazard and earthquake risk scenario whereas other like Bitola started at the very beginning. In this latter city as well as in much bigger cties like Buccarest or Sofia, the project allowed to created a very detailed GIS concerning hazard but also urban organisation. Other cities have update their own GIS in order, particularly, to be able to update the risk mitigation plan at city or even regional level.

Furthermore, one of the most important feature in this project is the involvement of the decision makers at city level. From the very beginning of the project they were fully integrated to the working process and their interest in the project was increasing as progress was observed in the different workpackages.

Some general impacts of the project are already observed :

- The creation of a basic tool for the decision-makers responsible for risk management, by means of implementing an earthquake scenario at city scale.
- The completion of a European manual for implementing earthquake scenarios, taking into account the distinctive European features.
- The assessment of a plausible earthquake, validated by city representatives, in terms of direct and indirect damages (cost, victims), with particular attention to old town centres, cultural heritage and the economic impact.
- The development of a database highlighting natural phenomena, exposed elements and their vulnerability in view of the occurrence of these phenomena.
- The development within the cities of services specialised in taking account of these risks in order to establish « **Management Plans** » and « **Plans of Action** » in the short, medium and long term.
- The creation of inter-city Euro-Mediterranean synergy enabling permanent exchanges with regard to the problems posed by natural disasters.

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