SIRCO

Development and Implementation of a Seismic Risk Simulator for the Portuguese mainland

Implementation Report and User Manual

Luis Sá

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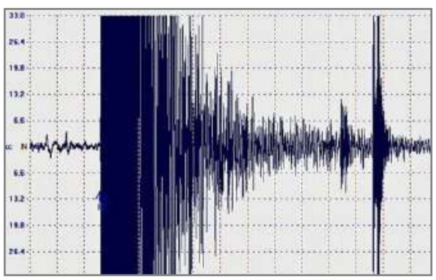
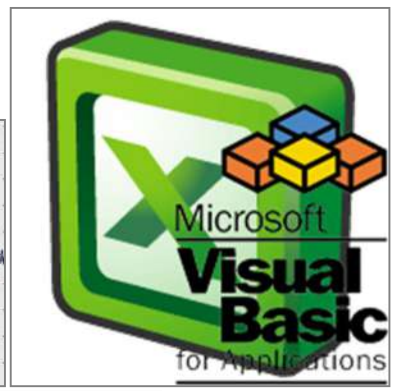
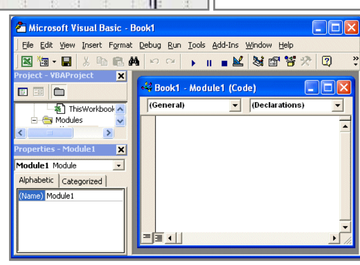
Seismic simulator for the Portuguese mainland

PART A - THEORETICAL CONCEPTS IN BRIEF

(Internally developed under the powers in charge of ANPC / DNPE / UPRA / NGA)



I. Introduction

Portugal has a high seismic risk taking into account the vulnerabilities associated with human occupation and the history of recorded seismic events. Given the inevitability of the occurrence of earthquakes, the approach of the seismic issue in a national context should be based on analysis of its fundamental aspects, and necessarily reflect the factors that contribute to the existence of a "real" risk of disaster to society. It is invaluable existence and maintenance of a simulator of damage from an earthquake with the ability to view a scenario, with potential damage indication, whose type has uncertainty difficult to determine empirically. The simulator and the applications of the data it produces serve as a supporting framework for planning and preparing the response to a seismic emergency, consisting of a mathematical simulation consists of damage virtually calculation models which can be produced by any seismic setting. At present there are two regions of the country covered by such tools, Lisbon and the Algarve, continuing a gap with regard to the remaining territory. So, in an attempt to address this, the ANPC and the Municipality of Lisbon, joining efforts and expertise, developed a simulator prototype whose methodology is applicable to the Portuguese mainland across the board.

II. Framework

The simulator applications and the data produced by it serve as a support reference to planning and preparing the response to an emergency earthquake, consisting of a mathematical simulation model comprises calculating the damages likely to be virtually produced by any seismic setting.

In this report gives to the work developed for the design and implementation of a simulator to scale the Portuguese mainland, the realization of which included:

1. Collect, process, harmonize and integrate the simulator all previously existing data or from previous projects of ANPC or projects done in seismic risk area for the city of Lisbon.
2. Implement the simulator all developed calculation models, namely:
    a. Attenuation laws
    b. calculation model of soil effects on the propagation of seismic wave from the surface to bedrock (site effects)
    c. Quantification of the seismic action to the surface,
    d. Spatial distribution, by statistical sub-section, mobile people, for the 12 months of the year,

e. Distribution of this population "in-house" and "out-house" for each month of the year and over several periods of the day, also separated by statistical subsection.
f. loss calculation models for:
    i. edified
    ii. Population
g. Tsunamis modeling results, in the form of wave height,
h. Economic damage Associates

3. Design, develop and adapt the simulator for use by ANPC.

III. Integration of Previous Project Information

They were used as a source of information, and more important as a database source, various variables for the study of seismic risk of AML and surrounding municipalities (AML-CL) and the Study of seismic risk and Tsunami Algarve (ERSTA). However, much of the key information used therein coated is not usable character either due to the use of compiled files in DLL format and / or BIN and therefore hardly editable either by using information currently outdated basis and example such statistical information of the extracted dating back 2001 Census.

This was the important information collected via SMPC / CML:

- How to calculate the seismic action via attenuation laws derived from utterances Family Rosenblueth-Esteva and Gutenberg-Richter, deep estimating the intensity from a magnitude and epicentral distance to the location to simulate;
- Local seismic action modeling through the impedance contrast methodology; locally calculating acceleration or deceleration of estimated intensities.
- Modeling of damage in built using the model of Coburn & Spencer

In addition, the information obtained by the analysis work undertaken in the AML-LC and was ERSTA:

- spatial distribution curves by statistical sub-section, the mobile population in the 12 months of the year;
- Distribution curves of this population "in-house" and "out-house" for each month of the year and over several periods of the day, also separated by statistical subsection.
- Modeling damage in populations using the Cambridge model

As is observed, it should be noted that in this work, the algorithms and key variables used in the temporal and spatial distribution of the population were based on those adopted in ERSTA and to some extent also in the study of AML-CL.

Other sources of information were used, of which we highlight the technical information attached to HAZUS software / FEMA and the research project EU FP-6 - neries.

It is assumed in this simulation that the seismic action is designated as prescribed in EC8 thus aaseismic tion will be considered Type 1 or Type 2.

Therefore, taking the epicenter of the coordinates in each scenario chosen, the type of earthquake was defined according to the following rule:

Sismo.Tipo will always = 1, except it is the cases where (X.epic> 81,000 ∧ Y.epic> 160 700) ∨ (X.epic> 123,000 ∧ Y.epic> 0), for which it is considered that the earthquake will be type 2.

IV. simulator Content Development

1. Programming language

Built on the EXCEL environment in Visual Basic language, all scripts are present and are editable by an authorized user. Only as a visualization tool we opted for the longer Dean ArcView 3.2 ESRI for still being a use fast software, effective and still currently recognized as such by most GIS users, running in such different environments like the old Windows 98 or current Windows 8, which denotes its comprehensive versatility.

2. Used methodology

For a better perception of the methodology can be observed in Figures 1,2 and 3 wishing to lay the considered steps. The construction of the methodology is based on the premise that the seismic risk is estimated due to the danger of occurrence of a phenomenon and exposure of vulnerable elements to this occurrence. In summary, these are the settings base to use this document

- Danger - Defined as the temporal and spatial probability of a given natural or technological phenomenon with a given intensity or magnitude.
- Vulnerability - level of damage of an element or group of elements exposed, resulting from the occurrence of a natural or technological phenomenon.
- Risk-expected probability of damage to human lives and property due to a particular phenomenon. This probability is calculated according to the danger and vulnerability, interests primarily explain how these two primary components were calculated.

Pets Danger

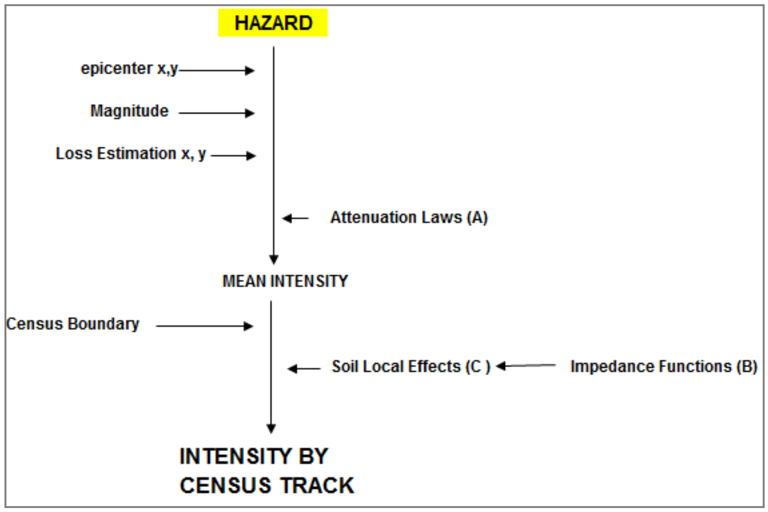


Figure 1 - Methodology for estimating the danger

Explanation:

Given a quake, with its epicenter in the X, Y coordinates and a magnitude m, we can calculate what the danger associated with a distada statistical sub-section V kilometers that has a soil characteristics with the W. For this we have to know the attenuation laws using (variable (a) in the figure), the characteristic impedance of that soil (B) and which phenomenon resulting (C), ie the local effects of acceleration or not.

Calculation (A) - Laws Attenuation

For this seven attenuation laws analysis were used. They were created with data from different areas of the globe, including the Iberian Peninsula.

i. **Bakun and Wentworth (1997): California, USA**

$$I_{MMI} = 3.67 + 1.17M_W - 3.19\log\left(R_{epi}\right)$$

ii. **Bakun and Scotti (2006):** French SCR

$$I_{MSK} = 4.48 + 1.27M_W - 3.37\log\left(\sqrt{R_{epi}^{\ 2} + h^2}\right)$$

iii. **Bakun (2006): Basin & Range, USA**

$$I_{MMI} = 0.44 + 1.70M_W - 0.0048\Delta_h - 2.73\log\left(\Delta_h\right)$$

where:

$$\Delta_h = \sqrt{R_{epi}^2 + h^2}$$

$$h = 10$$

$$\sigma = 0.58$$

iv. **Pasolini et al. (2008): Italy**

$$I_{MCS} = I_E - 0.0086\left(\sqrt{R_{epi}^{\ 2} + h^2} - h\right) - 1.037\left[\ln\left(\sqrt{R_{epi}^{\ 2} + h^2}\right) - \ln(h)\right]$$

where:

$$I_E = 2.460M_W - 5.862$$

$$h = 3.91$$

$$\sigma = 0.69$$

v. Esteva & Rosenblueth (1967): California

$$I_{MMI} = c1 + c2M - c3\ln R$$

vi. Lopez et al. (2000): Iberia

$$I = 5.557 + 0.902 \cdot I_0 + 0.014 \cdot I_0^2$$

vii. Crespellani et al. (1993): Italy

$$I_{MMI} = 6.39 + 1.756M - 2.747\ln(R + 7)$$

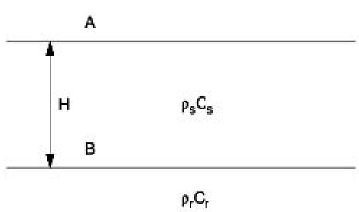
Employing a combination of these seven laws attenuation was achieved through an iterative methodology, a satisfactory relationship between magnitude, epicenter and the distance to it. The iterative methodology can be summed up by the rule "the most similar to the original simulator." Thus, by using different "runs" in the original simulation and compared with data obtained through the attenuation laws now tested, it was concluded that the expression by selected iteration is one that obtains the most similar to the results of macrossísmicas calculations of intensities of the first simulator and the concomitant damage reported by coeval sources 1755 or 1909.

Intensity (1 to 13) felt at a point = (Intensity given by Law 6) + 0.5 (arithmetic mean intensities given by the laws 1,2,3,4,5,7) 0.5

Calculation of (B) - Impedance

The modification of the seismic movement due to topographical and geotechnical local conditions is called local effect. This amplification or attenuation is obtained by comparing the response of a site with a reference point, i.e. a point located on the flat rock. These site effects are mainly observed in the ridge lines and in alluvial valleys, where buildings suffer greater damage than one might expect from its distance from the epicenter of the earthquake.

The impedance contrast between features sediment and rock properties of a soil (expression 3). Thus, the lower the impedance contrast, softer sediment (as represented in figure A) are compared with the bedrock / bedrock (B). We consider the simple case of a horizontal layer of soil over a space subjected to an elastic wave into an infinite half plane S (1D)



It analytical formula that expresses the ratio of the surface displacement at point A and a point B located at the interface between the surface layer of soil and the bedrock is given by the expression:

$$\beta = \frac{\rho_s C_s}{\rho_r C_r}$$

β Impedance contrast between sediments and bedrock
ρ_s Soil density (T/m^3)
C_s Shear wave velocity in sediments (m/s)
ρ_r Bedrock density (T/m^3)
C_r Shear wave velocity in bedrock (m/s)

(Expression 3)

Thus, using a simplification in one dimension, we can estimate using the reference values of which the expected impedance contrasts for each region / in subsection statistical study. This requires the following information:

- dominant geology by statistical sub-section;
- speed reference value of the S wave for each geological family;
- reference value of specific gravity for each geological family.

From the rasterization of the geological map of Portugal 1: 1000000, available for free through the OneGeology project and the intersection of information associated with the statistical subsections INE, via GIS GIS, it was possible to which the predominant geological formation by subsection.

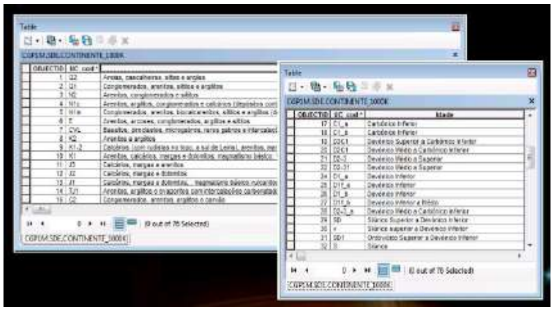


Figure - Geological Map of Portugal and associated information

Then there were obtained for each geological formation of reference values for the wave propagation velocity and specific gravity, it has been established as bedrock values associated with the rock type formation igneous plutonic or intrusive, as is the case of Monchique, Sintra, Star and other rock formations further north.

Calculation (C) - Effect Site

11A from the information obtained and using the expression 3 is then possible to obtain a hemispheric class classification 19 impedance contrast (β). We know that the analytical formula for the ratio between the displacements at the surface point A and point B located at the interface between the soil surface and bedrock is given by:

CL_IMPED	CL_GEOTECN
1	Q1
2	K1
3	Q2
4	J1
5	J3
6	D2-3
7	J2
8	at
9	N1m
10	TJ1
11	PAg
12	C1_b
13	N2
14	K1-2
15	f1
16	C1-2
17	sigma2
18	E
19	D3C1

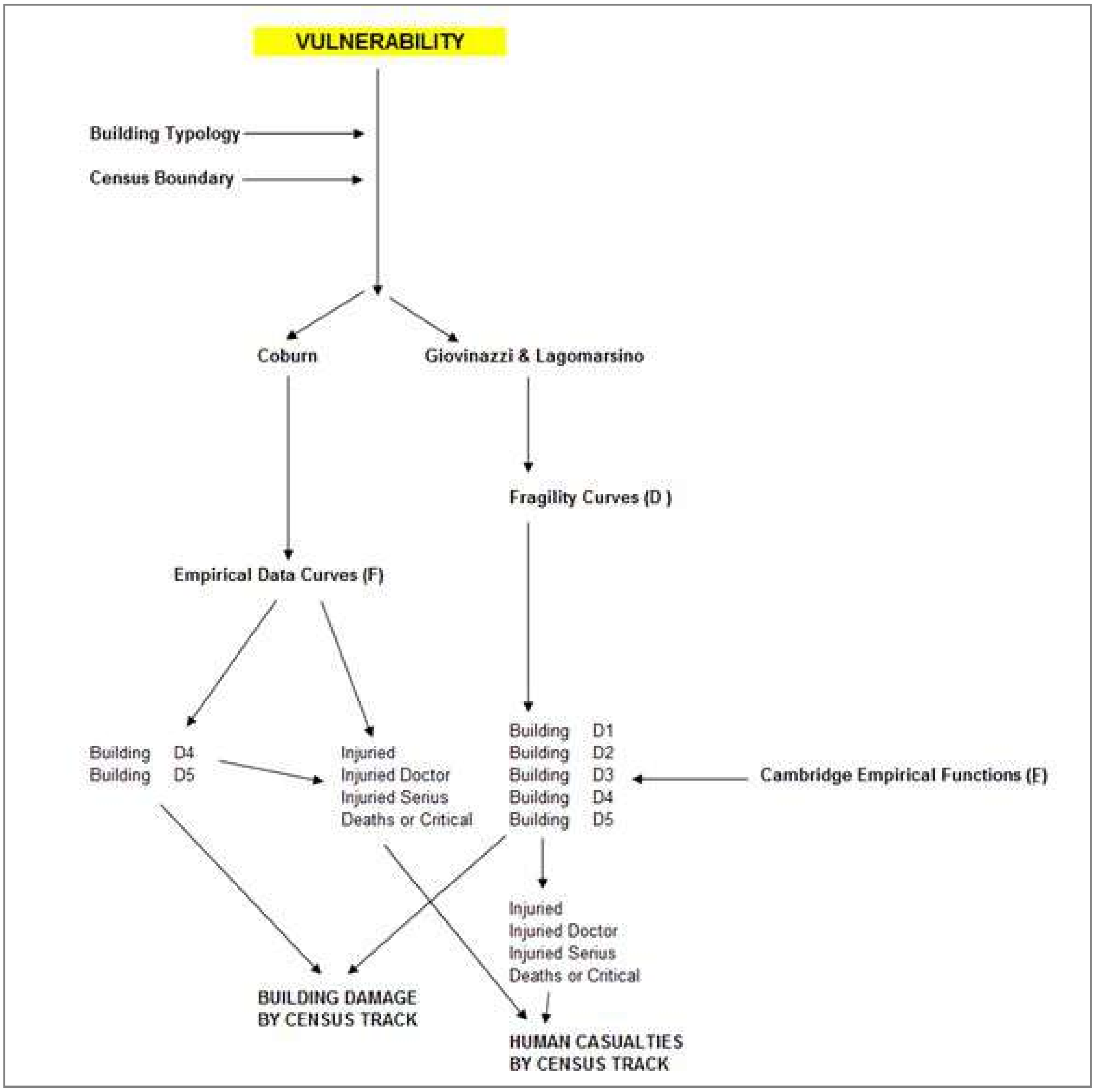
$$\frac{u_A}{u_B} = \frac{1}{\sqrt{\cos^2(k_s \cdot H) + \beta^2 \cdot \sin^2(k_s \cdot H)}}$$

- H is the soil layer height.
- $k_s = \frac{2\pi f_c}{C_s}$ is the wavenumber where C_s is the shear wave velocity in sediments and f_c is the predominant frequency of the input signal.
- β is the impedance contrast between sediments and bedrock.

It is known that the maximum potential amplification $\left(\frac{u_A}{u_B}\right)_{max}$ then correspond to: $\left(\frac{u_A}{u_B}\right)_{max} = \frac{1}{\beta}$

That is, the maximum potential amplification is equivalent to the inverse of impedance contrast. If we for example, a β = 0.4, the potential maximum amplification factor will be (1 / 0.4) = 2.5 being the value to be in terms of design, by application of the philosophy "worst case scenario".

Pets Vulnerability



The vulnerability is defined as the damage level of an element or group of elements exposed, resulting in the occurrence of a natural or technological phenomenon. Vulnerability functions (or fragility curves) of an exposed element representing the probability that its response to the earthquake exceeds its various states performance limits based on physical and economic considerations. For a population of buildings exposed to the danger of earthquake, the fragility functions are related to the probability of overcoming limits of multiple damage states certain measures of gravity ground motion. The essential components required for the development of fragility functions are:

- Parameter ground motion (correlated with the damage)
- Grading of Construction
- Conservation state
- uncertainties

The general procedures used for the development of fragility functions can be grouped as empirical or analytical. A striking example is a method that has been proposed by two researchers Italian (Giovinazzi and Lagomarsino, 2001, 2004) leading to setting of damage probability functions based on Macroseismic scale EMS-98 (Grünthal, 1998).

Calculation (D) - Fragility Curves "Giovinazzi and Lagomarsino "

The EMS-98 scale defines qualitative descriptions of "few," "many" and "many" to five degrees of damage (D1 to D5) to intensity levels ranging from V to XII in six different classes reduce their vulnerability (a to E or a to F). Problems related to "incompleteness" and "vagueness" of the matrices were discussed assuming a beta distribution damage. Matrices likelihood of damage produced for each class of vulnerability are related to the inventory construction by using an empirical vulnerability index depending on the building type, the construction features of a building (e.g., number of floors, irregularities, etc.) and construction practices typically used.

Information on the national built were taken from the results of Census 2011. These provided information on the resident population and this population, number of buildings and their size, build date, etc.

The definition of a classification system for the characterization of the exposed buildings and the description of its damage is an essential step for risk analysis, to ensure a consistent interpretation of data and results. One way to associate each building to a class type can be done with the help of EMS98 (Grünthal, 1998). On this scale, the buildings are classified according to their type and structural vulnerability of various classes are defined: A (most vulnerable) to one end (E or F) less vulnerable.

Vulnerability class of the different buildings based on the EMS98 (adapted from Sousa,2006)

Date of construction	Number of floors	Concrete (EBAR)	Masonry (EARG)	Adobe/ Mud (EPAT)	Other (EORE)
Before 1919	All	--	B	A	A
1920 – 1960	All	C	C	A	A
1961 – 1985	All	D	C	A	A
1986 – 2009	All	E	D	A	A

For each type of building identified a vulnerability factor is most likely assigned along with a likely range. Taking into account some work Teves-Costa & Barrier (2008) to the city of Lisbon, minimum, average and maximum levels of vulnerability were chosen for each identified typological class

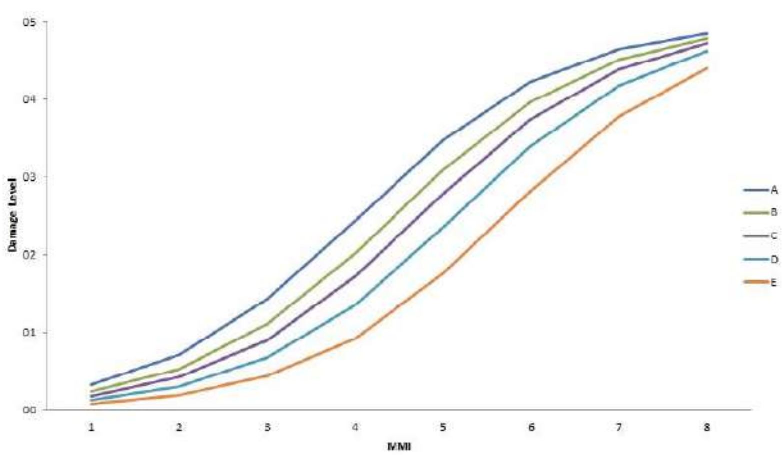
Vulnerability indices applied for each typological class

Typological class	Minimum	Mean	Maximum
M>1919	0.531	0.773	1.016
M20_60	0.491	0.745	1.056
M61_85	0.491	0.698	0.956
M86_95	0.451	0.634	0.836
RC20_60	0.522	0.681	0.742
RC61_85	0.482	0.640	0.752
RC86_95	0.462	0.555	0.662
RC<1996	0.426	0.533	0.722

From the intersection of the last two tables, we obtain an average value of vulnerability (Vi) for each class. At this point, according Giovinazzi and Lagomarsino (2002, 2004) applies to words to obtain
µD which is the level of vulnerability.

$$\mu_D = 2.5\left[1 + \tanh\left(\frac{I + 6.25V_I - 13.1}{2.3}\right)\right]$$

Then the damage distribution is estimated using a beta distribution whose use is possible via various software having been using in this case Excel2007 and MiniTab15. The fragility curves can finally be estimated after calculating the probability density function.



These fragility curves indicate the probability of a building typology undergo a certain degree of damage or higher (D1 to D5), depending on the intensity Macrossísmica (I-XIII). Resulting from this method one obtains a final table then crossing the seismic intensity with the expected damages.

	Danos E.M.S. 98 por classe Tipologia				
MMI	A	B	C	D	E
1	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1
4	1	1	1	1	1
5	1	1	1	1	1
6	2	2	1	1	1
7	3	3	2	2	1
8	4	4	3	3	2
9	5	4	4	4	3
10	5	5	5	5	4
11	5	5	5	5	5
12	5	5	5	5	5
13	5	5	5	5	5

Calculation of (E) - Cambridge curves

The Cambridge method considers that human injury (injuries and deaths) are due to the presence of people in buildings that were damaged. Thus, it was considered in the implementation of this simulator that in the case of buildings actually collapsed (total collapse), the mortality rate would be 90%, and injured rate equal to 10%, following a similar distribution to that recognized in the original model . This formulation is explained in the following table, where we list the coefficients used for damage level.

	s1	s2	s3	s4
Dano1	0.000	0.000	0.000	0.000
Dano2	0.005	0.000	0.000	0.000
Dano3	0.020	0.015	0.005	0.000
Dano4	0.200	0.150	0.080	0.060
Dano5	0.015	0.010	0.075	0.900

Where: S1-injured Passenger; S2 minor injuries requiring hospital treatment; S3- Graves; S4-dead or Unrecoverable

Calculation (F) - Empirical Curves Coburn & Spencer

Coburn et al. (1992) proposed a global model for the estimation of seismic victims, considering the type of construction, the people in the building, the occupation at the time of occurrence of the earthquake, the number of prisoners occupants in the collapse, distribution of lesions collapse and post mortality collapse.

The "case fatality rate", which is the ratio of deaths to the number of occupants present in the buildings that collapsed when the earthquake is set to estimate the number of victims. The victims are assumed to be due to the number of buildings collapsed and its lethality ratio. This is expressed in terms of number of preset parameter M, which are derived from, or compared to published data from historical earthquakes analyzed. Using these parameters, the relationship lethality and the number of people killed in an earthquake can be defined by the following expressions:

$$LR - M_1 \times M_2 \times M_3 \times (M_4 + (1 - M_4) \times M_5) \times M_6$$

$$C = D \times LR$$

where LR is the fatality rate, M1 population by building M2 is the occupation at the time of the earthquake, M3's occupants arrested for collapse, M4 is the distribution injury collapsed, M5 is the post mortality collapse and M6 represents the collapsed buildings in more severe damage state. C is the number of victims and D is the number of buildings collapsed.

Dependent factors are variable construction typology M3, M4 and M5 Coburn and Spence calculated as a function of ground motion intensity for masonry buildings and the buildings of reinforced concrete. In this study, both collapse of a wall or total collapse are considered provoking lesions in human victims. Note that the self-rescue of the occupants efforts were also considered. Thus, the occupants trapped by the collapse is calculated as a percentage of the population that built occupant.

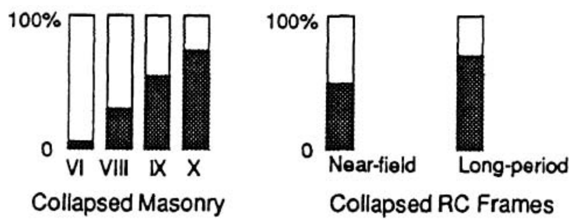


Figure X: The estimate of M3 parameter based on the type of construction. (Coburn et al., 1992)

The M4 parameter represents the distribution of injuries of prisoners occupants at the time of collapse. Coburn and Spenc (1992) argue that injuries and deaths are usually caused by entrapment or by choking dust stemmed from structural elements. Thus, the distribution of lesions in four stages (ranging from minor injuries to deaths) is proposed for masonry buildings and reinforced concrete. This distribution was also collected from injury and mortality statistics of past events.

Triage Injury Category	Masonry	RC
1) Dead or unsaveable	20	40
2) Life threatening cases needing immediate medical attention	30	10
3) Injury requiring hospital treatment	30	40
4) Light injury not necessitating hospitalization	20	10

Table X -yThe distribution injury collapse of occupants trapped (%) suggested by Coburn and Spence (2002)

The M5 parameter represents the mortality after the collapse, this variable is defined in terms of search and rescue time and the level of injury to the occupants arrested. Coburn and Spence (2002) proposed a global value and assuming the post collapse death function does not change considerably from country to country, or one region to another.

Situation	Masonry	RC
Community incapacitated by high casualty rate	95	-
Community capable of organising rescue activities	60	90
Community + emergnecy squads after 12 hours	50	80
Community + emergency squads + SAR experts after 36 hours	45	70

Table Percentage of survivors trapped in buildings with severe damage which subsequently die (Coburn and Spence, 2002)

Estimation of Risk

The final risk value is calculated by combining the hazard (macrossísmicas calculating intensities via attenuation laws) to the vulnerability of the building (through methodologies Coburn & Spencer Giovinazzi + & Lagomarsino & Cambridge) expressed in terms of:

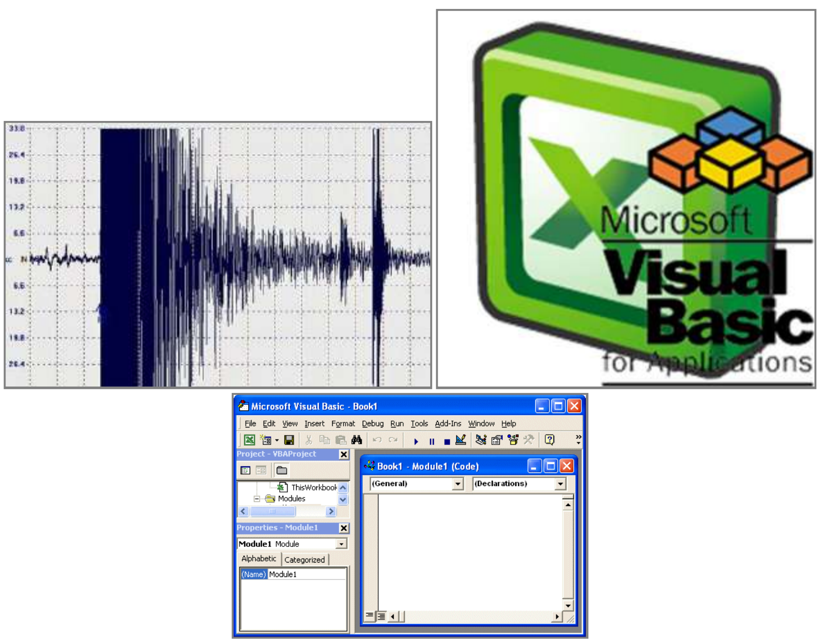
- number of mortal victims
- number of victims with minor injuries

- number of homeless people
- No buildings with minor damage
- No buildings with moderate damage
- No buildings with severe damage
- No collapsed buildings
- Economic losses - 2nd phase (expected)
- Modeling Tsunami - Stage 2 (predicted)

Seismic simulator for the Portuguese mainland

PART B - USER MANUAL EXPEDITO

(Developed by ANPC under the powers in charge of DNPE / UPRA / NGA)



1. Installation

A.Deverá open the Installation CD or other storage location, file sim_cont.zip

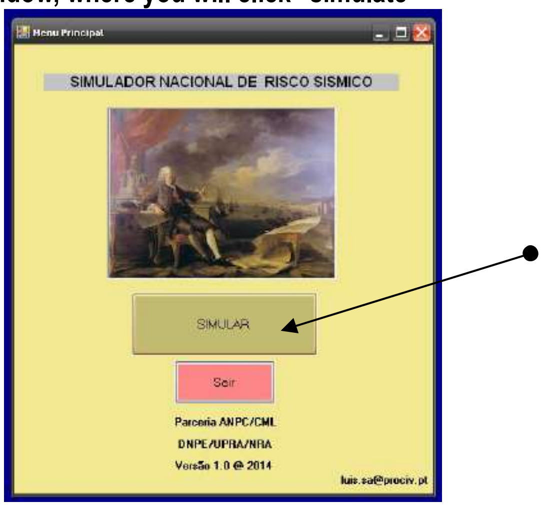
B. Unzip the files to a folder of your choice

C. Click the file setup.bat

D. wait 1 to 2 minutes

E. You should now have one drive Q: Where will click on sim_cont_vb.exe file that will be the beginning of the simulator file

F. You will find the following window, where you will click "simulate"



G. Click "Running simulation"
H. You will get the control panel simulator

I. Here you can choose which of the earthquake parameters you want to simulate, ie latitude, longitude, magnitude, Month, Earthquake Time or else simulate two historical earthquakes, 1755 or 1909. You can also generate a Google Earth file with the epicenter.

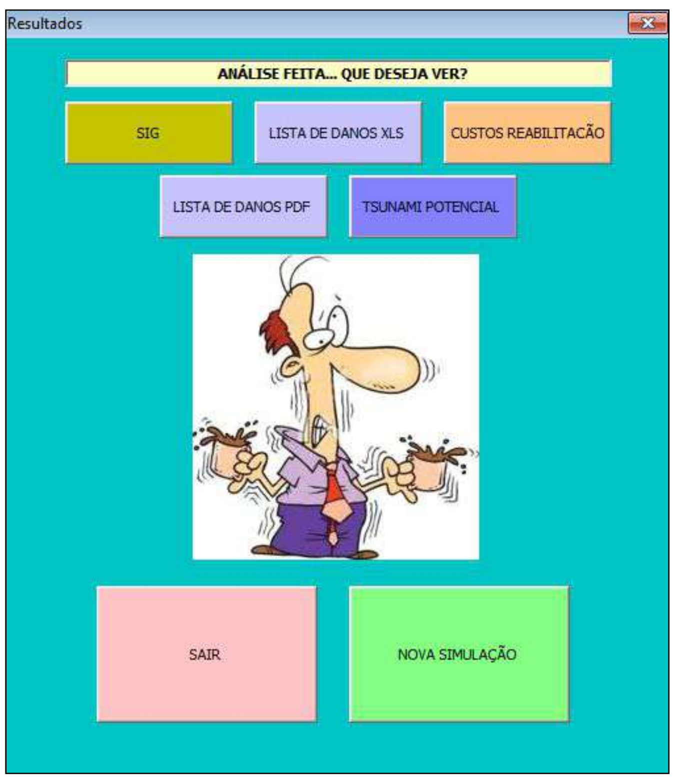
J. If you need to convert pooderá coordinates using the corresponding button in the upper left corner that you provide a web link to Igoe site.

http://www.igeoe.pt/utilitarios/coordenadas/

K. The button "Help" provides the opening of this file that is now reading

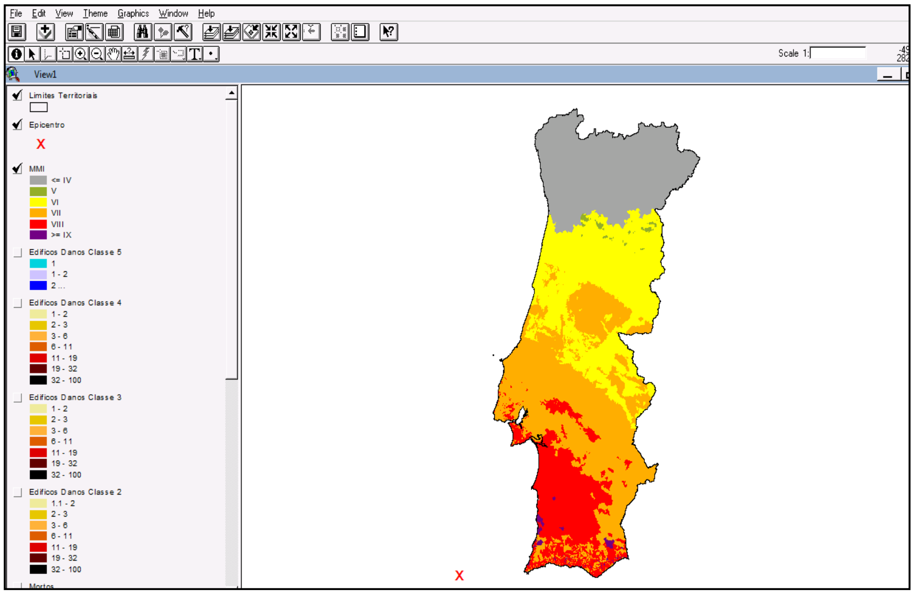
L. entering data and clicking "Simulation" Historical or earthquakes will get the "wait" window where a progress bar will guide you. Depending on computer capacity this may take 4-10 minutes.

M. After processing will open the next window, accompanied by a beep

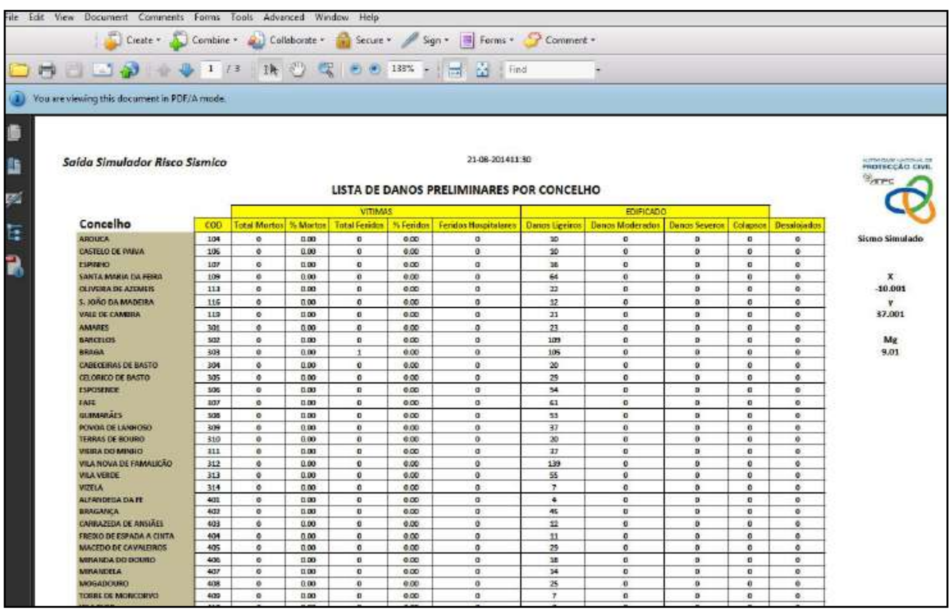


N. At this point, there are three cases to see results on human and material damage:

- In GIS by clicking "View GIS" that will open the file in proj1.apr ArcView 3.2, and the systematization of data at the level of statistical subsection



- In list format via PDF file of the aggregate damage to county



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LISTA DE DANOS PRELIMINARES POR CONCELHO

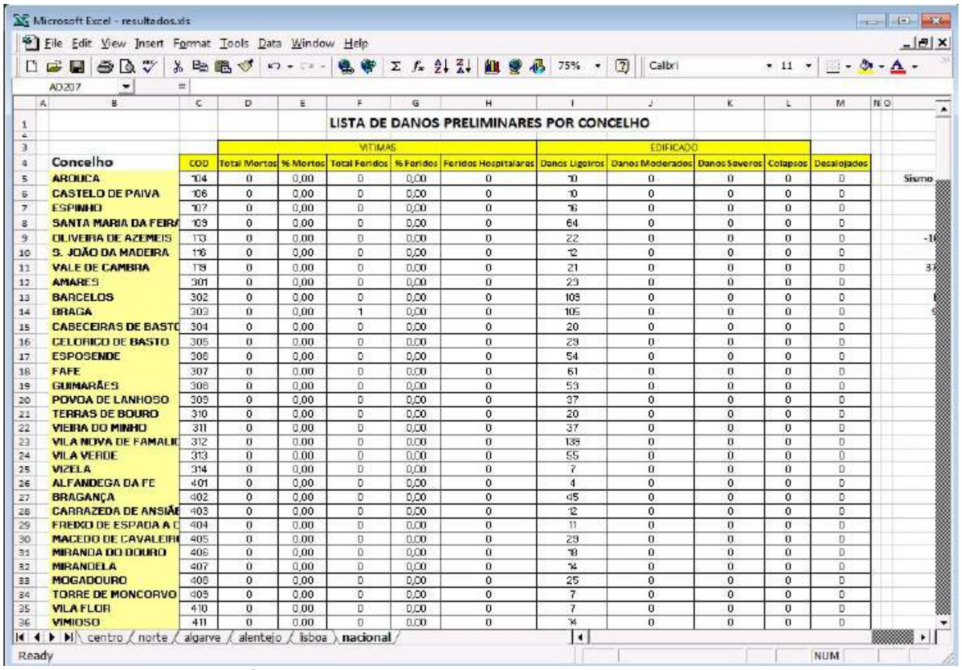
Concelho	COD	VITIMAS					EDIFICADO				
		Total Mortos	% Mortos	Total Feridos	% Feridos	Feridos Hospitalares	Danos Ligeiros	Danos Moderados	Danos Severos	Colapsos	Desalojados
AROUCA	104	0	0.00	0	0.00	0	30	0	0	0	0
CASTELO DE PAIVA	106	0	0.00	0	0.00	0	30	0	0	0	0
ESPINHO	107	0	0.00	0	0.00	0	38	0	0	0	0
SANTA MARIA DA FEIRA	109	0	0.00	0	0.00	0	64	0	0	0	0
OLIVEIRA DE AZEMEIS	113	0	0.00	0	0.00	0	22	0	0	0	0
S. JOÃO DA MADEIRA	116	0	0.00	0	0.00	0	32	0	0	0	0
VALE DE CAMBRA	119	0	0.00	0	0.00	0	21	0	0	0	0
AMARES	301	0	0.00	0	0.00	0	23	0	0	0	0
BARCELOS	302	0	0.00	0	0.00	0	109	0	0	0	0
BRAGA	303	0	0.00	1	0.00	0	105	0	0	0	0
CABECEIRAS DE BASTO	304	0	0.00	0	0.00	0	20	0	0	0	0
CELORICO DE BASTO	305	0	0.00	0	0.00	0	29	0	0	0	0
ESPOSENDE	306	0	0.00	0	0.00	0	54	0	0	0	0
FAFE	307	0	0.00	0	0.00	0	61	0	0	0	0
GUIMARÃES	308	0	0.00	0	0.00	0	53	0	0	0	0
POVOA DE LANHOSO	309	0	0.00	0	0.00	0	37	0	0	0	0
TERRAS DE BOURO	310	0	0.00	0	0.00	0	20	0	0	0	0
VIEIRA DO MINHO	311	0	0.00	0	0.00	0	37	0	0	0	0
VILA NOVA DE FAMALICÃO	312	0	0.00	0	0.00	0	139	0	0	0	0
VILA VERDE	313	0	0.00	0	0.00	0	55	0	0	0	0
VIZELA	314	0	0.00	0	0.00	0	7	0	0	0	0
ALFANDEGA DA FE	401	0	0.00	0	0.00	0	4	0	0	0	0
BRAGANÇA	402	0	0.00	0	0.00	0	45	0	0	0	0
CARRAZEDA DE ANSIÃES	403	0	0.00	0	0.00	0	12	0	0	0	0
FREIXO DE ESPADA A CINTA	404	0	0.00	0	0.00	0	11	0	0	0	0
MACEDO DE CAVALEIROS	405	0	0.00	0	0.00	0	29	0	0	0	0
MIRANDA DO DOURO	406	0	0.00	0	0.00	0	18	0	0	0	0
MIRANDELA	407	0	0.00	0	0.00	0	34	0	0	0	0
MOGADOURO	408	0	0.00	0	0.00	0	25	0	0	0	0
TORRE DE MONCORVO	409	0	0.00	0	0.00	0	7	0	0	0	0

Sismo Simulado

X
-10.001
Y
37.001

Mg
9.01

- Or in xls file for later export and / or edit in spreadsheet of damage caused by the simulated earthquake, aggregated to the county

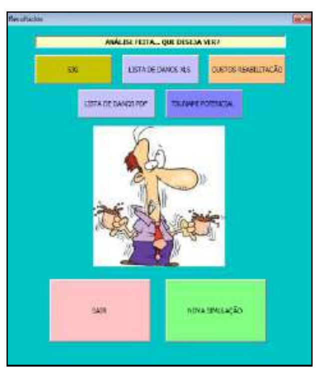


LISTA DE DANOS PRELIMINARES POR CONCELHO

		VITIMAS					EDIFICADO				
Concelho	COD	Total Mortos	% Mortos	Total Feridos	% Feridos	Feridos Hospitalares	Danos Ligeiros	Danos Moderados	Danos Severos	Colapsos	Desalojados
AROUCA	104	0	0,00	0	0,00	0	10	0	0	0	0
CASTELO DE PAIVA	106	0	0,00	0	0,00	0	10	0	0	0	0
ESPINHO	107	0	0,00	0	0,00	0	16	0	0	0	0
SANTA MARIA DA FEIRA	109	0	0,00	0	0,00	0	64	0	0	0	0
OLIVEIRA DE AZEMEIS	113	0	0,00	0	0,00	0	22	0	0	0	0
S. JOÃO DA MADEIRA	116	0	0,00	0	0,00	0	12	0	0	0	0
VALE DE CAMBRA	119	0	0,00	0	0,00	0	21	0	0	0	0
AMARES	301	0	0,00	0	0,00	0	23	0	0	0	0
BARCELOS	302	0	0,00	0	0,00	0	109	0	0	0	0
BRAGA	303	0	0,00	1	0,00	0	105	0	0	0	0
CABECEIRAS DE BASTO	304	0	0,00	0	0,00	0	20	0	0	0	0
CELORICO DE BASTO	305	0	0,00	0	0,00	0	29	0	0	0	0
ESPOSENDE	306	0	0,00	0	0,00	0	54	0	0	0	0
FAFE	307	0	0,00	0	0,00	0	61	0	0	0	0
GUIMARÃES	308	0	0,00	0	0,00	0	53	0	0	0	0
POVOA DE LANHOSO	309	0	0,00	0	0,00	0	37	0	0	0	0
TERRAS DE BOURO	310	0	0,00	0	0,00	0	20	0	0	0	0
VIEIRA DO MINHO	311	0	0,00	0	0,00	0	37	0	0	0	0
VILA NOVA DE FAMALIC	312	0	0,00	0	0,00	0	139	0	0	0	0
VILA VERDE	313	0	0,00	0	0,00	0	55	0	0	0	0
VIZELA	314	0	0,00	0	0,00	0	7	0	0	0	0
ALFANDEGA DA FE	401	0	0,00	0	0,00	0	4	0	0	0	0
BRAGANÇA	402	0	0,00	0	0,00	0	45	0	0	0	0
CARRAZEDA DE ANSIÃE	403	0	0,00	0	0,00	0	12	0	0	0	0
FREIXO DE ESPADA A C	404	0	0,00	0	0,00	0	11	0	0	0	0
MACEDO DE CAVALEIR	405	0	0,00	0	0,00	0	29	0	0	0	0
MIRANDA DO DOURO	406	0	0,00	0	0,00	0	18	0	0	0	0
MIRANDELA	407	0	0,00	0	0,00	0	14	0	0	0	0
MOGADOURO	408	0	0,00	0	0,00	0	25	0	0	0	0
TORRE DE MONCORVO	409	0	0,00	0	0,00	0	7	0	0	0	0
VILA FLOR	410	0	0,00	0	0,00	0	7	0	0	0	0
VIMIOSO	411	0	0,00	0	0,00	0	14	0	0	0	0

N. Rehabilitation - Financial Costs

It has also created a rehabilitation cost estimation module that will focus only on the financial costs of reconstruction and rehabilitation of housing affected. This estimate was based on studies done by LNEC (Sousa, 2007) in which through the use of the value of construction costs per m2 in Portugal, published annually in Ordinance by the Republic Daily, one can estimate in theory which totals (in € and municipality) of capital to be applied in order to allow the rehabilitation of the Portuguese building stock that would be affected by the now simulated earthquake.

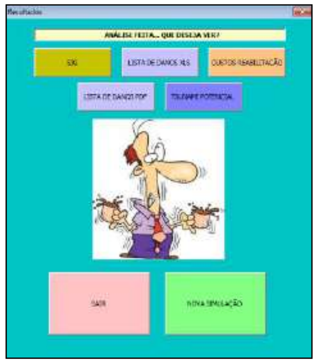


N. Tsunami - Estimated Wave Height

Despite the doubts raised, the programmer was decided to create an additional module that by Gusiakov methodology - Chubarov (1985, 2001), and assuming a seismic magnitude Mw at the epicenter, it is estimated a potential value flood wave for point on the coast, through the expression:

$$I = 3.55M_w - 27.1$$

Class I = Tsunami (Imamura Soloviev-scale); Mw = magnitude of the earthquake (Richter scale)
Note that the above referenced expression was based on data generated tsunamis in the Pacific Ocean so its adaptation to national conditions shall be complied with reservations.



PART C - NOTES FINAL

He tried to work with this provide the ANPC planning tool and to support prevention policies and response to situations of occurrence of earthquakes of moderate to high intensity.

Thus passes the ANPC to be provided with results produced by different models, which is not a scientific weakness of evidence but the acceptance that there are no perfect formulations but different approaches, but robust, to the same complex reality and therefore is best realize with uncertainty margins than in an absolute way translated results, certain, unquestionable, that there is not.

Although seemingly complex, the developed simulator is designed so without user intervention, starting any scenario chosen by activating a set of predefined options, which constitute a balanced approach to any situation. Thus, the user will just have to make alternative formulations of options if you wish and when you feel ready to do so.

Finally, the introduction of file generation procedure with a summary of all data and most significant results generated in each scenario, a form of, with extreme simplicity, incorporate all this information in texts, reports, presentations or other forms communication, study and dissemination of the information produced. It is the will of the author provide a second phase which will associate the seismic risk the risk of tsunami and concurrently performing an economic analysis of the damage generated a simulated earthquake.

Anyway, the first phase or not, so we hope to have effectively contributed to a decrease in seismic risk, then towards improving security we love.

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