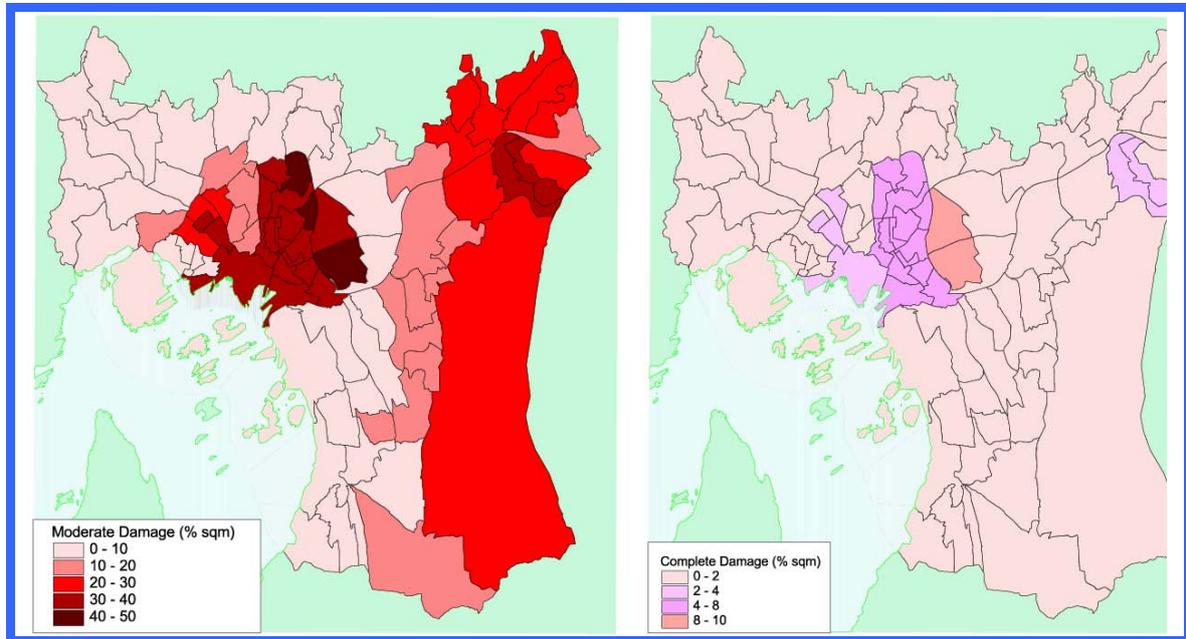


RISKICG v2.4: USER AND TECHNICAL MANUAL



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1. INTRODUCTION.

This earthquake loss estimation tool provides local, state and regional officials with a state-of-the-art decision support tool for estimating possible losses from future earthquakes. This forecasting capability enables users to anticipate the consequences of future earthquakes and to develop plans and strategies for reducing risk. GIS-based software (i.e, Arcview), can be utilized at multiple levels of resolution to graphically show losses results and to prepare response strategies.

Some of the first earthquake loss estimation studies were performed in the early 1970's following the 1971 San Fernando earthquake. These studies put a heavy emphasis on loss of life, injuries and the ability to provide emergency health care. More recent studies have focused on disruption to roads, telecommunications and other lifeline systems. The present loss estimation tool computes analytically, based on ground shaking estimates, the degree of damage on specific construction groups and detailed as well as gross economic losses.

Recently the National Institute of Buildings Sciences (NIBS) has developed a tool (HAZUS-MH) for the Federal Emergency Management Agency (FEMA) in order to provide a powerful technique for developing earthquake loss estimates for use in:

Anticipating the possible nature of an earthquake disaster and the scope of the emergency response needed to cope with an earthquake disaster, such as

- Developing plans for recovery and reconstruction following a disaster, and
- Mitigating the possible consequences of earthquakes.

The methodology generates an estimate of the damage consequences for a city or a region from a “scenario earthquake”, i.e., an earthquake with a specified magnitude and location. The resulting loss estimate will generally describe the scale and the extent of damage and disruption that may result from such an earthquake. Using such computations the following information can in principle be obtained:

- Quantitative estimates of losses in terms of direct costs for repair and replacement of damaged buildings and lifeline system components; direct costs associated with loss of function (e.g. loss of business revenue, relocation costs); casualties; people displaced from residence; quantity of debris; and regional economic impacts.
- Functionality losses in terms of loss-of-function and restoration times for critical facilities such as hospitals, and components of transportation and utility lifeline systems and simplified analyses of loss-of-system-function for electrical distribution and potable water systems.
- Extent of induced hazards in terms of fire ignitions and fire spread, exposed population and building value due to potential flooding and locations of hazardous materials.

All the system, methods, and data have been coded into a user-friendly software that operates through a Geographical Information System (GIS) which is called HAZUS-MH. The ESRI GIS system is used by HAZUS-MH.

In a simplified form, the steps followed by the HAZUS methodology are:

1. Select the area to be studied. This may be a city, a county or a group of municipalities.
2. Specify the magnitude and location of the scenario earthquake. In developing the scenario earthquake, considerations should be given to the potential fault locations.
3. Provide additional information describing local soil and geological conditions, if available.
4. Using formulas embedded in HAZUS, probability distributions are computed for damage to different classes of buildings, facilities, and lifeline system components and loss-of-function estimates are made.
5. The damage and functionality information is used to compute estimates of direct economic loss, casualties and shelter needs. In addition, the indirect economic impacts on the regional economy are estimated for the years following the earthquake.
6. An estimate of the number of ignitions and the extent of fire spread is computed. The amount and type of debris are estimated. If an inundation map is provided, exposure to flooding can also be estimated.

The earthquake-related hazards considered by the methodology in evaluating casualties, and resultant losses are collectively referred to as Potential Earth Science Hazards (PESH). Most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking, but there are also other feature of earthquakes (fault rupture, liquefaction and land sliding) that can cause permanent ground displacements and have an adverse effect upon structures, roads, pipelines, and other lifeline structures, which are also considered.

Soil type can have a significant effect on the intensity of ground motion at a particular site. The software contains several options for determining the effect of soil type on ground motions for a given magnitude and location.

Tsunamis and seiches are also earthquake-caused phenomena that can result in inundation or waterfront damage. In the methodology, potential sites of these hazards may be identified, but they are evaluated only if special supplemental studies are performed.

The type of buildings and facilities considered in HAZUS-MH are as follows:

General Buiding Stock: The commercial, industrial and residential buildings in the studied region are not considered individually when calculating losses. Instead, they are grouped together into 36 model building types and 28 occupancy classes and degrees of damage are computed for groups of buildings.

Essential Facilities: These include medical care facilities, emergency response facilites and schools. Specific information is compiled for each building so the loss-of-function is evaluated in a building-by-building basis.

Transportation lifeline systems: This include highways, railways, lighth rail, bus systems, ports, ferry system and airports and they are broken in components such as bridges,

stretches of roadway or track, terminal, and port warehouses. The damage and losses are computed for each component of each lifeline.

Utility lifeline systems: These include potable water, electric power, waste water, communications, and liquid fuels (oil and gas) and are treated in a manner similar to transportation lifelines.

High potential loss facilities: These include dams, nuclear power plants, military installations and damage and losses that needs supplementary specific studies to be evaluated.

All results from HAZUS-MH are provided as “best estimates”, and no uncertainty in the results are provided for.

The downside of these fascinating developments implemented in HAZUS-MH is that it has been so intimately connected to the US environments that it is practically impossible to apply to the rest of the world.

We have in the present study developed and adapted the HAZUS methodology to greater flexibility and freed the methodology from the ArcGIS “grip”.

A more important extension is that a logic tree scheme with weighted input of uncertain parameters has been incorporated, and an example of seismic damage scenarios for the city of Oslo have been conducted and published.

2. TECHNICAL DESCRIPTION.

While the HAZUS approach is attractive from a scientific/technical perspective, the fact that it is tailored so intimately to US situations and specific GIS software makes it difficult to apply in other environments and geographical regions. One goal of the present developments was therefore to implement the HAZUS methodology and computation schemes in a different environment, and we have to this side implemented the computational core methodology in MATLAB™. We have also expanded the method into a logic tree scheme so that parameters can be included with weights.

The approach is often called the “capacity-spectrum method”, because it combines the ground motion input in terms of response spectra (spectral acceleration versus spectral displacement as shown in Figure 1) with the building specific capacity curve. The philosophy is that any building is structurally damaged by its permanent displacement, (and not by the acceleration by itself). For each building and building type the inter-story drift (relative drift of the stories in a multi story structure) is a function of the applied lateral force that can be analytically determined and transformed into building capacity curves (capacity to withstand accelerations without permanent displacements). Building capacity curves naturally vary from building type to building type, and also from region to region reflecting on building regulations and local practice. Under the HAZUS umbrella FEMA developed capacity curves for 36 US building types in four earthquake load regimes (reflecting the variation in building regulations as function of time across the US). These 144 capacity curves are developed analytically, but adjusted so that empirical knowledge is incorporated in the curves whenever possible. The building capacity curve is defined through three control points: *Design*, *Yield* and *Ultimate* capacity (Figure 2). Up to the yield point, the building capacity curve is assumed to behave elastically linear. From the yield point to the ultimate point, the

capacity curve changes from an elastic to a fully plastic state (curved form), and the curve is assumed to remain fully plastic past the ultimate point (linear form). A bilinear representation (two linear parts) is sometimes used to simplify the model shown in Figure 2. The vulnerability curves (also called fragility curves) are developed as lognormal probability distributions of damage from the capacity curves (Figure 3).

The structural damage states are (as in most other proposed schemes) divided into four damage states, *slight*, *moderate*, *extensive* and *complete*. A detailed description of these damage states are found many places (Figure 4 shows the description for light frame wood buildings).

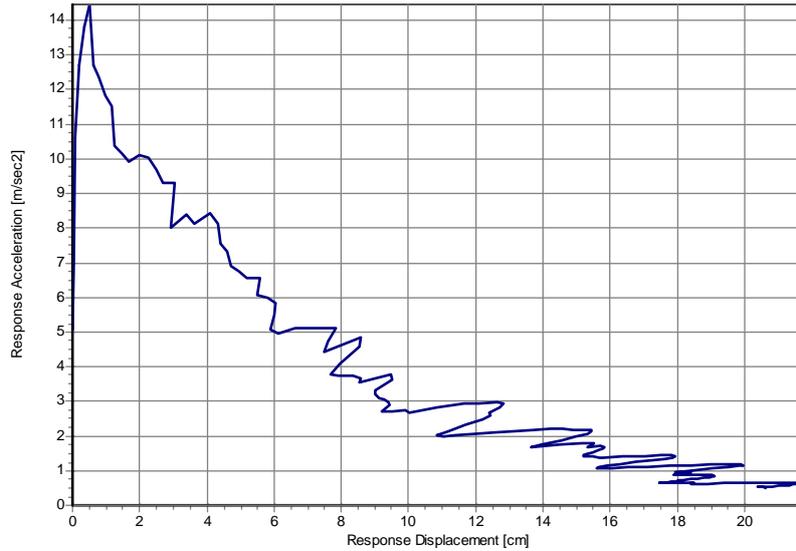


Figure 1. The methodology is based on presenting the ground motion response spectral ordinates (at given damping levels) of acceleration versus spectral displacement. The response spectral values above are relatively smooth because they are computed from a synthetic accelerogram adapted to a piecewise linear response spectrum.

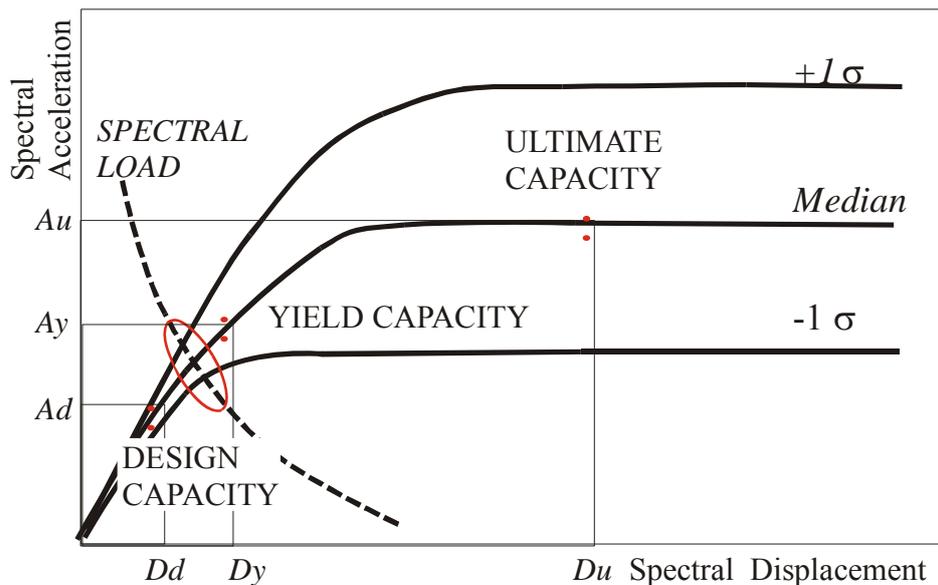


Figure 2. The principle of the building specific capacity curve intersected by the load curve

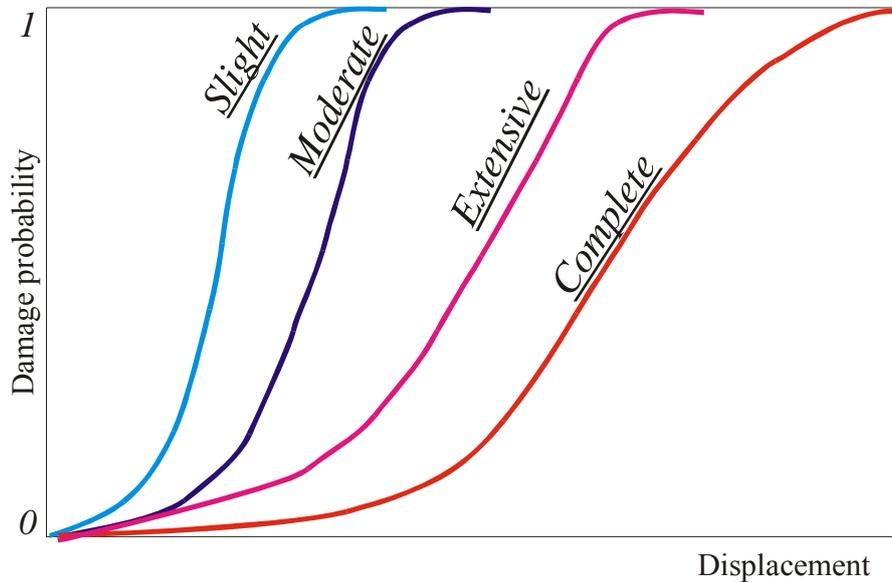


Figure 3. The derived vulnerability (or fragility) probability functions.

Damage State		Description
	Slight	Small plaster cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneers. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as “large” cracks).
	Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
	Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
	Complete	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

Figure 4. The four damage states described for light frame wood buildings.

2.1 RISKICG overview.

The HAZUS methodology covers a wide range of different damages and losses to buildings, lifelines, people, etc., however in the present version of RISKICG we have only implemented the first part of the methodology, the estimation of damage to the building stock and the economic losses related to these physical damages. All results are provided with uncertainties facilitating the easy computation of e.g. median value and different damage percentiles.

RISKICG requires quite an extensive basis information in a number of input files. These can easily be generated as tables in Excel, and exported as ASCII table files with all required information given in the matrixes.

The smallest area provided is the census tract, and for each census tract the basis information is provided.

The basis information is the building database (which is also somewhat difficult to generate). This is a type of information that is normally provided by local agencies or governments, and as detailed as possible. Less detailed information will naturally be useful, however, implicating higher uncertainty of the results.

The building database should contain a maximum of details about building materials, building techniques, built area, floors of the building, height, foundations, seismic regulations used in the construction, use of the building, number of dwellers (if human losses are going to be computed), year of construction, etc.

The building information is classified according to building type, built square meters in each one of the census tracts which form the region under study or as an individual building if a site-specific study is going to be done.

The building type classification can be done according to HAZUS methodology (see www.fema.gov/hazus documents or previous HAZUS reports), and then pushover (capacity) curves can be selected from those provided in HAZUS documents. As new methods for developing capacity curves mature, RISKICG also allows for use these, or a building classification can be conducted using programs such as SAP2000 (CSI, 2000). This or other programs may then be used compute the pushover and fragility curves.

A key point in any seismic risk assessment is the ground motion (level of shaking). The RISKICG can compute deterministic ground motion scenarios from historical or user-provided earthquakes and can also carry out the seismic risk studies with basis in probabilistic shaking maps. For deterministic earthquakes the ground motion is obtained through selectable attenuation relationships. A number of well established relationships are implemented (e.g. Ambraseys et al., 1996 and Douglas et al., *personal communication*), but any new user provided relationship can easily be implemented. Currently it is assumed that the used relationships refer to for rock sites since soil response is covered in a separate step. Since RISKICG is based on spectral shaking and spectral pushover curves, ground motion is provided at three frequencies that define a simplified spectrum: PGA, spectral acceleration at 1Hz and 3Hz. All ground motion is provided in units of gravity (% g).

A probabilistic ground motion scenario may also be used as ground shaking input as will be explained in more detail below.

The ground motion at a specific site may be amplified through a soil cover. The soil amplification factors were taken from the 1997 NEHRP provisions. However any other soil amplification factors can easily be implemented.

Amplification of Ground Motion-Local Site Conditions

The methodology characterizes ground shaking using a standardized response spectrum shape, which consists of four parts: peak ground acceleration (PGA), a region of constant spectral acceleration at periods from zero seconds to T_{AV} (seconds), a region of constant spectral velocity at periods from T_{AV} to T_{VD} (seconds) and a region of constant spectral displacement for periods of T_{VD} and beyond (Figure 5).

The region of constant spectral acceleration is defined by S_a at 0.3 s. The constant spectral velocity region has S_a proportional to $1/T$ and is anchored to S_a at 1.0 s.

$$\begin{aligned}
 S_a(T) &= S_{a@0.3} && \text{if } 0 < T < T_{AV} && \text{(short periods – acceleration domain)} \\
 S_a(T) &= S_{a@1.0} / T && \text{if } T_{AV} < T < T_{VD} && \text{(long periods – velocity domain)} \\
 S_a(T) &= S_{a@1.0} T_{VD} / T^2 && \text{if } T > T_{VD} && \text{(very long periods – displacement domain)}
 \end{aligned}$$

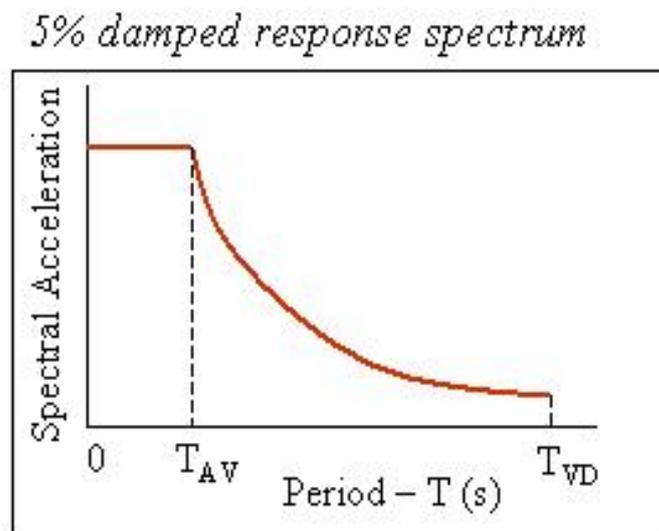


Figure 5. Standard Shape of the response spectrum

The period T_{AV} is based on the intersection of the region of constant spectral acceleration and constant spectral velocity and its value varies depending on the values of spectral acceleration that define these two intersecting regions.

$$T_{AV} = S_{a@1.0} / S_{a@0.3}$$

The constant spectral displacement region has spectral acceleration proportional to $1/T^2$ and is anchored to spectral acceleration at the period T_{VD} , where constant spectral velocity transitions to constant spectral displacement. (Not plotted in Fig. 5).

The period T_{VD} is based on the reciprocal of the corner frequency, f_c , which is proportional to stress drop and seismic moment. This frequency is estimated from Joyner & Boore (1988) relationship as a function of moment magnitude, so:

$$T_{VD} = 1 / f_c = 10^{(M-5)/2}$$

where M is the moment magnitude. When the moment magnitude is not known (probabilistic earthquake scenario), the period T_{VD} is assumed to be 10 seconds ($M = 7.0$).

Amplification of ground shaking to account for local site conditions is based on the site classes and soil amplification factors proposed for the 1997 NEHRP Provisions. The NEHRP Provisions do not provide soil amplification factors for PGA or PGV. The Methodology amplifies rock (Site Class B) PGA by the same factor as that specified in Table 1 for short period (0.3 s) spectral acceleration, as expressed in the following expression:

$$PGA_i = PGA \cdot FA_i$$

where PGA_i is PGA for site class i (in units of g); PGA is for site class B (in units of g) and FA_i is the short period amplification factor for site class i , for spectral acceleration SA_S . Also, it amplifies rock (Site Class B) PGV by the same factor as that specified in Table 1 for 1.0-second spectral acceleration using the expression:

$$PGV_i = PGV \cdot FV_i$$

where PGV_i is PGV for site class i ; PGV is for site class B and FV_i is the short period amplification factor for site class i , for spectral acceleration SA_1 .

The Construction of Demand Spectra including soil effects are done using the following equation for short periods:

$$SA_{Si} = SA_S \cdot FA_i$$

and the following equation for long periods:

$$SA_{Li} = SA_1 \cdot FV_i$$

and the period, T_{AV} , which defines the transition period from constant spectral acceleration to constant spectral velocity is a function of site class, as given in the following equation:

$$T_{AVi} = (SA_1 / SA_S) (FV_i / FA_i)$$

where SA_{Si} is the short-period spectral acceleration for Site Class i (in units of g); SA_S is the short-period spectral acceleration for Site Class B (in units of g); FA_i is the short period amplification factor for site class i , for spectral acceleration SA_S ; SA_{Li} is the 1-second period spectral acceleration for Site Class i (in units of g); SA_1 is the 1-second period spectral acceleration for Site Class B (in units of g); FV_i is the short period amplification factor for site class i , for spectral acceleration SA_1 and T_{AVi} is the

transition period between constant spectral acceleration and constant spectral velocity for Site Class i (sec).

Finally the period, T_{VD} , which defines the transition period from constant spectral velocity to constant spectral displacement is not a function of site class and it is defined by the equation:

$$T_{VD} = 1 / f_c = 10^{[(M-5)/2]}$$

where f_c is the corner frequency and M is the moment magnitude, as explained previously.

For evaluation of building damage is better to plot the response spectrum as a function of the spectral displacement (rather than the period). This could be done due to the relation between the different spectral parameters:

$$S_a / \omega = S_v = S_d \omega$$

where ω is the circular natural frequency of the oscillator (i.e, $\omega = 2 \pi f$, where f is the frequency in Hz).

Table 1. Site amplifications factors provided by NEHRP Provisions. (*) Values based on judgement by HAZUS developers because they are not provided by NEHRP.

Site Class B Spectral Acceleration	Site Class				
Short-Period, SA_s (g)	A	B	C	D	E
≤ 0.25	0.8	1.0	1.2	1.6	2.5
(0.25, 0.50]	0.8	1.0	1.2	1.4	1.7
(0.50, 0.75]	0.8	1.0	1.1	1.2	1.2
(0.75, 1.0]	0.8	1.0	1.0	1.1	0.9
> 1.0	0.8	1.0	1.0	1.0	0.8*
1-Second Period, SA_1 (g)					
≤ 0.25	0.8	1.0	1.7	2.4	3.5
(0.1, 0.2]	0.8	1.0	1.6	2.0	3.2
(0.2, 0.3]	0.8	1.0	1.5	1.8	2.8
(0.3, 0.4]	0.8	1.0	1.4	1.6	2.4
> 0.4	0.8	1.0	1.3	1.5	2.0*

The final result of this process is the computation of a 5% damped response spectrum at the center of each census tract (where values of ground motion were computed) or the specific site under study.

Damage due to ground shaking

The building response (e.g. peak displacement) is determined by the intersection of the demand spectrum and the building capacity curve. The demand spectrum is based on the

PESH input spectrum reduced for effective damping (when effective damping exceeds the 5% damping level of the PESH input spectrum).

The elastic response spectra provided as a PESH input applies only to buildings that remain elastic during the entire ground shaking time history and have elastic damping values equal to 5%. This is generally not true on both accounts. Therefore, two modifications are made to elastic response spectra: a) demand spectra are modified for buildings with elastic damping not equal to 5%, and b) demand spectra are modified by the hysteretic energy dissipated by buildings “pushed” beyond their elastic limits. Modifications are represented by reduction factors by which the spectral ordinates are divided to obtain the damped demand spectra. The methodology reduces demand spectra for effective damping greater than 5% based on statistically-based formulas of Newmark and Hall (1982). These relationships estimate elastic response spectra at different damping ratios, B (expressed as a percentage) and represent all site classes (soil types) distinguishing between domains of constant acceleration and constant velocity. Ratios of these formulas are used to develop an acceleration-domain (short-period) reduction factor, R_A and a velocity-domain (1-second spectral acceleration) reduction factor, R_V , for modification of 5%-damped, elastic response spectra. These reduction factors are based on effective damping, B_{eff} , :

$$R_A = 2.12 / (3.21 - 0.68 \ln (B_{eff}))$$

$$R_V = 1.65 / (2.31 - 0.41 \ln (B_{eff}))$$

where B_{eff} is the effective damping given by the expression:

$$B_{eff} = B_e + B_h$$

where B_e is the elastic damping and B_h is the hysteretic damping, which is a function of the yield and ultimate capacity points (ATC-1996), (see figure 2) as follows:

$$B_h = 63.7 k [A_y/A_u - D_y/D_u]$$

where k is a degradation factor that defines the effective amount of hysteretic damping as a function of earthquake duration.

B_e is the elastic (pre-yield) damping of the model building type (5% for Mobile Homes-MH, 5%-7% for Steel buildings-S, 7% for Concrete-C and Precast-Concrete buildings-P, 7%-10% for Reinforced Masonry buildings-RM, 10% for UnReinforced Masonry URM and Masonry buildings-M and 10%-15% for Wood buildings-W) following the recommendations of Newmark and Hall (1982).

The methodology recognizes the importance of the duration of ground shaking on building response by reducing the effective damping (i.e. κ factors) as a function of shaking duration. For scenario earthquakes of magnitude $M \leq 5.5$, effective damping is based on the assumption of ground shaking of Short duration ($\kappa=0.80$), if the magnitude is $M \geq 7.5$ it is assumed a ground shaking of Long duration ($\kappa=0.40$) and for all the other earthquakes it is assumed a ground shaking of Moderate duration ($\kappa = 0.20$).

The new demand spectral acceleration, $SA(T)$, in units of acceleration (g) is defined at short periods (acceleration domain), long periods (velocity domain) and very long

periods (displacement domain) using the 5% damped response spectrum and dividing by the before mentioned factors following the expressions:

$$\begin{aligned} Sa(T) &= SA_{si} / R_A && \text{if } 0 < T < T_{AVB} \text{ (short periods – acceleration domain)} \\ Sa(T) &= (SA_{li} / T) / R_V && \text{if } T_{AVB} < T < T_{VD} \text{ (long periods – velocity domain)} \\ Sa(T) &= (SA_{li} \cdot T_{VD} / T^2) / RV(B_{TVD}) && \text{if } T > T_{VD} \text{ (very long periods – displ. domain)} \end{aligned}$$

where:

SA_{si} , is the 5% damped, short-period spectral acceleration for site Class i (in units of g), as defined previously.

SA_{li} , is the 5% damped, 1-second period spectral acceleration for site Class i (in units of g), as defined previously.

B_{TVD} , is the value of effective damping at the transition period, T_{VD} .

T_{AVB} , is the transition period between acceleration and velocity domains as a function of the effective damping at this period and it is defined by the equation:

$$T_{AVB} = T_{AVi} (R_A (B_{TAVB}) / RV (B_{TAVB}))$$

where:

T_{AVi} is the transition period between 5%-damped constant spectral acceleration and 5%-damped constant spectral velocity for Site Class i, as defined previously.

B_{TAVB} is the value of effective damping at the transition period, T_{AVB} .

The transition period T_{VD} is independent of effective damping (only depends of moment magnitude), as previously said.

In summary, the steps for calculating damage state probabilities are the following ones:

1. Calculate the spectral accelerations and spectral displacements at the site in question, taking into account soil response. This is in the form of a response spectrum.
2. Modify the response spectrum to account for the increased damping that occurs at higher levels of building response (non-linear behaviour). Computation of B_e and B_h and reduction factors R_A and R_V .
3. Create or choose a capacity curve for the model building type which shows how the building responds as a function of the laterally applied earthquake load.
4. Overlay the building capacity curve with the modified response spectrum (demand curve). The building displacement (performance point) is estimated from the intersection of the building capacity curve and the response spectrum (Figure 6).
5. The estimated building displacement is used to define the damage degree at the intercept of the fragility curve and the damage probability curve (Figure 7).

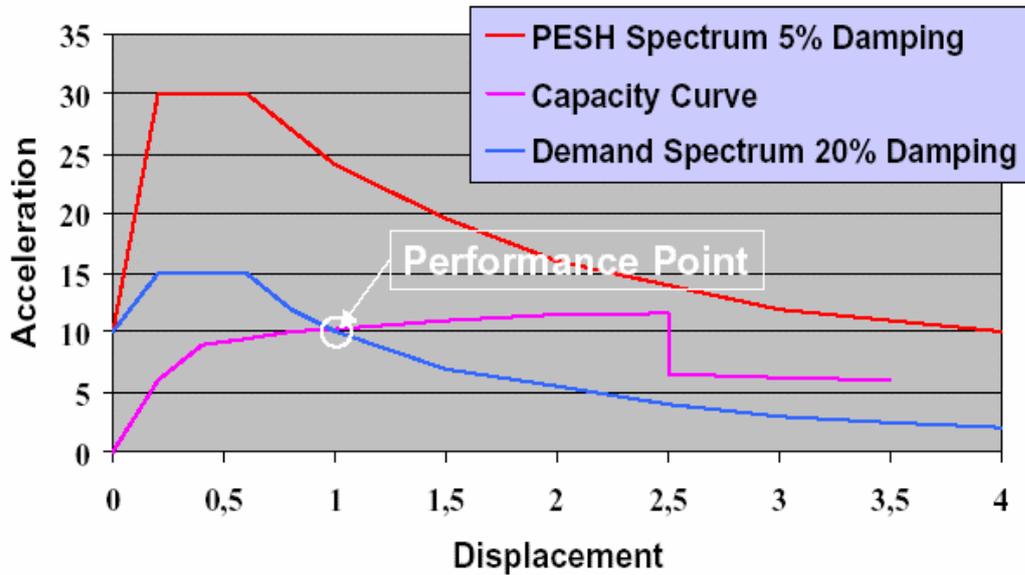


Figure 6. Estimation of building displacement from a given PESH input.

The conditional probability of being in, or exceeding, a particular damage state, ds , given the spectral displacement, S_d , (or other seismic demand parameter) is defined by:

$$P[ds|S_d] = \Phi \left[\frac{1}{\beta_{ds}} \ln \left(\frac{S_d}{\bar{S}_{d,ds}} \right) \right]$$

where:

$\bar{S}_{d,ds}$ is the median value of spectral displacement at which the building reaches the threshold of damage state, ds ,

β_{ds} is the standard deviation of the natural logarithm of spectral displacement for damage state, ds , and

Φ is the standard normal cumulative distribution function.

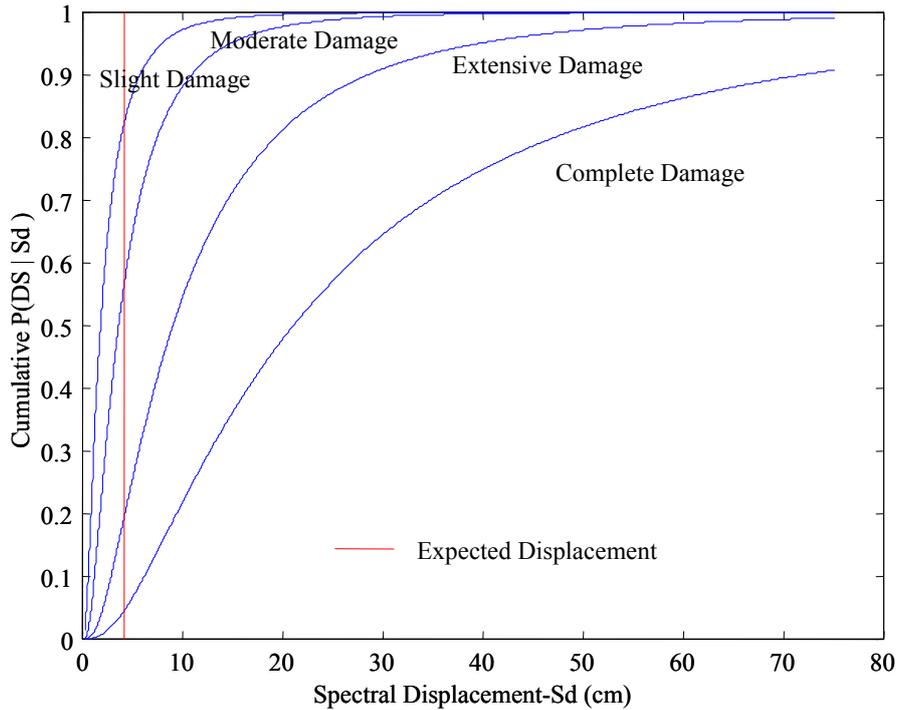


Figure 7. The expected displacement (obtained from the performance point) is used to interrogate the fragility curves in order to compute the damage probability in each one of the damage states.

Cumulative probabilities are defined to obtain discrete probabilities of being in each of the five damage states (Figure 8).

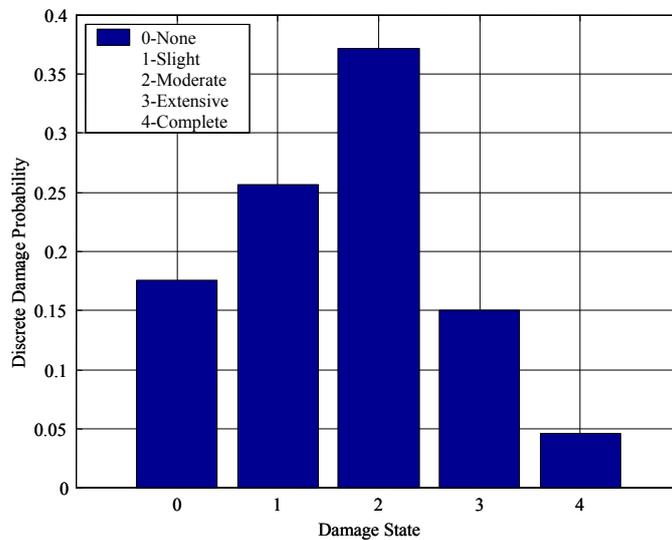


Figure 8. Discrete damage probabilities.

Final damage results are given as absolute square meters of damaged building type so users are able to present these results using Excel or any other software in any desired format, for example as percentage of built area (in square meters) normalized by the total built area in each census tract or normalized by the total built area in the studied region (summed all census tracts). Also, the results can be given as absolute number of damaged buildings.

Economic Losses:

The software can now estimate the total amount of economic losses (in any input currency) in any census tract caused by the structural damage.

The economic losses are computed in the following way:

$$EconomicLosses = CI \cdot \sum_{i=1}^{OccupType} \sum_{j=1}^{BuildingType} \sum_{k=1}^{DamageState} FA_{ij} \cdot PMBTSTR_{k,j} \cdot RCS_{k,i,j}$$

where:

CI: Regional cost multiplier. Currently is set to 1.0, but can have different values for each census tract in order to take into account the geographic cost variations.

FA_{ij}: Built area of the model building type *j* in the occupancy type *i* (square meters).

PMBTSTR_{k,j}: Damage probability of a structural damage *k* (slight, medium, extensive or complete) for the model building type *j*.

RCS_{k,i,j}: Cost of repair or replacement (by m²) in the input currency of structural damage *k* for occupancy type *i* and model building type *j*.

3. THE RISKICG M-SCRIPT (v.2.3).

3.1 RISKICG installation.

The full program comprise 18 m-script files (Matlab script files):

- *riskicg.m*: The core file of the software which runs under MATLAB 7.01 or lower.
- *startwin.m*: Script to initialise the window environment in order to choose between probabilistic or deterministic analysis.
- *Dettool.m*: Function file (called by startwin.m) to initialise the window environment in order to input data for a deterministic earthquake seismic risk study.
- *Probttool.m*: Function file (called by startwin.m) to initialise the window environment in order to input data for a probabilistic shake map seismic risk study.
- *Computetool.m*: Function file (called by dettool.m) which starts the main processes of seismic risk computation for a deterministic earthquake.
- *Computetoolp.m*: Function file (called by probtool.m) which starts the main processes of seismic risk computation based on a probabilistic shake map.
- *Gmotion.m*: Function file which gets the ground motion at the center of each census tract from a deterministic earthquake. The attenuation relationships provided are several, and new attenuation relations are easily implemented. The

function also computes ground motion amplification using NEHRP factors. This function is called by *computetool.m*.

- *Att_sub.m*: Function file with attenuation relationships from different authors. The function provides the ground motion values (units of g) for PGA, SA at 0.3s and SA at 1.0s. This function is called by *gmotion.m* and it is an adaptation of the NPRISK subroutine. Some of the relations implemented don't have coefficients for a 0.3 s attenuation function.
- *Dtorry.m*: Function file used to compute the closest distance from a point (latitude, longitude) to a segment (lat1,lon1)-(lat2,lon2). This function is called by *gmotion.m*.
- *Gmotionp.m*: Function file which amplifies the ground motion at the center of each census tract from probabilistic shaking maps, using NEHRP factors. This function is called by *computetoolp.m*.
- *Damagep.m*: Function file which computes the probability of damage for the building stock using the capacity spectrum method. This function is called by *computetool.m* and *computetoolp.m*.
- *Fitcapcurv.m*: Function file which finds the performance point fitting the capacity curve to an analytical function with the following form: $y=a*(1-\exp(-x*b))$. This function is called by *damagep.m*.
- *Squaredam.m*: Function file which computes the absolute square meters of damaged built area for each model building type in each census tract. This function is called by *computetool.m* and *computetoolp.m*.
- *Numdam.m*: Function file which computes the absolute number of damaged buildings for each model building type in each census tract. This function is called by *computetool.m* and *computetoolp.m*.
- *Losssqm.m*: Function file which computes the total economic losses due to structural damage. This function is called by *computetool.m* and *computetoolp.m*.
- *Tree.m*: Function file used to fit the damage estimation results coming from each branch of the logic tree to a normal distribution function. Computes median(mean) value and 16 and 84 percentiles. This function is called by *computetool.m* and *computetoolp.m*.
- *Treeloss.m*: Function file used to fit the economic loss results coming from each branch of the logic tree to a normal distribution function. Computes median(mean) value and 16 and 84 percentiles. This function is called by *computetool.m* and *computetoolp.m*.
- *Fitnorm.m*: Function file to compute the mean and the variance from a set of data and the confidence intervals assuming Normal (μ,σ) distribution. Confidence intervals are obtained using the T-Student distribution for a chosen alpha (0.16 and 0.84) (16 and 84 percentiles). For different alpha please change

the value in the function callback. This function is called by *tree.m* and *treeloss.m*.

All these files have to be copied to the folder in which the input data is going to be stored.

The following input files are needed to run RISKICG properly:

a) For a deterministic earthquake seismic risk study:

earthquake.txt: Input file containing the information about the earthquake to be used in the seismic risk study. This file includes different earthquakes with corresponding weights to be run the logic tree methodology.

Example:

```
%Earthquake scenarios information
%1st column is the weight for the logic tree scheme,
%2nd column is latitude in degrees (e.g.: 50.90)
%3rd column is longitude in degrees (eg.: 10.90)
%4th column is focal depth in km (eg.: 20)
%5th column is Ms magnitude (6.0)
%6th column is Mw magnitude (6.0)
%7th column is Fault orientation in degrees from North (e.g. 0.0)
%8th column is Dip Angle in degrees (e.g: 0.0)
%9th column is Fault Mechanism:Strike-Slip/Normal(1);Reverse(2);All(3)
0.33 59.90 10.90 20.00 5.50 5.50 0.00 90.00 2
0.34 59.90 10.90 20.00 6.00 6.00 0.00 90.00 2
0.33 59.90 10.90 20.00 5.50 5.50 0.00 90.00 2
```

attenuation.txt: Input file containing the label of the different attenuation relationships to be used in the study (and its corresponding weights).

Example:

```
%Ground motion information.
%First column is weight the second column is the label of PGA att. rel.; the third column is the
%label of sa at 0.3 s att. rel. and the fourth column is the label of sa at 1.0 s att. rel.
%For each attenuation relationship periods at 0s (PGA), 0.3s and 1.0 should be given with same
%weights because each computation will need ground motion at these three periods
0.6 30 33 35
0.4 170 171 172
```

The above means Ambraseys for PGA (30), sa at 0.3 s (33) and sa at 1.0s (35) weighted 0.6 and Douglas for PGA (170), sa at 0.3 s (171) and sa at 1.0 s (172) weighted 0.4.

b) For a probabilistic shake map seismic risk study:

shakefiles.txt: Input file containing the name of the files with the probabilistic ground motion information, and the corresponding weights.

Example:

0.60 shakecenter1.txt
0.20 shakecenter2.txt
0.20 shakecenter3.txt

The above means 0.6 and 0.2 and 0.2 weights for the three inputfiles.

shakecenter???.txt: Where ??? goes from 1 to the number of files. The file contains for each census tract (center coordinates) information of the probabilistic ground motion at PGA, 0.3 seconds and 1.0 seconds. All values are for rock and in % of g. Note: These centre coordinates must be defined independently of RISKICG. If unknown: When the shapefiles with all the census tracts have been created in Arcview, the center of each census tract is easily obtained using the internal scripts of Arcview.

Example:

%CTRA	LAT	LON	SOIL	PGA	0.3s	1.0s
0100100001	59.914	10.719	2	0.2548	0.3160	0.0866
0100100002	59.916	10.711	2	0.2548	0.3160	0.0866
0100100003	59.919	10.707	2	0.2548	0.3160	0.0866
0100100004	59.916	10.698	2	0.2548	0.3160	0.0866

c) Common files for both type of studies

soilfiles.txt: Input file containing the name of the files with the center of each census tract and the corresponding soil type, and the corresponding weight

Example:

0.33 soilcenter1.txt
0.34 soilcenter2.txt
0.33 soilcenter3.txt

soilcenter???.txt: Where ??? goes from 1 to the number of files. This file contains the information about the geographical coordinates of the center of each census tract in which the studied region has been divided. This file also contains a column with the soil type associated to that census tract.

The soil column has the following code:

(Hard Rock: 1; Rock: 2; Very dense soil and soft rock: 3; Stiff Soils: 4 and Soft Soils: 5). The shear wave velocities and descriptions of the different soils are given in the 1997 NEHRP Provisions (FEMA, 1997).

These centre coordinates must be defined independently of RISKICG. If unknown: When the shapefiles with all the census tracts have been created in Arcview, the center of each census tract is easily obtained using the internal scripts of Arcview.

Example:

<i>% TRACT</i>	<i>LATITUDE</i>	<i>LONGITUDE</i>	<i>SOIL</i>
0100100001	59.91401	10.7187	2
0100100002	59.91562	10.71144	2

In the example file the TRACT column has a string format of 10 characters, because it was obtained to fit HAZUS input files, however the RISKICG code accepts any integer numerical format. Coordinates must be provided in geographical coordinates for the representation and Arcview, and can be used later to prepare maps in other coordinate systems if desired.

vulnerfiles.txt: Input file containing the name of the files with the capacity and fragility curves, and the corresponding weight

Example:

0.33 capacity1.txt fragility1.txt
 0.34 capacity2.txt fragility2.txt
 0.33 capacity3.txt fragility3.txt

Capacity???.txt: Input file containing the information of the different capacity (push-over) curves. Very often there may be three files or more files representing the variability of the capacity (for example median, 84'th percentile and 16'th percentile, or three curves). Each of the used model building types must be represented in these files (15 building types in the example below).

Example:

<i>%mbt</i>	<i>Dy(ord.)</i>	<i>Ay(ord)</i>	<i>Du(ord)</i>	<i>Au(ord)</i>	<i>ks</i>	<i>km</i>	<i>kl</i>	<i>be</i>	<i>fraction</i>	<i>Pre-code(Ordinary)</i>
1	0.24	0.2	4.32	0.6	0.5	0.3	0.1	15	0	%W1
2	0.16	0.1	2.35	0.25	0.4	0.2	0	10	0	%W2
3	0.15	0.062	2.75	0.187	0.4	0.2	0	5	0	%S1L
4	0.44	0.039	5.33	0.117	0.4	0.2	0	5	0	%S1M
5	0.16	0.1	1.88	0.2	0.4	0.2	0	5	0	%S2L
6	0.61	0.083	4.85	0.167	0.4	0.2	0	5	0	%S2M
7	0.16	0.1	1.88	0.2	0.4	0.2	0	7	0	%S3
8	0.27	0.067	2.46	0.15	0.4	0.2	0	7	0	%S4M
9	0.12	0.1	1.2	0.2	0.4	0.2	0	10	0	%S5L
10	0.34	0.083	2.27	0.167	0.4	0.2	0	10	0	%S5M
11	0.29	0.052	3.46	0.156	0.4	0.2	0	7	0	%C1M
12	0.26	0.083	2.60	0.208	0.4	0.2	0	7	0	%C2M
13	0.26	0.083	1.95	0.188	0.4	0.2	0	10	0	%C3M
14	0.24	0.2	2.4	0.4	0.4	0.2	0	10	0	%URML
15	0.27	0.111	1.81	0.222	0.4	0.2	0	10	0	%URMM

The first column *mbt* is the index of building type; (*dy*, *ay*) is the yield capacity point in units of inches and g respectively; (*du*, *au*) is the ultimate capacity point in units of inches and g respectively; *ks*, *km* and *kl* are the degradation factors (*kappa*) for *short*, *moderate* and *large* duration earthquakes, as explained in the methodology; *be* is the elastic damping in percentage, for each one of the model building types according to the recommendations of Newmark & Hall (1982) for materials at or just below their yield point (explained in the technical description of this report); *fraction* is just a dummy value kept from the original files. The last column is only a reference to know which model building type corresponds to each number and it remember also to the user that

this file is a pre-code capacity curve for ordinary buildings. (Other possibilities may be moderate seismic design capacity curve for inferior to code buildings or low moderate seismic design capacity curve for superior to code buildings).

Fragility???.txt: Input file containing the information of the different fragility curve which has to be used in combination with its corresponding *Capacity???* (push-over) curve.

%mbt	smedian	sbeta	mmedian	mbeta	emedian	ebeta	cmmedian	cbeta	Pre-Code Seismic Design Level
1	0.40	1.01	1.00	1.05	3.09	1.07	7.56	1.06	%W1
2	0.69	1.04	1.71	0.97	5.29	0.90	12.96	0.99	%W2
3	1.04	0.85	1.65	0.82	3.50	0.80	8.64	0.95	%S1L
4	1.73	0.70	2.76	0.75	5.84	0.81	14.40	0.98	%S1M
5	0.86	1.01	1.38	0.96	3.46	0.88	8.64	0.98	%S2L
6	1.44	0.73	2.30	0.75	5.76	0.80	14.40	0.98	%S2M
7	0.43	1.06	0.69	1.03	1.73	1.07	4.73	0.89	%S3
8	1.15	0.81	1.85	0.80	4.62	0.94	12.60	1.00	%S4M
9	0.52	1.20	1.04	1.11	2.59	1.08	6.05	0.95	%S5L
10	0.86	0.85	1.73	0.83	4.32	0.94	10.08	0.99	%S5M
11	1.20	0.73	1.92	0.77	4.80	0.83	12.00	0.98	%C1M
12	0.96	0.86	1.83	0.83	4.74	0.80	12.00	0.98	%C2M
13	0.72	0.90	1.44	0.86	3.60	0.90	8.40	0.96	%C3M
14	0.32	1.15	0.65	1.19	1.62	1.20	3.78	1.18	%URML
15	0.50	0.99	1.01	0.97	2.52	0.90	5.88	0.88	%URMM

The first column *mbt* is the index of building type; *smedian* is the median value of spectral displacement at which the building reaches the threshold of the damage state, slight; *sbeta* is the standard deviation of the natural logarithm of spectral displacement of damage state, slight; the next column are the same for damage states: moderate (*mmedian* and *mbeta*), extensive (*emedian* and *ebeta*) and complete (*cmmedian* and *cbeta*).

ATTENTION: In the example file, fragility curves were taken from HAZUS and they were obtained as probability functions in terms of spectral displacement in inches, that's the reason because spectral displacement is given in this file in units of inches. If fragility curves are going to be input in other units then changes has to be made in the code.

Header.txt: Input file contains the needed headers to create the damage output files that can be plotted with Arcview. %CTRA LONGI LATIT SOILT are always the same but the other ones has to be 5 labels * number of model building type (that is 5*15 = 75 labels in the example). The last label is NUMB

Example:

```
%CTRA LONGI LATIT SOILT W1N W1S W1M W1E W1C W2N W2S W2M W2E W2C S1LN S1LS S1LM S1LE
S1LC S1MN S1MS S1MM S1ME S1MC S2LN S2LS S2LM S2LE S2LC S2MN S2MS S2MM S2ME S2MC S3N S3S
S3M S3E S3C S4MN S4MS S4MM S4ME S4MC S5LN S5LS S5LM S5LE S5LC S5MN S5MS S5MM S5ME S5MC
C1MN C1MS C1MM C1ME C1MC C2MN C2MS C2MM C2ME C2MC C3MN C3MS C3MM C3ME C3MC URMLN
URMLS URMLM URMLE URMLC URMMN URMMMS URMMM URMMME URMMC NUMB
```

It is all one text line with the following labels: The first column CTRA is the label for the identification of the census tract; the LONGI and LATIT are the labels for geographical coordinates of the center of the census tract; the SOILT is the label for the soil type in each census tract, the next labels are repeated for each damage state and for each model building type. So if more building types are added then new labels have to

be written in the input file. For example, if we have a new model building type called NB, then five labels have to be added: NBN, NBS, NBM, NBE, NBC (for the damage states N-None, S-Slight, M-Median, E-Extensive and C-Complete). Finally the last label NUMB is for a column with an order number.

Building Classes:

No	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1	W1	Wood, Light Frame (\leq 5,000 sq. ft.)		All	1	14
2	W2	ft.) Wood, Greater than 5,000 sq. ft.		All	2	24
3	S1L	Steel Moment Frame	Low-Rise	1-3	2	24
4	S1M		Mid-Rise	4-7	5	60
5	S1H		High-Rise	8+	13	156
6	S2L	Steel Braced Frame	Low-Rise	1-3	2	24
7	S2M		Mid-Rise	4-7	5	60
8	S2H		High-Rise	8+	13	156
9	S3	Steel Light Frame		All	1	15
10	S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise	1-3	2	24
11	S4M		Mid-Rise	4-7	5	60
12	S4H		High-Rise	8+	13	156
13	S5L	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise	1-3	2	24
14	S5M		Mid-Rise	4-7	5	60
15	S5H		High-Rise	8+	13	156
16	C1L	Concrete Moment Frame	Low-Rise	1-3	2	20
17	C1M		Mid-Rise	4-7	5	50
18	C1H		High-Rise	8+	12	120
19	C2L	Concrete Shear Walls	Low-Rise	1-3	2	20
20	C2M		Mid-Rise	4-7	5	60
21	C2H		High-Rise	8+	12	120
22	C3L	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise	1-3	2	20
23	C3M		Mid-Rise	4-7	5	50
24	C3H		High-Rise	8+	12	120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26	PC2L	Precast Concrete Frames with Concrete Shear Walls	Low-Rise	1-3	2	20
27	PC2M		Mid-Rise	4-7	5	50
28	PC2H		High-Rise	8+	12	120
29	RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise	1-3	2	20
30	RM1M		Mid-Rise	4+	5	50
31	RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise	1-3	2	20
32	RM2M		Mid-Rise	4-7	5	50
33	RM2H		High-Rise	8+	12	120
34	URML	Unreinforced Masonry Bearing Walls	Low-Rise	1-2	1	15
35	URMM		Mid-Rise	3+	3	39
36	MH	Mobile Homes		All	1	12

Builtarea.txt: Input file containing the total built area of each model building type (in square meters) for each census tract.

Example:

```
% TRACT W1 W2 S1L S1M S2L S2M S3 S4M S5L S5M C1M C2M C3M URML URMM NONE
0100100001 8964 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 466779 11697 3175 55755 0.0 97850
0100100002 5549 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 356913 0.0 6722 67675 0.0 11551
```

The first column *TRACT* is the census tract identifier and it has to be in the same order that the one given in the file *soilcenter(i).txt*. The next column has the built area information for each one of the model building types. If more building types are included then more columns has to be added. The last column contains the built area which can not be assigned to any of the model building types because of the lack of information. **Note:** NONE “building type” is excluded from the computations (they are unknown model building types). This means that if a large percentage of the building mass is of unknown building type, then all cumulative end-results will be wrong since a large part of the building mass is excluded from the computations. Anyway if this file is modified adding or removing model building types, it always has to be kept the column UNKNOWN (so if there is no unknown buildings, then put all the column to 0).

This type of input file can be easily obtained through the databases provided by the local agencies using Access or Matlab.

Numbuild.txt: Input file containing the total number of buildings of each model building type for each census tract.

Example:

```
% TRACT W1 W2 S1L S1M S2L S2M S3 S4M S5L S5M C1M C2M C3M URML URMM NONE
0100100001 10 0 0 0 0 0 0 0 0 0 202 1 1 33 0 49
0100100002 10 0 0 0 0 0 0 0 0 0 164 0 1 39 0 29
```

The first column *TRACT* is a number with the census tract identification and it has to be in the same order of the one given in the file *soilcenter(i).txt*. The next column has the number of buildings for each one of the model building types. If more building types are included then more columns have to be added. The last column contains the number of buildings which can not be assigned to any of the model building types because of the lack of information.

This type of input file can be easily obtained through the databases provided by the local agencies using Access or Matlab.

These last two files are not needed at the same time if only one of the damage results are desired.

Ocupmbtj.txt: Where *j* goes from 1 to the number of model building types. These files contains the built area (in square meters) in each one of the occupancy types for each census tract and they are needed for the computation of the economic losses. For example, *ocupmbt1.txt* contains the built area for the model building type 1 (that is,

W1) classified by occupancy type (RES1, RES3, ...) and in each one of the census tracts.

Example: ocupmbt1.txt

% TRACT	RES1	RES3	RES4	RES5	COM1	COM2	COM3	COM4	COM5	COM6	COM7	COM8	
COM9	COM10	IND1	IND2	IND3	AGR	REL1	GOV1	GOV2	EDU1	EDU2			
0100100001	130.000	690.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	7454.000	0.000	350.000	320.000	0.000	0.000	0.000	0.000
0100100002	1083.000	1644.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1854.000	0.000	968.000	0.000	0.000	0.000	0.000	0.000
0100100003	686.000	2769.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	1076.000	316.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0100100004	2845.000	7086.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
370.000	0.000	0.000	0.000	0.000	0.000	536.000	0.000	902.000	0.000	0.000	0.000	0.000	0.000
0100100005	105815.000	76820.000	909.000	0.000	1199.000	0.000	0.000	0.000	45.000	0.000	0.000	0.000	5913.000
0.000	38.000	0.000	0.000	0.000	22.000	167.000	0.000	0.000	500.000	2468.000	0.000	0.000	0.000
0100100006	2691.000	21016.000	0.000	0.000	0.000	4213.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	543.000	1445.000	0.000	587.000	301.000	0.000	0.000	0.000	0.000
0100100007	843.000	4217.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	721.000
0.000	0.000	0.000	0.000	0.000	0.000	112.000	0.000	856.000	337.000	0.000	0.000	0.000	0.000
0100100008	104.000	3042.000	0.000	0.000	0.000	43.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	555.000	0.000	30.000	0.000	0.000	0.000	0.000	0.000
0100100009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	452.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0100100010	3284.000	2313.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	3121.000	0.000	0.000	0.000	1072.000	0.000	972.000	0.000	0.000	0.000	0.000	0.000

Residential classes:

No	Label	Occupancy Class	Description
		Residential	
1	RES1	Single Family Dwelling	Detached House
2	RES2	Mobile Home	Mobile Home
3	RES3	Multi Family Dwelling	Apartment/Condominium
4	RES4	Temporary Lodging	Hotel /Motel
5	RES5	Institutional Dormitory	Group Housing (military, college), Jails
6	RES6	Nursing Home	
		Commercial	
7	COM1	Retail Trade	Store
8	COM2	Wholesale Trade	Warehouse
9	COM3	Personal and Repair Service	Service Station /Shop
10	COM4	Professional /Technical Services	Offices
11	COM5	Banks /Financial Institutions	
12	COM6	Hospital	
13	COM7	Medical Office /Clinics	Office
14	COM8	Entertainment and Recreation	Restaurants /Bars
15	COM9	Theatres	Theatres
16	COM10	Parking	Garage
		Industrial	
17	IND1	Heavy	Factory
18	IND2	Light	Factory
19	IND4	Food /Drug /Chemicals	Factory
20	IND3	Metals / Mineral Processing	Factory
21	IND5	High Technology	Factory
22	IND6	Construction	Office
		Agriculture	
23	AGR	Agriculture	
		Religion/Non-Profit	
24	REL	Church	
		Government	

25	GOV1	General Services	Office
26	GOV2	Emergency Response	Police / Fire Station
		Education	
27	EDU1	Schools/Libraries	
28	EDU2	Universities /Colleges	Does not include group housing

elossd.txt: This file contains the economic information in order to compute economic losses due to slight structural damage, to a specific model building type with given occupancy. The quantities are given in the user desired currency.

Example:

```
%NO W1 W2 S1 S2 S3 S4 S5 C1 C2 C3 PC1 PC2 RM1 RM2 URM MH LABEL
1 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 0.0 %RES1
2 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 0.0 %RES3
```

elossmd.txt: This file contains the economic information in order to compute economic losses due to moderate structural damage, to a specific model building type with given occupancy. The quantities are given in the user desired currency. The format is the same as before.

elossed.txt: This file contains the economic information in order to compute economic losses due to extensive structural damage, to a specific model building type with given occupancy. The quantities are given in the user desired currency. The format is the same as before.

elosscd.txt: This file contains the economic information in order to compute economic losses due to complete structural damage, to a specific model building type with given occupancy. The quantities are given in the user desired currency. The format is the same as before.

3.2 RISKICG flowchart.

The RISKICG computation can be summarized in the following flowchart (figure 8)

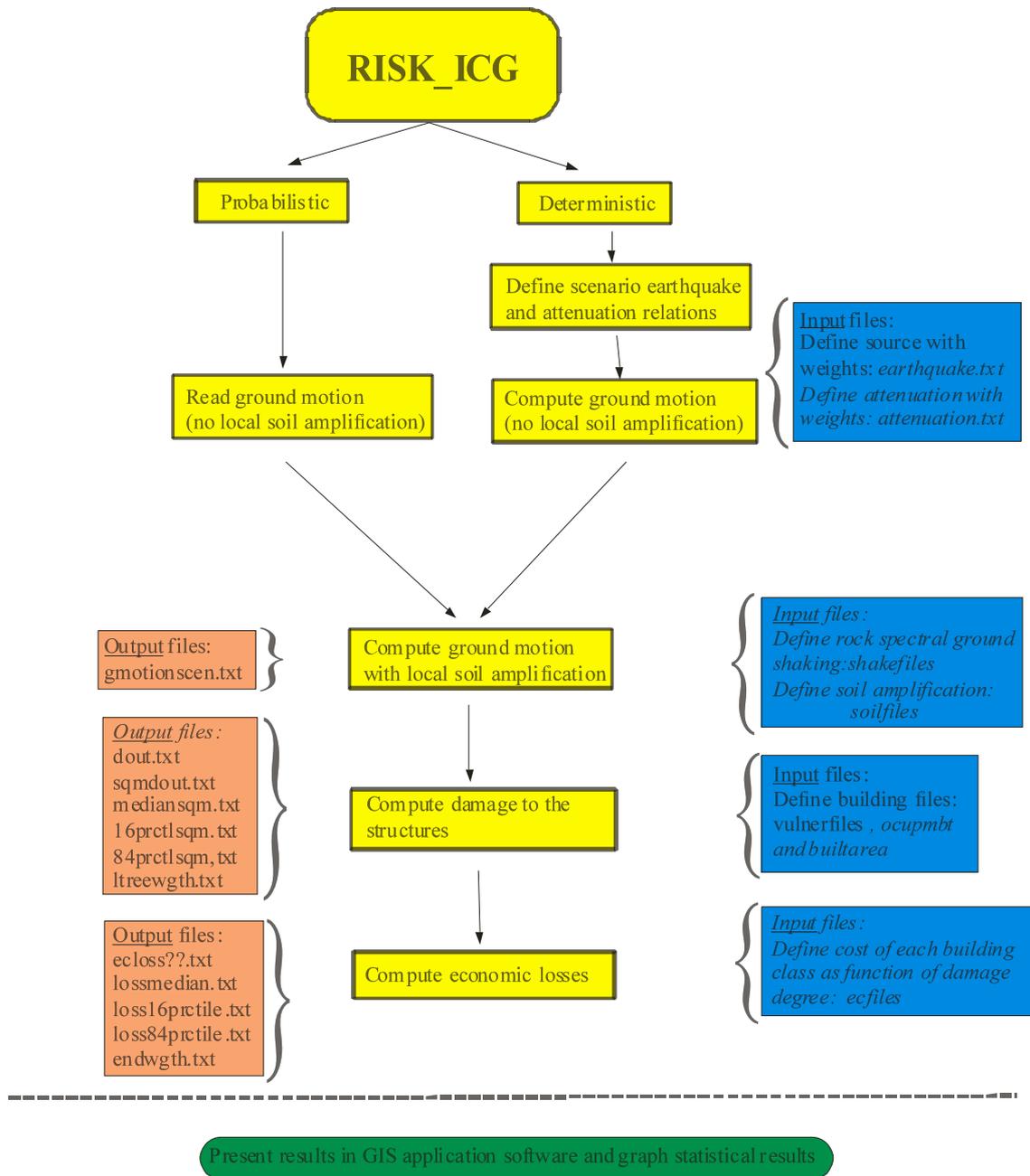


Figure 8. RISKICG v. 2.3 flow chart.

4. RUNNING RISKICG

Within the Matlab environment the user has to go to the folder where riskicg is installed and write:

> riskicg.

Then the a window (Figure 9) will be opened. At this moment you have the possibility to choose between carrying out a deterministic earthquake risk scenario using or using a probabilistic shake map, just clicking on one of the corresponding buttons.

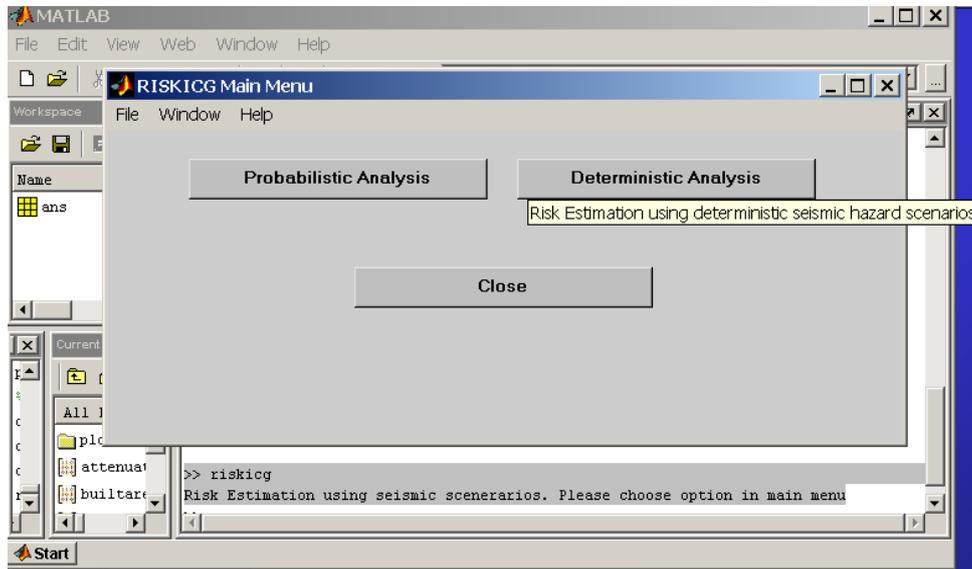


Figure 9. Main Riskicg menu.

If a deterministic analysis is going to be carried out the following window (Figure 10) will appear.

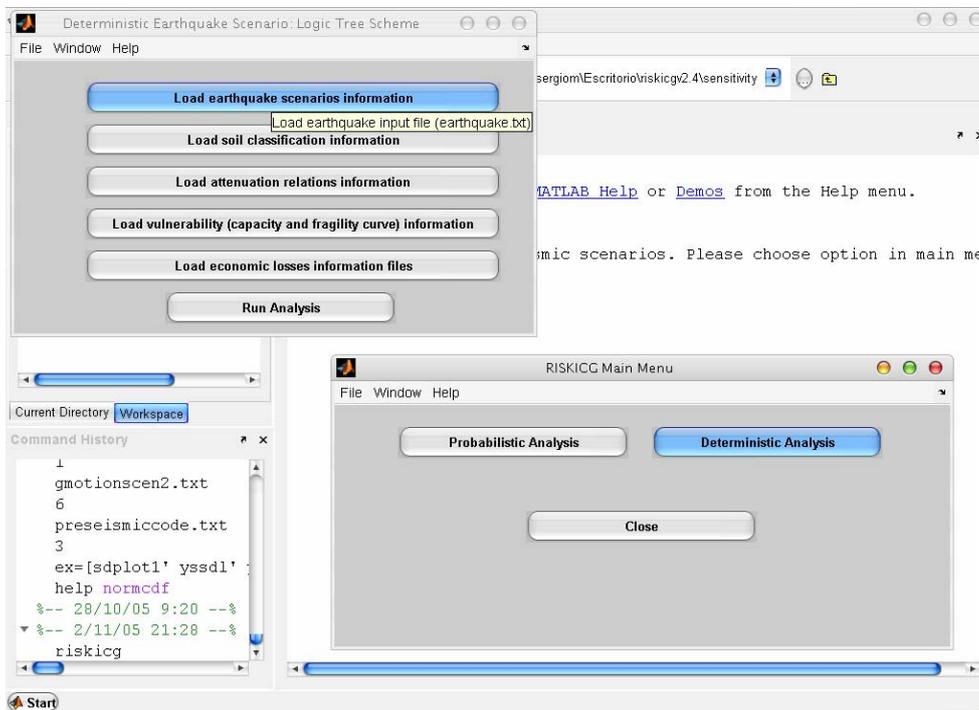


Figure 10. Main menu for a deterministic earthquake scenario.

The user has to click now in each one of the buttons to load the main input files (earthquake.txt; soilfiles.txt; attenuation.txt; vulnerfiles.txt ecflest.txt) and the after clicking in the button Run Analysis, the computation process start.

If the probabilistic shake map seismic risk study was chosen the user will see the following window (Figure 11).

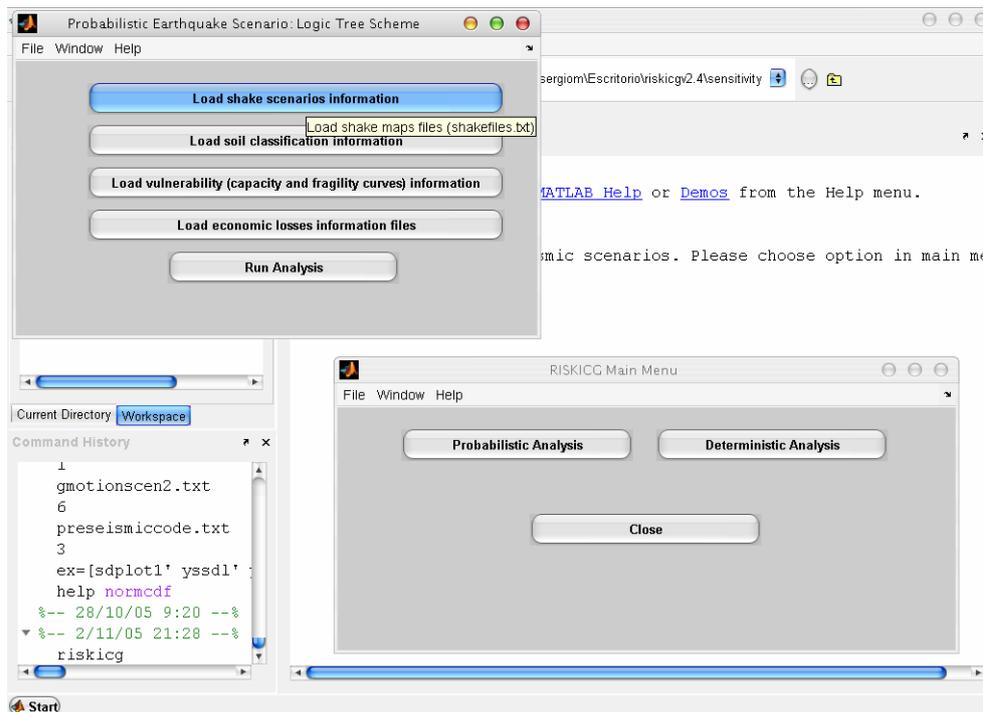


Figure 11. Main menu for a probabilistic shake map risk scenario.

The user has to click each one of the buttons to load the main input files (shakefiles.txt; soilfiles.txt; vulnerfiles.txt ecfiles.txt) and thereafter run the analysis.

The user must be aware that after clicking “Run Analysis” the program will require input to the question of output damage format (damage by square meter or by number of buildings), which will appear in the main Matlab window and has to be answered using the keyboard.

The computation time will depend on the size of the studied region (number of census tracts etc.), the details of the building information (number of model building types and number of building occupancy types), and the number of branches used in the logic tree methodology.

As an example, for the Oslo municipality, which has been divided into 84 census tracts, with 15 different model building types and 23 different occupancy types, a logic tree formed by 3 possibilities of earthquake source, 2 possible attenuation relationships, 3 possible soil types, 3 possible capacity curves and 2 possibilities of economic damage estimation (which means 108 branches), it takes 44 minutes on a laptop PC. That is 24 second/branch or approximately 3 branches/minute.

5. DEALING WITH UNCERTAINTIES.

Currently, the user can compute median values and percentiles (84th and 16th) of the risk results by means of a logic tree methodology in which the different branches of the tree can be weighed so that at the end of the computation, the risk results are multiplied by

their corresponding weights and all these values are fitted to a normal distribution in order to get the median values and percentiles. The branches of the logic tree shows currently uncertainties in: a) earthquake source, attenuation relationship, soil type, vulnerability curves and economic values of damaged built area if deterministic earthquake has been chosen or b) ground shaking probabilistic maps, soil type, vulnerability curves and economic values of damaged built area if probabilistic hazard has been chosen. An example has been given in Figure 9.

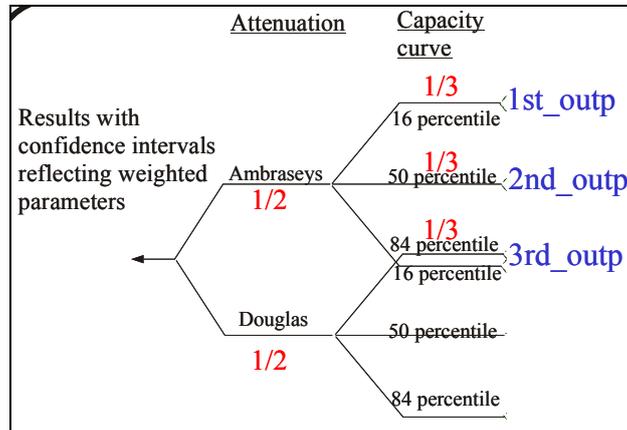


Figure 9. Logic tree structure with weights and corresponding output files.

6. OUTPUT FILES.

All the output files are written in a different folder called /output/.

The output files are:

16prct???.txt: Files corresponding to the 16th percentile of damage or economic loss

84prct???.txt: Files corresponding to the 84th percentile of damage or economic loss

median???.txt: Files corresponding to the median value of damage or economic loss.

Sqmct???.txt: File with results corresponding to the branch (number of the file) of the logic tree. Sqm means square meters.

If number of buildings instead of damaged area (sqm) is selected then the output files would have been nbuidct???.txt.

Eclosses???.txt: File with results corresponding to the branch (number of the file) of the logic tree containing the economic losses.

Dout??: Damage probability for each branch (number of the file) of the logic tree.

Ltrewth.txt: Weight of the damage results (excluding the branches of economic losses).

Endwght.txt: Final weight of the economic results (all possible branches included).

Gmotionscen?.txt: This are the files with the ground motion without and with soil amplification.

Distancias.txt: Dummy file with distances from each site to the source.

7. PLOTTING DAMAGE RESULTS IN ARCVIEW

All below is optional. The output from RISKICG can be plotted in any program the user prefers. ARCVIEW is only included as an example since the authors are familiar with that plotting package.

Output files have been prepared so they are easily imported in EXCEL. The user can import the text file in EXCEL as *delimited format* with *Tab* and *Comma* or *Space* as delimiters. In some columns a -1.0 indicates that there were no data to compute damage (built area or number of buildings). Consequently the damage has not been computed and a value of -1 has been assigned.

The user can use EXCEL to sum all columns with moderate damage (for example) and get a column with moderate damage for all the building types or sum all columns with moderate damage, extensive damage and complete damage obtaining a column with at least moderate damage for all the building types. In the sum user has to be carefully about the dummy value of -1 in some cells, so a suggestion is to change this dummy value to 0 before summing.

Finally, the files to be plotted in Arcview must be exported to dbf (Dbase 4) formatted files and they must contain at least the following columns:

%CTRA LONGI LATI other-columns-to-be-plotted NUMB

The user can run Arcview, create a new project, add a new view, include a theme in the view (for example the theme with Oslo census tracts) and add a table (the dbf file which is going to be plotted).

The user must click in the view window, in Theme+table in order to open the main table of the Oslo census tracts (as an example). Now, in the table window it is possible to see two different tables (Attributes of ..., which is the main table, and output.dbf (for example) which is the output file which is going to be plotted). Both tables should have a common column (maybe with different header but with the same data, for example CTRA or NUMB. Then, the user has to click first in the common column of output.dbf (make click in the header of the column) and the has to click in the common column of Attributes of ... (also in the header of the column), in that way it is possible to go to Join both tables using (CTRL+J), and the theme which is currently in the view window will contain all the information of the output results.

The user the can make click in THEME+EDIT LEGEND and choose a Legend Type: Graduated Color and choose as Classification Field the column which is going to be plotted. Then, the user can make a click in START EDITING and SAVE the EDITS AS a new theme file which will be added to the view. Then the process can be repeated for other columns keeping always the original theme without changes.

Probably a GIS expert can simplify this process but for a non-expert user is an easy way of plotting and creating new themes.

The same methodology of plotting can be used to plot results from ground motion.

8. SUMMARY AND CONCLUSIONS

A Matlab-based seismic risk tool has been developed and named RISKICG. This tool is still in development, but it can provide damage results and economic losses for the general building stock of a city or country and also for the essential facilities as schools, hospitals, emergency response facilities, etc. if they are provided as input information in the files. This can be done by introducing a new census tract and a new building type (if required) corresponding to the location and structure of the facility. This will involve changes in the files builtarea.txt and soilcenter?.txt and others.

The code has been written so that the user can introduce most of the needed inputs in a windows environment.

The input files are so transparent that they can be easily adjusted to any part of the world, only taking into consideration the possibility of new model building types with other capacity and fragility curves.

The m-scripts which form RISKICG are commented so that the user can go through the lines and easily change them if necessary.

Future development will be focused to try to include lifelines and human losses to damage results.

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Finally, an example of application of this methodology has been submitted as a paper to the Journal of Earthquake Engineering (ICG Contribution Number 61), which is currently in press, and it has been presented as a poster (ICG Contribution Number 60) in the XXIX General Assembly of the European Seismological Commission (12-17 September, 2004).

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