Universitat d'Alacant
Universidad de Alicante

NORSAR ICG

El Proyecto RESIS-II:

Reducción de Riesgos Sísmicos en Guatemala, El Salvador y Nicaragua con Cooperación Regional a Honduras, Costa Rica y Panamá

The SELENA loss computation tool and its Google Earth™*-based illustration tool RISe*

1 The SELENA methodology

Aware of the importance of a proper seismic risk estimation, the International Centre for Geohazards ICG, through NORSAR (Norway) and the University of Alicante (Spain), has developed the seismic loss computation software SELENA (*Seismic Loss Estimation using a Logic Tree Approach*; Molina *et al.*, 2009). SELENA is able to compute ground shaking maps, damage probabilities, absolute damage estimates as well as economic losses and numbers of casualties (**Figure 1**). It should be noted that the core of the HAZUS methodology (FEMA, 1999, 2003) was adopted for SELENA. However, one of the main difference between both tools is that SELENA works independent of any Geographic Information System, while HAZUS is connected to the ArcGIS software (ESRI, Inc.). The main innovation of SELENA is the implementation of a logic tree computation scheme (**Figure 2**), which allows the user to define weighted input parameters and thus being able to account for epistemic uncertainties. Final damage and loss results are provided with corresponding confidence levels. SELENA allows the provision of earthquake ground motion on three different ways:

- the provision of spectral ordinates taken out from probabilistic shaking maps and assigned to the geographical units (*'probabilistic analysis'*),
- the definition of deterministic scenario earthquakes (e.g. historical or user-defined events) and adequate/suitable ground motion prediction equations in order to compute the spectral ordinates in each geographical unit (*'deterministic analysis'*),
- provision of spectral amplitudes of recorded ground motion at the locations of seismic (strong motion) recording stations (*analysis with near-real-time data*).

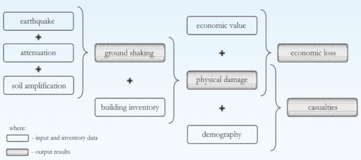

Figure 1. Principle flowchart of a deterministic analysis using SELENA. Outputs are provided on the level of geographical units (GEOUNITS).

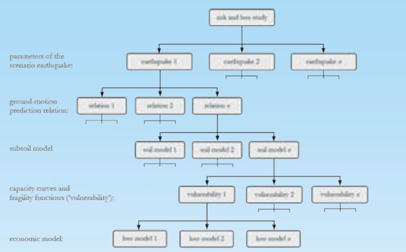

Figure 2. Logic tree computation scheme. Each branch will be weighted in order to compute the expected mean values and confidence levels.

The first step of each analysis type consist in the provision of seismic ground motion amplitudes at the center of each geographical unit. Thereby it has to be considered that these amplitudes can either represent the motion on rock conditions (deterministic and probabi-listic analysis) or already include amplification effects of local (near-surface) subsoil conditions (analysis with real-time data). Based on these acceleration values SELENA generates an elastic response spectrum (damping factor ξ = 5 %) following a selectable seismic code provision. Currently, the provisions of the U.S. seismic building code IBC-2006 (International Code Council, 2006), Eurocode 8 – Type 1 and Type 2 (CEN, 2002) and the Indian seismic building code IS 1893 (Part 1):2002 (BIS, 2002) with their soil amplification factors are incorporated. To determine the structural performance of a building under a lateral seimic load, the spectral displacement along its capacity curve is determined so that it is consistent with the seismic demand and at the same time reduced for nonlinear effects (**Figure 3**). In order to identify the so-called performance point on the building's capacity curve, two different capacity spectrum methods (CSM) are implemented: the traditional methodology as proposed by ATC-40 (ATC, 1996) and a recent modification of this procedure, the Modified Acceleration Displacement Response Spectra (MADRS) method as given by FEMA 440 (FEMA, 2005).

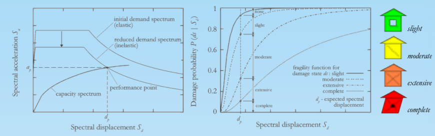

Figure 3. *(left)* Principle of the capacity spectrum method finding the performance point. *(right)* The respective spectral displacement is used to assign discrete damage probabilities on the fragility functions. Damage is classified into the four damage states *ds:* no, slight moderate, extensive and complete damage as defined by FEMA (1999).

Based on the damage results, both economic losses and number of casualties are calculated. The first requires a suitable economic model, which provides realistic costs for the repair or replacement of partly or completely damaged buildings and which then allows the appraisal of the total amount of economic loss in each geographical unit. The computation of economic losses caused by direct structural damage is done by adopting the methodology described by FEMA (2003).

The economic losses reflect those numbers which are required to repair or replace the damaged buildings. SELENA facilitates the computation of casualties for three different day time scenarios (night time, day time, commuting time). Thus, extreme cases of occupancy are covered which are strongly dependent on the time of the day. These scenarios are expected to generate the highest casualty numbers for the population at home (night time), the population at work or educational facilities (day time), and the population during rush hour (commuting time).

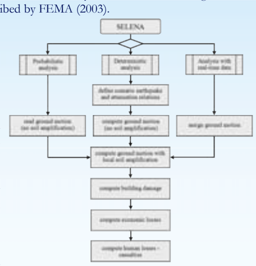

Figure 4. The computational process.

2 *RISe* - Risk Illustrator for SELENA

RISe (Risk Illustrator for SELENA) is a user-friendly, open-source software that is intended to be applied in parallel to SELENA in order to assist the user during the different stages of the risk computation process. Like SELENA, *RISe* is distributed free of charge under the GNU General Public License (GPL) through the NORSAR/ICG webpage (http://www.norsar.no). Since *RISe* is linked to the Google™ Earth visualization, the user automatically takes full advantage of the partly high-resolution satellite images provided by Google™ Earth that can be used, for instance, to demarcate study areas or to overlay risk and loss results. The availability of *RISe* with Google™ Earth is particularly important in situations where other commercial packages do not provide a high resolution database or for developing countries where many cities and municipalities cannot be displayed on high resolution base maps other than Google™ Earth satellite images.

As illustrated in **Figure 5**, *RISe* serves as an intermediary between SELENA and Google™ Earth to assist in the preparation of input files, the KML file generation of input, inventory and output files. *RISe* is intended for use before, during and after the core damage and loss computation process which is done using SELENA.

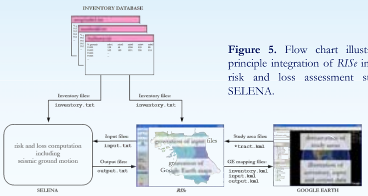

Figure 5. Flow chart illustrating the principle integration of *RISe* in a seismic risk and loss assessment study with SELENA.

Illustration of input and inventory files

Figure 6. Number of buildings in the geographical units disaggregated by model building type (color-shaded plot).

Figure 7. Number of residential (night-time) population in each geographical unit (absolute bar-chart plot).

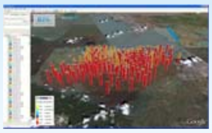

Figure 8. Percental distribution of coccupancy in each geographical unit (relative bar-chart plot).

Table 1. Overview of input and inventory files suitable to be converted into Google Earth maps (KML file format).

Input file (.txt)	Description
earthquake	1 placemark for each defined earthquake epicenter (only deterministic analysis)
numbuild	1 color-shaded map for each model building type
builtarea	1 color-shaded map for each model building type
population	1 absolute bar chart map
ocupmbt*l*	1 color-shaded map for each occupancy type and model building type *l*
occupancy	1 normalized bar chart map illustrating the distribution of building floor area to the main occupancy types RES, COM, IND, REL, GOV and EDU irrespective of model building type
soilcenter*k*	1 color-shaded map for each soil model *k*
shakecenter*i*	3 color-shaded maps for each shakemap *i* separate for PGA, S_a (0.3 *s*) & S_a (1.0 *s*)

Illustration of output files (damage and loss)

Figure 9. Ground motion amplitudes (here: spectral accelerations Sa) in the geographical units (color-shaded plot).

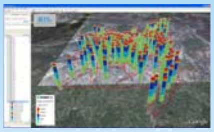

Figure 10. Damage probabilities in each geographical unit disaggregated by model building type (relative bar-chart plot).

Figure 11. Damage extent (damaged building area or numbers of buildings) in each geographical unit disaggregated by model building type (absolute bar-chart plot).

Table 2. Overview of output files suitable to be converted into Google Earth maps (KML file format).

Output file (.txt)	Description
gmotionsceni*i*	6 color-shaded maps (separate for PGA, S_a (0.3 *s*) & S_a (1.0 *s*) on rock and soil conditions) for each logic tree branch *i*
dout*i*	normalized bar chart maps separate for each model building type for each logic tree branch *i*
medianct	absolute bar chart maps separate for each model building type
16prctile	absolute bar chart maps separate for each model building type
84prctile	absolute bar chart maps separate for each model building type
lossmedian, loss16prctile, loss84prctile	absolute bar chart map (median ± 1σ)
hlbyinjurmean, hlbyinjur16, hlbyinjur84	absolute bar chart maps (median ± 1σ) for each injury severity level (1–4) and each daytime scenario (2 am, 10 am, 5 pm)
totalinjurmean, totalinjur16, totalinjur84	absolute bar chart maps (median ± 1σ) for cumulated casualty numbers separated for each daytime scenario (2 am, 10 am, 5 pm)

3 Open-source

SELENA

Unlike previous versions of SELENA which were online available to be executed in the MATLAB environment and thus required a full installation of MATLAB and some of its toolboxes, since June 2009 different formats of SELENA are now available :

(1) the conventional MATLAB code (version 4.1)
(2) "C" code (version 5.0) which can be compiled into
  (a) stand-alone binary independent of MATLAB and its toolboxes
  (b) binary (mex/oct) functions which can be used from within the MATLAB environment or even in the free (open-source) MATLAB clone GNU Octave.

The advantage of the C code consists especially in the fact that it runs approximately 50 times faster than MATLAB code.

Furthermore, an open documentation of the SELENA manual has been provided since it is now available in LATEX with all figure files in gnuplot .gpl format.

RISe - Risk Illustrator for SELENA

RISe fully substitutes the installation of a commercial Geographic Information System (GIS) and the purchase of satellite images in order to overlay the geo-referenced information. *RISe* is written in C# which can be coded in the Integrated Development Environment (IDE) provided free of charge by Microsoft (MS Visual Studio C# Express Edition 2008). Running the *RISe* tool only requires:

(1) the free Microsoft .NET framework (at least version 2.0), and
(2) Google Earth's free version.

Both, SELENA and *RISe* are provided free of charge through the GNU General Public License (GPL).

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The recent versions of the loss assessment software SELENA and its illustration tool *RISe* can be received through the NORSAR/ICG-webpage. (http://www.norsar.no).

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