LESSLOSS FINAL WORKSHOP
Risk Mitigation for Earthquakes and Landslides Integrated Project

Priority 1.1.6.3
Global Change and Ecosystems

DETERMINISTIC SCENARIOS AS INPUT MOTION FOR LOSS ASSESSMENT

Sub-Project 10 – Earthquake disaster scenario predictions and loss modelling for urban areas

Sub-Project 11 – Earthquake disaster scenario predictions and loss modelling for infrastructures

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ABSTRACT

A predominantly deterministic viewpoint has been adopted for computing seismic ground motion both for urban areas (SP10) and infrastructures loss modeling (SP11) at three selected areas: the cities of Lisbon (Portugal) and Thessaloniki (Greece), and the metropolis of Istanbul (Turkey). The generation of earthquake ground motion scenarios involves both the particular choice of earthquake sources with associated fault rupture parameters, and the ensuing ground motion field calculated by an appropriate numerical tool, or empirically estimated, at a set of selected points within the urban area of interest.

Ground shaking values are predicted for rock conditions and for two distinct frequency bands, i.e. the high frequency range (from 1.0 Hz to 4-5 Hz) in the case of damage evaluation for the vast majority of ordinary building, and the low frequency (≤ 2 Hz) more appropriate for lifeline system damage assessment.

The advanced simulation techniques allowed to properly consider the finite fault effects and directivity, which imply extreme expected values, and they are capable of quantifying the spatial variability of the ground motion near the extended fault.

Methods

The first important distinction among recommended approaches for creating ground shaking scenarios is between simplified and advanced methods. Simplified methods make use of empirical attenuation relations of ground motion parameters and of local geological data; they were investigated in detail and extensively applied in the previous EC Project Risk_UE [1]. Within LessLoss project, advanced methods are extensively applied because of their capability of physically representing the ground motion. Indeed, in case of relative nearness of seismic source to the city or to the lifelines structures, finite-fault effects and directivity could assume a very important role. Moreover, the high resolution of ground motion scenario can match with the complexity of geotechnical characterization, vulnerability data and exposure factors involved in the urban level losses estimations.

In a deterministic scenario, numerical tools are used to generate shaking ground motion. They usually require several input parameters to define the fault geometry, to simulate the rupture process on it and to reproduce the wave propagation from the source to the site in terms of S and P wave velocities and attenuation parameters. In particular, the choice of the reference sources can be inferred by seismo-tectonic considerations and historical seismicity data, as done in the case of Thessaloniki (see [2]). Otherwise independent probabilistic analyses can drive the selection of the sources by appropriate deaggregation analysis, as in the case of Lisbon [3] and Istanbul (Deliverables 83 [4] and Deliverable 85 [5]). The indicative return periods for applicative purposes are generally equal to 50 and 500 years. Moreover, different rupture models of the fault (location of the nucleation points, velocity of the rupture propagation, slip model, etc.) are hypothesized to consider the uncertainty on the modality of occurrence of next earthquakes.

In the present analysis, ground motion simulations were performed by two numerical methods: a hybrid stochastic-deterministic approach (DSM-Deterministic-Stochastic Method; [6]), used for all the investigated cases, and a non-stationary stochastic finite fault simulation method (RSSIM [7]), applied in the case of Lisbon. Both methods allow computing synthetic time series for direct S-wave field at bedrock sites, and are suitable to generate shaking scenarios near an extended fault whereby the direct S wave-field is generally dominant in amplitude with respect to the reflected and superficial phases (see [4]). The previous two methods produce results valid in the 1-20 Hz frequency band, to be used in the evaluation of ordinary buildings damage. Since most of the buildings are sensitive to the high frequency content of seismic radiation, peaks values (PGA, PGV), acceleration response spectra (PSA) and, at most, acceleration time series represent the main outcomes of the performed simulations.

To compute the complete wavefield of low frequency component of the ground motion ($f \leq 2$ Hz) a discrete-wavenumber/finite-element method COMPSYN [8] was used (see Deliverable 86 [9]). The synthetic seismograms has been used to estimate the seismic response of underground lifeline systems, having a tendency to follow the displacement and deformation patterns of the surrounding ground excited by the passage of seismic waves. PGD values, displacement time series and permanent displacement represent the main outcomes of the performed simulations.

When time series representative of the whole frequency range from 0 to 20 Hz are required for dynamic analysis or for site effects analysis, broad-band synthetic time series were computed merging the results from high and low frequency-simulation techniques.

Findings

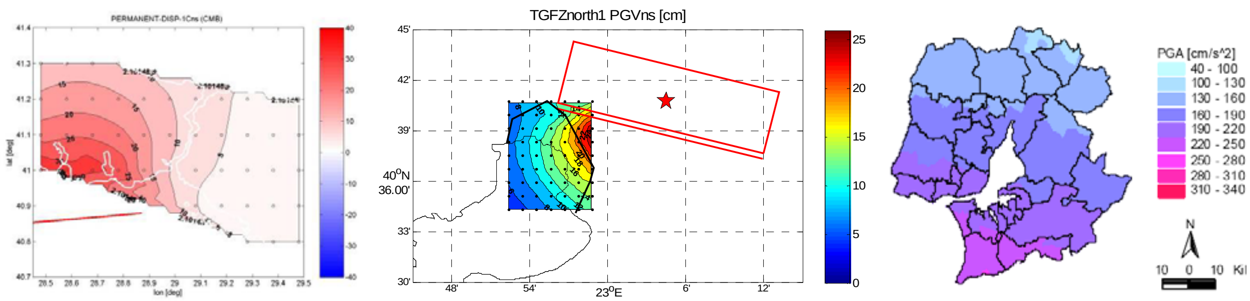
All the procedures and the ground shaking scenarios for the studied cities are exhaustively illustrated in Deliverables n. 83 and 85 (Sub_Project SP10 [4], [5]), in Deliverables n. 86 and 116 (Sub_Project SP11 [9], [10]) and in the respective Technical Dissemination volumes [11], [12].

Table 1 summarizes the geometrical and focal properties of the adopted source and Figure 1 illustrates examples, for each city, of Peak Ground maps corresponding to specific scenarios. In general the high frequency parameters as PGA and PGV show strong variability depending on kinematic and geometry features of the source, and the maximum shaking levels are associated to directive rupture propagation towards the city.

Strong motion parameters depending on the low frequency component of the ground motion, as PGD, are strictly related to the dimension of the source and to the receiver-source geometry.

Table 1 Reference earthquake

	Seismogenic zone	**Fault**	**M**	**Mo** (dyne.cm)	**LxW** (km^2)	**strike** (deg)	**dip** (deg)	**TR** (yrs)
Istanbul	*Central Marmara Basin*	CMF	7.4	1.7×10^{25}	108x20	81.5°	90°	500
	North Boundary Fault	NF	6.9	0.8×10^{25}	36x20	110°	90°	50
Thessaloniki	*Thessaloniki- Gerakarou*	North1	6.5	6.3×10^{25}	23 x 14	284°	60°	500
		North2	5.9	0.8×10^{25}	10 x 9	300°	60°	50
		North3	6.2	2.2×10^{25}	14 x 12	273°	60°	50
		South4	5.9	0.8×10^{25}	10 x 9	276°	60°	50
Lisbon	Scenario I	LTVF	4.4		1.4 x 2.3		55°	50
	Scenario II	LTVF	4.7		2.2 x 2.8		55°	75
	Scenario III	LTVF	5.7		8.4 x 6		55°	200
	Scenario IV	MPTF	7.6		110 x 24		24°	200
	Scenario V	MPTF	7.9		166 x 30		24°	500



Istanbul
Permanent Displacement [cm]
CMB fault (red line)
NS component, unilateral model.

Thessaloniki
Peak Ground Velocity (cm/s)
Norht1 fault (red box)
NS components, bilateral model

Lisbon
Peak Ground Acceleration [gal]
offshore source
The maximum scenario is shown

Figure 1 Examples of contour maps of ground shaking scenarios corresponding to a TR = 500 years, calculated on bedrock

Generally, ground shaking scenarios obtained through extended fault simulations present high variability mainly due to finite fault and directivity effects; in particular, ground motion is very sensitive to the position of the nucleation point on the fault plane (see Figure 2, left).

To handle with such a large variability, and to independently check the complexity of the shaking phenomena for applicative purposes, the results of advanced simulations need to be compared with alternative representations, such as those yielded by empirical predictive relationships (Figure 2, right).

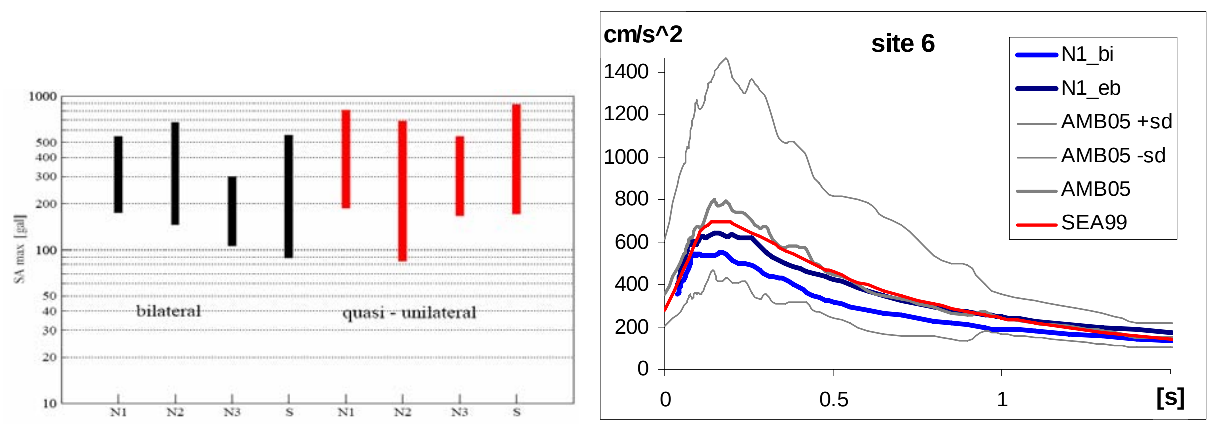


Figure 2 Left: variability of maximum values of 5% damping SA [gal] response spectrum for the metropolitan area of Thessaloniki. N1, N2, N3 and S refer to 4 different sources affecting the city. Right: Comparison of 5% damping SA response spectrum of numerical simulation (N1_bi and N1_eb) versus empirical attenuation (SEA99 = Spudich et al, 1999, AMB05 = Ambraseys et al., 2005) in site located downtown Thessaloniki.

The requirements of the users (engineers, local administrators, etc.) constrain the choice of the scenario to be adopted for loss modeling. For instance, in the case of Lisbon the maximum values of shaking is assumed as reference scenario [5]. However, the worst case scenario is not always requested: for the case of Istanbul, the representative scenario was selected by comparing the obtained peak values and response spectra with the empirical ground motion models available for the area (simulated values are within 1std of the empirical regressions).

Conclusions

Differently from previous projects [1], modern and sophisticated tools are applied to predict ground motions through deterministic approaches. These tools allow to account for ground motion variability considering different rupture scenarios, but further researches are needed to handle both aleatory and epistemic uncertainties to apply deterministic scenarios to damage and loss estimates.

Finally, the cooperation within the LessLoss Project increase the awareness of the great potential interaction between seismologists and engineers. This interaction was (and has to be) realized in the:

- efforts of seismological activity in matching practical requests for engineering applications (choice of reasonable scenario, ground motion variability level, etc.)
- implementation of engineering losses evaluation procedures with the effort of not disparaging the detailed level of shaking results (directivity and finite fault effects, extreme expected values of shaking levels, etc.)
- collection of new data and development of innovative approaches

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