Comparison of seismic risk estimates using different methods to model fragility

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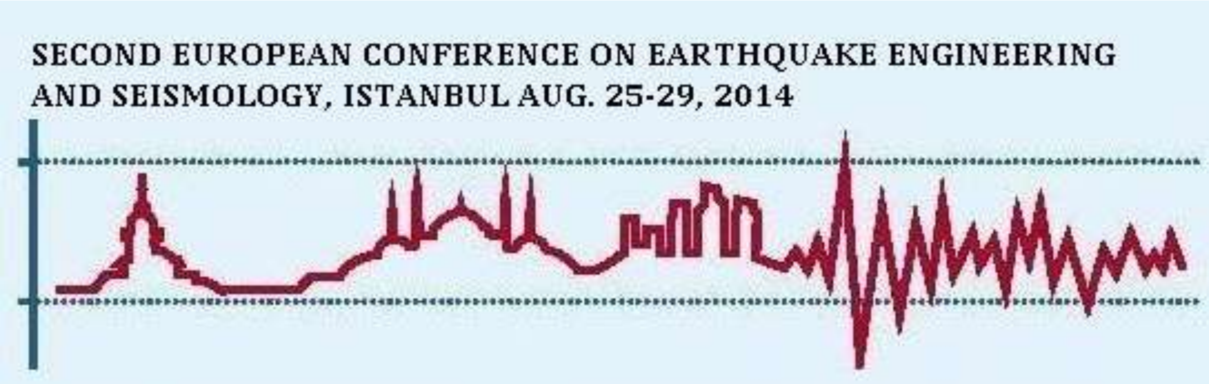

COMPARISON OF SEISMIC RISK ESTIMATES USING DIFFERENT METHODS TO MODEL FRAGILITY

Pierre Gehl[1], Ariane Ducellier[2], Caterina Negulescu[3], Jaime Abad[4] and John Douglas[5]

Seismic risk evaluations play an important role in preparing for future damaging earthquakes and, consequently, over the past couple of decades hundreds of such studies have been conducted. However, the assessment of seismic risk is always associated with significant uncertainties because of a lack of knowledge and data on earthquake hazard, vulnerability and exposure. This is especially true when assessing the risk of an entire city, where available building information is often rudimentary. These uncertainties have an impact on disaster planning and can lead to an inefficient use of resources. Consequently, in the past decade there have been great efforts made to assess, and potentially reduce, uncertainties within earthquake risk or loss assessments (e.g. Crowley et al., 2005; Cao and Petersen, 2006; Gehl et al., 2013; Rohmer et al., 2014). These studies have evidenced the great importance of, for example: uncertainty in ground-motion prediction and uncertainty in vulnerability models, on the final results. Generally, however, these studies have only considered one method to model building vulnerability, e.g. fragility curves based on pushover analyses or empirical vulnerability indices. Consequently the relative uncertainties of the various approaches to model vulnerability are difficult to assess. In addition, many studies assessing uncertainty consider only a few representative scenarios rather than estimating the annual frequencies of different levels of seismic risk.

In this study, partially funded by the EDF-led MARS project, we present a comparison of earthquake risk (in terms of the annual frequencies of attaining or surpassing various damage states) assessed using three approaches for a hypothetical city composed solely of mid-rise reinforced concrete buildings. The three methods considered are: (i) fragility curves derived by nonlinear time-history analyses accounting for variability in the mechanical properties of the structures (40 building variants are considered); (ii) fragility surfaces (Gehl et al., 2013) accounting for the influence of a second intensity measure on structural response; and (iii) an empirical approach using vulnerability indices (Lagomarsino and Giovinazzi, 2006) considering appropriate uncertainties in the estimation of these indices. The seismic hazard is generated using a stochastic procedure developed during the FP7 Syner-G project taking into account ground-motion and spatial variability in earthquake shaking from various seismogenic sources (Cavalieri et al., 2012).

The generated risk curves show that variability in mechanical properties has a considerable impact on the assessed risk, particularly for higher damage states and low annual frequencies (Figure 1). Comparing the results for the average fragility curves and the fragility surfaces shows that the consideration of an additional intensity measure on structural response has the impact of lowering the mean seismic risk for low frequencies because of the reduced uncertainty in the assessment (Figure 2). Finally comparing the curves obtained using the analytical and empirical approaches shows the

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importance of defining appropriate vulnerability indices and that the results of the two procedures present similar overall uncertainties (Figure 3).

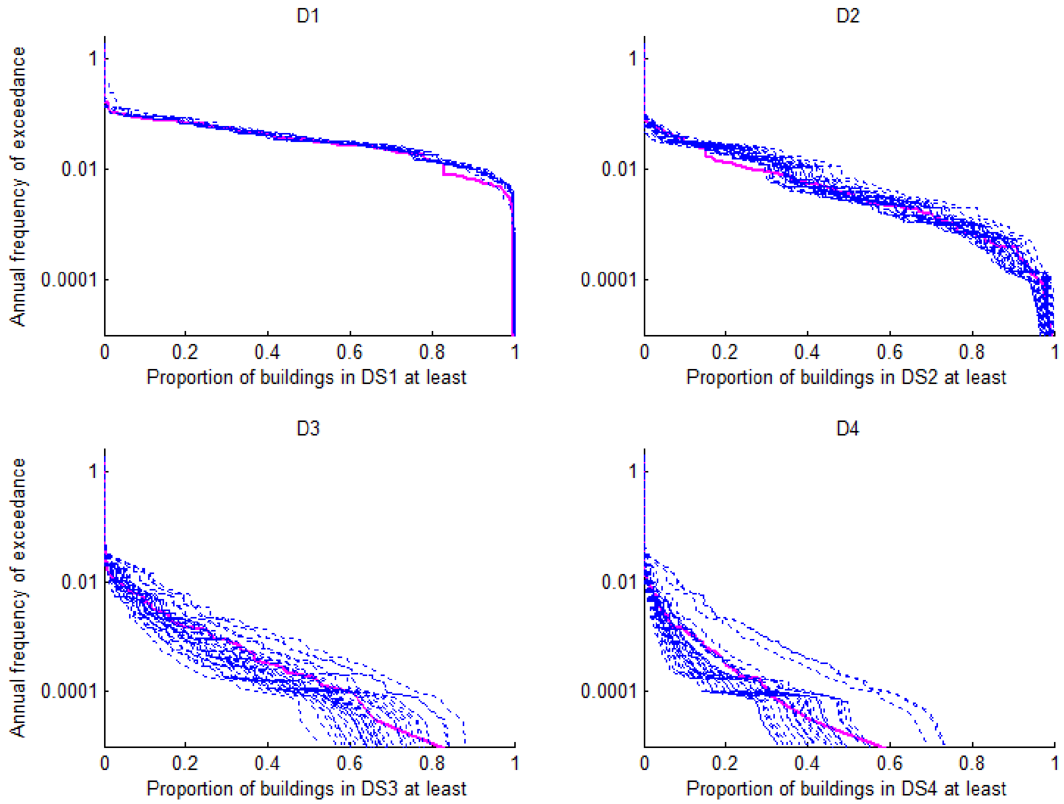

Figure 1. Annual frequencies of attaining or exceeding different damage states computed using fragility curves accounting for variability in the mechanical properties (dashed blue lines) and mean annual frequency (solid magenta lines), where DS1 corresponds to slight damage and DS4 corresponds to collapse.

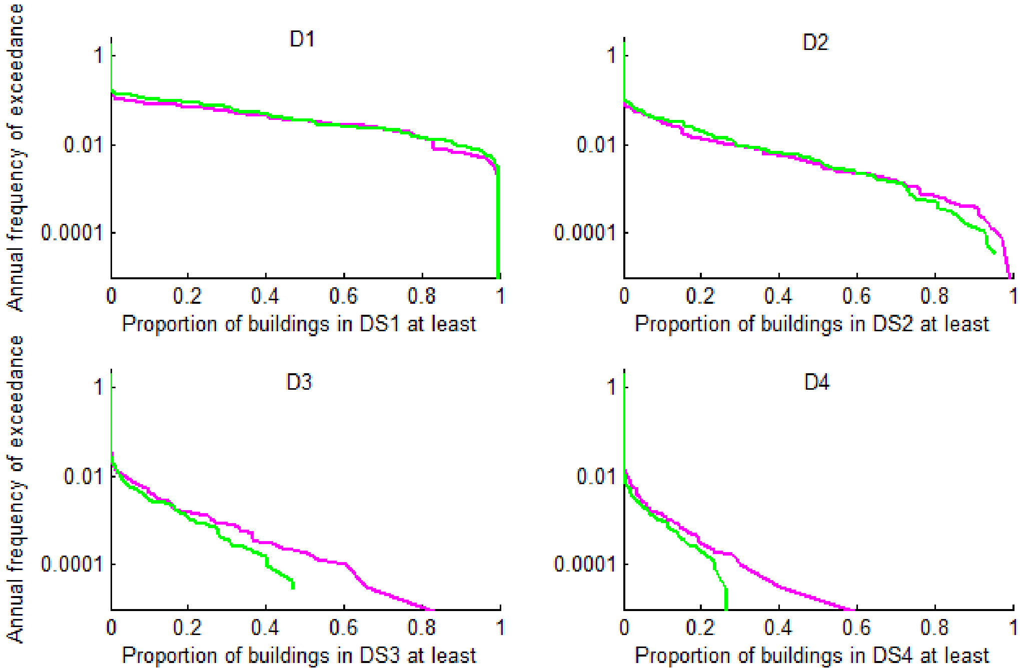

Figure 2. Mean annual frequencies of attaining or exceeding different damage states computed using fragility curves (magenta lines) and fragility surfaces (green lines).

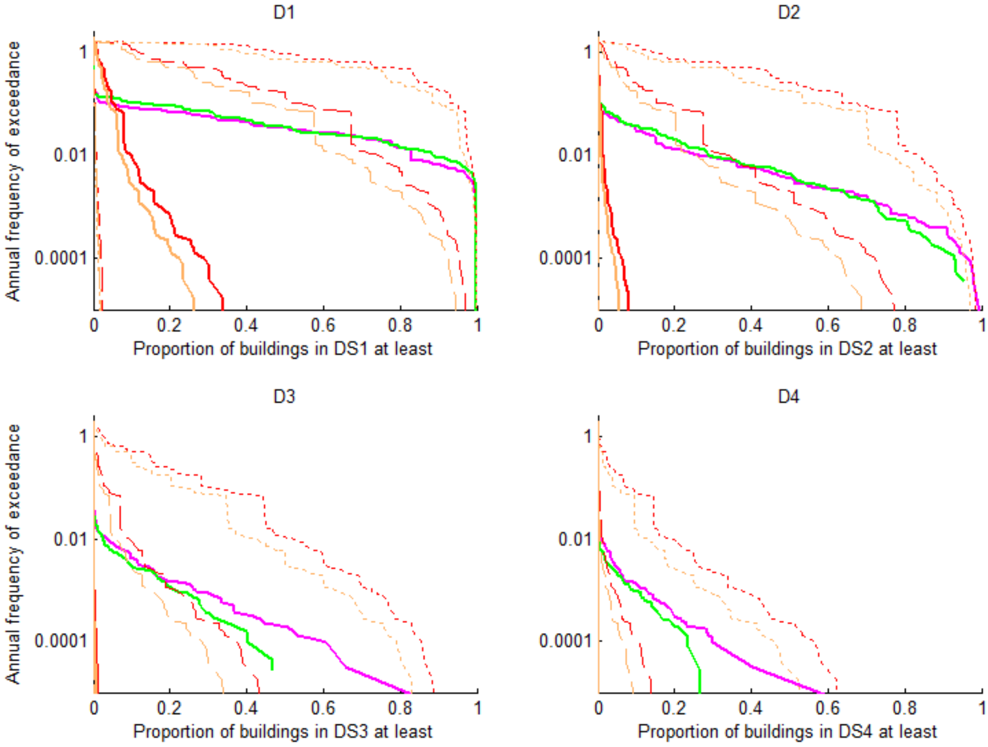

Figure 3. Mean annual frequencies of attaining or exceeding different damage states computed using fragility curves (magenta lines), fragility surfaces (green lines) and vulnerability indices (solid red and orange: best-estimate, dashed: plausible range and dotted: upper and lower bounds).

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