DISASTER REDUCTION THROUGH RISK TARGETS

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This contribution seeks to provide some replies with respect to seismic risk to the following questions:

- *How can science contribute to evidence-based target level setting on disaster risk reduction?*
- *How can policy-makers use findings from disaster risk scenarios?*
- *What are the emerging solutions that science can provide to address disaster risk?*

One of the best ways to reduce earthquake risk is through the enforcement of seismic design codes, which regulate how structures should be built to resist ground shaking. Examples of such codes include Eurocode 8 (EC8, also called EN 1998), which is in force in much of Europe, and the International Building Code, which is used in the United States. A key component of such codes is a seismic design map that indicates the level of ground motion (e.g. in terms of peak ground acceleration, PGA) that a structure should be designed to resist. These design maps are generally based on the 'constant hazard' assumption, which means that the ground-motion levels specified have a certain probability (e.g. 10%) to be exceeded within a given interval (e.g. 50 years). Such a combination of a single probability and interval means that the return period, e.g. 475 years, of such maps is uniform across the territory.

There is currently a move towards seismic design maps that are risk-targeted (e.g. Luco et al., 2007). In this framework, buildings conforming to the rules have a known annual risk of attaining or exceeding a certain damage state (e.g. collapse) that is uniform over a territory. Such a risk-targeted (also called performance-goal-based, risk-informed or risk-consistent) approach is more consistent with the aim of design maps, which is to provide a constant level of protection against earthquake risk to all citizens, than the 'common hazard' assumption. Generally seismic design codes regulate the construction of *new* buildings. Consequently *existing* structures continue to pose a significant risk to their inhabitants because they are generally less resistant to earthquake shaking as they were constructed before the advent of seismic codes. Design codes could be developed, however, to guide the retrofitting of existing structures to reduce this risk. As well as helping in the development of more appropriate design standards, the explicit calculation of the chance that a building collapses during an earthquake should lead to a wider appreciation of the disaster risk that populations currently experience. This would help guide future efforts to reduce this risk.

In the past decade the risk-targeting approach has become the focus of much research in developed countries and the approach was explicitly used to develop the recent US ASCE Standard 7–10 design code. Recent work on this topic includes the articles of Fiorini et al. (2014), for Italy, and Silva et al. (2014), for Europe, as well as the seminal work of Luco et al. (2007) and related documents. This brief document summarises the findings of Douglas et al. (2013), for France, Ulrich et al. (2014a), who derive EC8-consistent fragility curves, and Ulrich et al. (2014b), who estimate the earthquake risk for France using this approach.

The development of risk-targeted design maps relies on three independent inputs: a) seismic hazard curves derived using probabilistic seismic hazard assessment for each grid point on the map; b) fragility curves expressing the probability that a

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structure, designed using the building code, attains or exceeds a certain damage state given a level of shaking; and c) knowledge of the risk level that is acceptable to the local population. Douglas et al. (2013) develop seismic design maps using the risk-targeted approach for mainland France and they assess the sensitivity of the results to various inputs. This sensitivity analysis highlighted the importance of appropriate fragility curves for buildings designed using EC8. When making the common assumption that fragility curves can be expressed as a lognormal distribution, the two parameters that need to be defined are: the probability X that a building attains or exceeds a certain damage state given shaking equal to its design PGA, and the standard deviation β of the lognormal distribution. In view of the lack of estimates for X and β, Ulrich et al. (2014a) develop a set of fragility curves for a series of regular reinforced-concrete buildings with three storeys (3 m high) three bays (4 m long) and four frames (4 m long) designed for different PGAs. For the risk of collapse, they find that X varies between 1.7×10^{-7} (for a design PGA of $0.7 m/s^2$) and 1.0×10^{-5} (for a design PGA of $3.0 m/s^2$) and β is between 0.4 and 0.5. These values are similar to the values assumed by Douglas et al. (2013) ($X=10^{-5}$ and $\beta=0.5$) when testing the risk-targeting approach for mainland France, although as shown below these apparently minor differences have significant impact on the results. For the risk of structural yielding, they find that X varies from 0.14 (for a design PGA of $0.7 m/s^2$) to 0.85 (for a design PGA of $3.0 m/s^2$).

Ulrich et al. (2014b) apply the findings of Ulrich et al. (2014a), the seismic hazard model used by Douglas et al. (2013) and the French seismic design map currently in force (based on a constant return period of 475 years) to produce maps of the seismic risk for regular three-storey buildings in mainland France. The average annual probability of collapse nationally is 9×10^{-6}, which compares favourably to the risk level assumed to be acceptable for the French population by Douglas et al. (2013) (1.0×10^{-5}). However, this risk varies from 3×10^{-7} (in the areas of lowest seismicity, e.g. Paris) to 8×10^{-5} (in the most seismically active areas, e.g. the Pyrenees). Similar large variations are noticeable in the annual probability of structural yield, which varies between 0.03% and 2.3% with an average of 0.3% (i.e. about 300 times higher than the annual probability of collapse). The variation in annual probabilities of structural yield and collapse demonstrates that the French population is subjected to widely varying seismic risk (by a factor of more than 200 times for collapse) despite a design code that varies with geographical location.

The risk-based approach described here could help guide Member States in establishing relevant target levels for the reduction of earthquake risk in terms of deaths and economic losses. This could be done by, first, calculating the current annual risk of building collapse using currently-available seismic hazard maps and appropriate fragility curves. This computed risk could be expressed in terms of potential deaths and economic losses through assuming occupancy rates and building costs. Based on this calculated risk various approaches to improve the building stock (e.g. retrofitting or demolition of the most-vulnerable structures) could be assumed to study their impact on risk levels. In view of these calculations an appropriate risk-reduction target could be defined and ways that this target could be reached implemented. Finally, the risk model could be revisited periodically to check that the risk-reduction targets are being attained.

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