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Earthquake loss analysis and cost-benefit exploration for earthquake damage mitigation: evaluating retrofitting investments in France

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With increasing impacts in countries' economies, actual earthquakes cost in average tens of billons of dollars and kill more than 35,000 people per year worldwide. They generate a variety of economic and human impacts: direct losses typically measured in terms of property damage, building contents loss, business inventory loss, injuries and deaths; and indirect economic losses such as business interruption, relocation expenses, earthquake-induced supply shortages, demand reductions and income losses. Due to the rising concentration of economic assets and people living in urban areas exposed to seismic hazard, but especially after the extensive damage observed following the latest earthquakes which caused catastrophic losses, seismic risk awareness have considerably increased in the last decades, and the usefulness of loss estimation models has been fully recognised. Moreover, the increased occurrence of induced seismicity has also heightened public concern. Induced earthquakes can now occur in regions where little or no natural seismicity was expected. In those regions, the building stock may be more vulnerable, since no earthquake design rules were to be applied and this seismicity can have an important impact on the built environment.
A loss estimation model is a tool used to assess potential losses due to the occurrence of a hazard, and directly related with the damage of existing structures and infrastructures. In Europe, the building stock is predominantly old, and it was built mainly at times when no earthquake design rules were established. In low-to-moderate seismic hazard regions (France, Spain...) the application of conventional earthquake loss models requires so much information that the evaluation struggles to find sufficient political motivation and financial resources, for example, to complete the seismic hazard evaluation or the seismic inventory of buildings of the study region. However, the risk from natural hazard is becoming more and more significant, especially since the exposure has considerably increased with time.
In France for example, numerous critical infrastructures and more than 17 million people are exposed to important seismic hazard. The repetition of historical earthquakes would produce very large potential losses on present-day urbanisations. Using an exposure model derived from census datasets (INSEE), the seismic vulnerability distribution of buildings calculated using Support Vector Machine (SVM) methods and input seismic hazard calculated from regulatory accelerations from French codes, we perform in the first step of this work economic earthquake loss estimations by means of a semi-empirical intensity-based approach. We propose then several hypothetical large-scale retrofitting scenarios with increasing investment costs for three cities in France. The benefits in terms of the reduction of expected damage to buildings are compared with the costs of each retrofitting measure.