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Spatio-temporal earthquake risk assessment for the Lisbon Metropolitan Area – A contribution to improving standard methods of population exposure and vulnerability analysis

Sérgio Freire (1) and Christoph Aubrecht (2)
(1) New University of Lisbon, Portugal (sfreire@fcsh.unl.pt), (2) AIT Austrian Institute of Technology, Vienna, Austria

The recent 7.0 M earthquake that caused severe damage and destruction in parts of Haiti struck close to 5 PM (local time), at a moment when many people were not in their residences, instead being in their workplaces, schools, or churches. Community vulnerability assessment to seismic hazard relying solely on the location and density of resident-based census population, as is commonly the case, would grossly misrepresent the real situation.
In particular in the context of global (climate) change, risk analysis is a research field increasingly gaining in importance whereas risk is usually defined as a function of hazard probability and vulnerability. Assessment and mapping of human vulnerability has however generally been lagging behind hazard analysis efforts. Central to the concept of vulnerability is the issue of human exposure. Analysis of exposure is often spatially tied to administrative units or reference objects such as buildings, spanning scales from the regional level to local studies for small areas. Due to human activities and mobility, the spatial distribution of population is time-dependent, especially in metropolitan areas. Accurately estimating population exposure is a key component of catastrophe loss modeling, one element of effective risk analysis and emergency management. Therefore, accounting for the spatio-temporal dynamics of human vulnerability correlates with recent recommendations to improve vulnerability analyses.
Earthquakes are the prototype for a major disaster, being low-probability, rapid-onset, high-consequence events. Lisbon, Portugal, is subject to a high risk of earthquake, which can strike at any day and time, as confirmed by modern history (e.g. December 2009). The recently-approved Special Emergency and Civil Protection Plan (PEERS) is based on a Seismic Intensity map, and only contemplates resident population from the census as proxy for human exposure. In the present work we map and analyze the spatio-temporal distribution of population in the daily cycle to re-assess exposure to earthquake hazard in the Lisbon Metropolitan Area, home to almost three million people. New high-resolution (50 m grids) daytime and nighttime population distribution maps are developed using dasymetric mapping. The modeling approach uses areal interpolation to combine best-available census data and statistics with land use and land cover data. Mobility statistics are considered for mapping daytime distribution, and empirical parameters used for interpolation are obtained from a previous effort in high resolution population mapping of part of the study area. Finally, the population distribution maps are combined with the Seismic Hazard Intensity map to: (1) quantify and compare human exposure to seismic intensity levels in the daytime and nighttime periods, and (2) derive nighttime and daytime overall Earthquake Risk maps.
This novel approach yields previously unavailable spatio-temporal population distribution information for the study area, enabling refined and more accurate earthquake risk mapping and assessment. Additionally, such population exposure datasets can be combined with different hazard maps to improve spatio-temporal assessment and risk mapping for any type of hazard, natural or man-made. We believe this improved characterization of vulnerability and risk can benefit all phases of the disaster management process where human exposure has to be considered, namely in emergency planning, risk mitigation, preparedness, and response to an event.