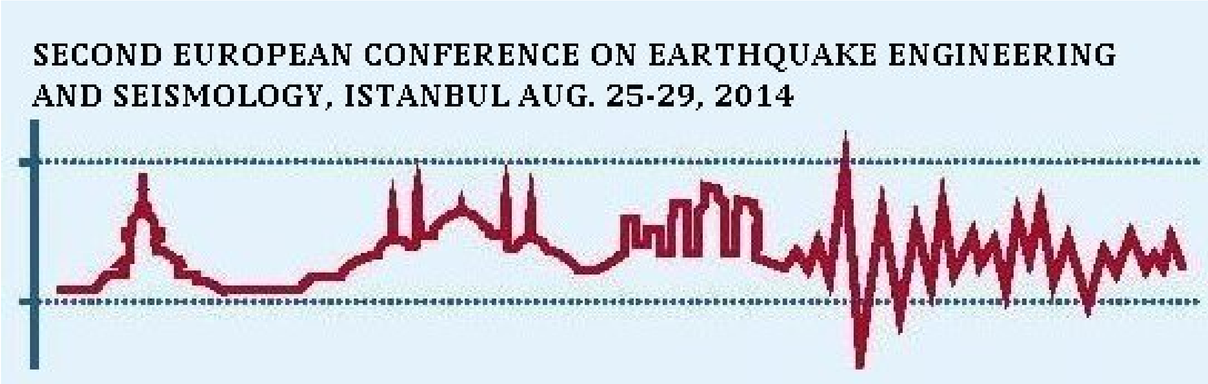

PRELIMINARY EXPOSURE AND SEISMIC VULNERABILITY ASSESSMENT OF PORT AU PRINCE (HAITI) BASED ON SATELLITE IMAGERY, LIDAR, AND STATISTICAL INFERENCE.

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Collecting input data for exposure and seismic vulnerability assessment, such as construction materials, age, height and size of buildings, could become a challenging task in certain scenarios. Official cadastral databases are a valuable source of information; however, either not all countries have an updated cadaster or there is not a data distribution policy available that allows users access the data. A further difficulty for the cities to update the building stock information is the high urbanization rate they are experiencing nowadays. This rapid urban growth is generally unsupervised and not planned, therefore not included in official records. Field campaigns to make an inventory of the building stock carried out by experts in civil engineering and/or architecture is another option for data collection. Nevertheless, as it is an expensive, arduous, and time-consuming approach, it is rather used within sampling approaches.

Given this, novel methodologies and techniques for exposure and vulnerability assessment need to be developed as a supplement to existing procedures. That is the motivation of the present research, whose main goal is to test a new methodology based on the combination of remotely sensed data, such as satellite images and LiDAR points, statistical sampling and Bayesian information integration, for exposure and vulnerability evaluation of the urban agglomeration in and around Port au Prince (Haiti). The selection of the study area is based on the potential seismic hazard in the south of Haiti, since significant stress still remains in the Enriquillo-Plantain Garden fault after the 2010 earthquake (Calais et al., 2010). The cooperative line with the Haitian Ministry of the Environment initiated by the Technical University of Madrid (UPM) in 2010, and the recently started collaboration between the UPM and the GFZ German Research Centre for Geosciences, is the working frame of this research, which is structured in the following three main sequential parts:

1. Stratification of the study area into homogeneous regions regarding urban structure. The data used in this part are a time-series of medium resolution, freely available Landsat satellite images (from 1973, 1989, 1999 and 2009). The images have been analyzed following the procedure described in Wieland, et al. 2012. First, areas that show similar construction date period have been identified, by a change detection analysis of classified built-up areas in all images. Second, regions with homogeneous land use/land cover (LULC) have been identified in the built-up area of the 2009 satellite image, following a machine learning supported object-based image analysis. Finally, both layers have been spatially intersected to

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obtain the stratification of the study area into homogeneous regions (or strata) in terms of age of structures and LULC.

The strata reduce the complexity of the study area and provide the sub-populations for the subsequent stratified statistical analysis.

2. Exposure estimation in the study area. The number of buildings exposed to the seismic hazard has been derived from the estimation of building density in samples selected in each stratum. Three data sources have been used and compared in this stage of the study, namely: crowd-sourced database compiled by the Haitian Ministry of Public Works after the 2010 earthquake, containing a thorough description of the buildings in Port au Prince; contour of the buildings automatically derived from LiDAR points provided by OpenTopography (freely available[5]); and manually digitized building footprints using high resolution aerial images provided by ImageCat Inc. and the Rochester Institute of Technology (freely available[6]). The building density in each sample has been estimated following a bootstrap procedure.

   A validation of the proposed method has been carried out in the metropolitan area of Port au Prince. From each data source, the 95% confidence interval for the median of the expected number of buildings has been computed in the strata of the city and compared to the observed value extracted from the crowd-sourced database. The resulting estimates of building numbers are highly satisfactory and the three data sources show comparable estimates for the validation area. Using the validated estimators, the expected number of buildings per stratum could be calculated for the entire study area.

3. Vulnerability evaluation in the study area. The exposure obtained in the previous stage has been classified into prevalent building typologies (BT). According to the results of recent research on this field (Molina et al., 2013 -analytical approach- and Hancilar et al., 2013 – empirical approach), the building stock of the region can be divided into three predominant BT: RC-M and RC-L, representing buildings with reinforced concrete structure, medium- and low-rise, respectively; M&W, describing low-rise buildings made of masonry and wood. Based on expert knowledge, three attributes of the buildings have been identified as key parameters for the BT classification; specifically height, materials of the roof and site area. A probability distribution of these parameters in the samples has been estimated from a combination of the three data sources mentioned in the previous stage. Finally, a Bayesian Network has been built to integrate such information, together with the expert knowledge, in order to estimate the probability distribution of BT per stratum (Pittore and Wieland, 2012).

In conclusion, the presented work could prove that an integration of remotely sensed data analysis with statistical inference and Bayesian Networks is feasible and can, moreover, provide a valuable approach to estimate exposure and seismic vulnerability in a time- and cost-effective manner.

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