EARTHQUAKE IMPACT ASSESSMENT USING GLOBAL HUMAN SETTLEMENT LAYER (GHSL) DATA

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ABSTRACT

Rapid impact assessment in the aftermath of a damaging earthquake is of great importance for countries prone to high seismic activity as well as for relatively quieter regions of the world which could be affected by an unexpected earthquake. Several loss assessment tools are available for the estimation of the level and geographical extent of the damage as soon as preliminary earthquake parameters are made available through seismological centers. Building and population exposure however is a key component in the estimation of the earthquake impact on the community. In the present paper we investigate the usability of a publicly available global data set, the GHSL (Global Human Settlement Layer) provided by JRC (http://ghslsys.jrc.ec.europa.eu/) in the form of built-up area and population exposure as raster grids of various resolutions with ELER, the Earthquake Loss Estimation Routine, a tool developed for earthquake damage and risk assessment, compatible with different levels of sophistication of the exposure data.

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Rapid impact assessment in the aftermath of a damaging earthquake is of great importance for countries prone to high seismic activity as well as for relatively quieter regions of the world which could be affected by an unexpected earthquake. Several loss assessment tools are available for the estimation of the level and geographical extent of the damage as soon as preliminary earthquake parameters are made available through seismological centers. Building and population exposure however is a key component in the estimation of the earthquake impact on the community. In the present paper we investigate the usability of a publicly available global data set, the GHSL (Global Human Settlement Layer) provided by JRC (http://ghs lyns.jrc.ec.europa.eu/) in the form of built-up area and population exposure as raster grids of various resolutions with ELER, the Earthquake Loss Estimation Routine, a tool developed for earthquake damage and risk assessment, compatible with different levels of sophistication of the exposure data.

Introduction

Development of tools and databases for rapid impact assessment after damaging earthquakes is one of major challenges of earthquake engineering. Reliable exposure databases compatible with robust methodologies of impact assessment are key components of this effort. In the present study we try to explore the usability of a freely available global dataset of human settlement with the earthquake damage and casualty assessment methodology and software (ELER: Earthquake Loss Estimation Routine) developed within the context of EU FP6 NERIES Project [1, 2], through a case study conducted for the 2010 Haiti earthquake.

GHSL - Global Human Settlement Layer

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The development of the GHSL - Global Human Settlement Layer – database is an effort undertaken by Joint Research Centre (JRC) and the DG for Regional Development (DG REGIO) of the European Commission, together with GEO Human Planet Initiative, to provide global-scale information on the human presence on the Earth, obtained via open data and methods. GHSL provides three types of global scale data. The population grid [1] provides the distribution of population, expressed as the number of people per cell, in two cell sizes, 250 m and 1km. The database is assessed for the years 1975, 1990, 2000 and 2015. The built-up area grid [2] contains information in the form of the ratio of the built-up region to the total area for each grid cell. It is available for three resolution levels, i.e. 38 m, 250 m and 1km. Time evolution of the built-up regions over the globe can be traced via the data pertaining to the years 1975, 1990, 2000 and 2014. This type of data can bring additional sophistication to impact assessments, in case structural fragilities per period of construction (e.g. in relation with changes of construction types over the years or the issuance of earthquake resistant codes) are available. The settlement model dataset [3] provides for a 1km resolution the classification of each cell as “rural”, “urban cluster ≈ low density cluster” or “urban centre ≈ high density cluster”. This type of land-use data is extremely important as it provides the first clue for the association of the cell with related building fragility models.

The ELER Methodology for Earthquake Damage Assessment

The ELER methodology [1, 2] involves a multi-level impact assessment, depending on the availability of input exposure data. Level 1 damage assessments are based on a grid based distribution of number of buildings, in conformity with a selected building taxonomy and corresponding fragility functions that can be based on intensities or peak ground amplitudes such as PGA or PGV. The result is the number of damaged buildings in different damage grades as well as casualties for each cell. Here the challenge is the development of a grid based building inventory and population distribution as such data are not readily available for most regions of the world. Our aim in this study is to investigate the possibility of developing such a database through the use of GHSL data for the case of the 2010 Haiti earthquake.

A Case Study: 2010 Haiti Earthquake

The epicenter of the Mw 7.0 earthquake that struck Haiti on 12 January 2010 was estimated at a depth of 13 km, 25 km south-west of the capital Port-au-Prince [6]. The death toll of the devastating earthquake was in the order of 220,000, while it caused extensive damage to buildings throughout the Port-au-Prince region and in the rural areas and towns to the west of the city. Approximately 105,000 residences were completely destroyed and more than 208,000 buildings were severely damaged [7].

Development of the Exposure Data

The 1 km cell size data of settlement type (as rural, low density urban and high density urban), built-up region and population distributions downloaded from the GHSL database were combined in a single file for the region covered by the ground motion distribution. Then the following steps were conducted to estimate a 1 km grid of number of buildings: (1) classification of each cell as a rural, low density or high density urban zone; (2) computation of total built-up area in msq for each cell; (3) assignment of a representative building footprint area for each settlement type; (4)
calculation of number of buildings per cell; (5) cross-checking with the population per building obtained as well as with remote sensing data (Figure 1).

Hancilar et al. (2013) [7] developed empirical fragility functions for the Haiti region based on damage data obtained by remote sensing as well as field surveys. The damage grades for which probabilities of exceedences are provided are D3 (Substantial to heavy damage), D4 (Very heavy damage) and D5 (Destruction). Here we have adopted the both MMI intensity and PGV based fragility functions proposed for three levels of built-up zone density, i.e. for high, medium and low density built-up zones, as corresponding to high density urban, low density urban and rural settlement types of our building exposure model respectively.

Figure 1. Input data and exposure model. (a) settlement layer; (b) built-up region per kmsq; (c) population per cell; (d) the developed building exposure model, each 1 kmsq cell associated with a settlement type, number of buildings and population.

The Estimated Damage

ELER calculates the ground motion input for the earthquake damage estimation as a ground shaking map of a selected intensity measure (e.g. PGA, PGV or intensity) via user defined earthquake source parameters and ground motion prediction models, including site effects as well as corrections with recorded ground motions. It also offers the possibility of using external ground shaking data as input ground motion. In the present case, we use the USGS ShakeMap data [6] for the 2010 Haiti earthquake as external ground motion input.

The total number of damaged buildings are estimated as 77,560, 47,430 and 18,900 for damage grades D5, D4 and D3 respectively for PGV based assessments, while the corresponding numbers are 35,800, 18550 and 6,150 for MMI Intensity based assessments. Figure 2 presents the ground motion input and the resulting damage distribution maps of D5 (complete) damages for the
PGV based assessment.

Conclusions

In the present study we explore, with the help of a case study, the suitability of a freely available global human presence database for earthquake impact assessment. Acknowledging that large uncertainties pertain to each step of the procedure, from the estimation of the ground motion to building inventory and fragilities, we were able to provide a consistent estimate of the damage distribution through the use of the GHSL database (e.g. about 80,000 buildings were estimated to be in damage state D5, while the corresponding reported value was approximately 105,000 residential units). The methodology can be further improved via calibration of the estimated building inventory with field data and introduction of uncertainties through the built-up quality data also provided by GHSL.

Figure 2. Left: ground motion input for damage estimation as PGV (USGS ShakeMap); right: corresponding PGV based damage distributions for damage grade D5

References


