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A WEB APPLICATION FOR RAPID SEISMIC RISK ASSESSMENT

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Abstract: Numerous computer models have been developed for seismic loss analyses at urban and regional scales. They seem, however, ill-suited to custom application to the specific Canadian hazard and exposure settings and, more importantly, inadequate for utilization by the broader non-expert public safety community. Therefore, communication of the potential seismic risk results to local stakeholders, such that they can properly understand their exposure and vulnerability, represents an outstanding challenge. The objective of the present study is to describe the methodological background and ongoing development activities of the Rapid Risk Evaluator (ER2), a relatively rapid and user-friendly risk assessment application, developed to overcome the current communication barriers between risk experts and decision makers. Developing ER2 included: pre-computing site-specific databases containing ground motion scenarios, prediction of potential attenuation with distance and local site amplification, a standardized inventories of buildings' structural properties and occupancy categories, and assessment of the seismic vulnerability using hazard-compatible vulnerability functions. These functions correlate directly the intensity of the seismic shaking to the probability of damage and direct economic and social losses. This approach allows for conducting risk scenarios in large urban centers within minutes. The above approach was programmed into an easy to run web-application. Equipped with graphic user interface, ER2 allows non-expert users to run otherwise complex seismic risk scenarios through a simple intuitive selection process. An example of ER2 applied to a hypothetical earthquake event in Quebec City is included to illustrate the simplicity of the user interface and capabilities of the application.

1 PROJECT OVERVIEW

The primary motivation of this research is to overcome the current communication barriers between the risk experts on one-hand side and decision makers on the other. The objective is twofold: to propose relatively rapid approach for seismic risk assessment at urban scale, and to develop software in a way that they can be used by non-experts. A simplified methodology was developed for a first-order computation of the potential negative impacts with vulnerability analysis based on the concept of hazard-compatible damage functions, which correlate directly the intensity of the seismic shaking to the probability of exceedance of a specified damage state.

For a relatively rapid and user-friendly risk assessment, the methods were prototyped into an interactive web-based application, ER2 (Abo El Ezz et al. 2019). It allows non-expert users to run otherwise complex risk scenarios at a 'press of a button' through a simple intuitive selection process. Seismic risk assessment methods and comprehensive sets of stored site-specific databases are presented. An example of ER2 applied to a hypothetical earthquake event about 7 km from the Old Quebec City is presented to illustrate the simplicity of the user interface and capabilities of the application.

2 METHOD

The seismic risk assessment process involves the quantification of three input components: seismic hazard, inventory of assets at risk and respective vulnerability, and of the resulting impacts. The seismic hazard is determined with earthquake magnitude, focal distance and local soil conditions. The assets at risk, in this case, are the existing buildings combined with the population distribution in the affected area. The vulnerability represents the physical, economic and social susceptibility to damage as function of the intensity of the earthquake motion. The expected negative impacts are obtained in terms of physical damage, economic losses as percentage of reconstruction costs and social losses (shelter needs, number of injuries and casualties).

2.1 Seismic hazard

An algorithm has been developed with specified magnitude, distance and hypocenter depth as input parameters. It applies the latest generation of ground-motion prediction models, e.g. AA13 GMPE (Atkinson and Adams 2013), for reference response spectral accelerations on stiff soils. It provides the needed peak ground acceleration value (PGA) and 5% damped spectral accelerations at periods of 0.3 and 1.0 s (Sa0.3 and Sa1.0) as IMs at the centroid of each census tract. Probabilistic scenarios are conducted using the embedded national database with specified return periods as suggested by seismic hazard maps of the 2015 National Building Code of Canada (NRCAN 2015, NRC 2015).

2.2 Inventory

ER2-Earthquake draws upon provincial datasets from the Hazus Canada database (Ulmi et al. 2014). Specifically, the application uses population and dwelling data aggregated at the level of the census tracts. The needed information consists of parameters related to the structure (location, year of construction, square footage, number of stories, design code) and occupancy type (residential, commercial, industrial, agricultural, governmental).

2.3 Vulnerability

Central to the vulnerability analysis is the concept of a fragility curve assumed representative for a group of buildings with similar structural properties (FEMA 2012). Fragility curves combine the expected damage states of the given building type to a particular IM. The building damage estimates are determined as probabilities of being in each damage state. They are then translated into direct economic losses expressed as percentages of the replacement costs of buildings. Direct economic losses are estimated based on the concept of damage factors (DF), which correlate the cost of repairs for each damage state (i.e. slight, moderate, extensive, and complete) to the replacement cost of the building. The respective mean damage factor (MDF) is then computed as the ratio between the expected repair cost value and the replacement cost of the building. Direct social losses are estimated in terms of the expected number of injuries and fatalities.

2.4 ER2-Earthquake Web Implementation

Background data includes seismic scenarios, inventory of buildings and vulnerability databases that are stored on a dedicated server for the current version of the application. Data retrieval process and selection of the different options are accompanied by intuitive on-screen prompts that guide the user through different functionalities. The vulnerability database includes 128 building classes subjected to 100 earthquake scenarios with combinations of magnitude (M5 to M8), distances (R10 to 60km) and site classes (A to E) for a total of 12,800 fragility sets. Application of ER2 is illustrated for a hypothetical earthquake event within Quebec City limits. It starts with opening of a new simulation dialog box. It provides an easy way to navigate the map and to prepare the planned scenario (Figure 1a). For simple point source scenario, single clicking on the map selects the epicenter location (Figure 1b). Here, the point source is located about 7 km from the Old Quebec City. A magnitude M6.0 is selected with hypocentral depth of 10km. The studied region is auto-determined with a corresponding radius (e.g., 50km) adjusted to the boundaries of the affected census tracts. The closest distance to the centroid of census tract is measured and applied in the calibrated point source model of the GMPE to obtain the IMs of the considered scenario. For probabilistic scenarios, the user clicks on the map to choose the location of the center of the study and selects the return period (Figure 1c). For the illustrated scenario, a return period of 2 475 years, or 2% in 50 years, is selected. The needed IMs are retrieved directly from the stored database of each return period. The red "Run" button initiates the simulation. Within the study area in Eastern Canada, all IMs are adjusted for the local site conditions. The application then automatically retrieves the aggregated inventory data across each of the affected census tracts and determines the damage states and the corresponding economic and social losses of existing building types with respect to the IMs. Following the completion of the analyses, the user is prompted to select and display the resulting map layers and simulation statistics for the entire study area (Figure 1d) where the aggregated direct economic losses on the census tract level are shown. The tool can also show more details related to the scenario for a specific census tract (Figure 4e,f) including the shaking intensities, direct economic loss, number of buildings in each damage state (no damage, slight, moderate, extensive, complete) and the number of injuries and fatalities. The user has the option to download and save the analysis results and summary reports.

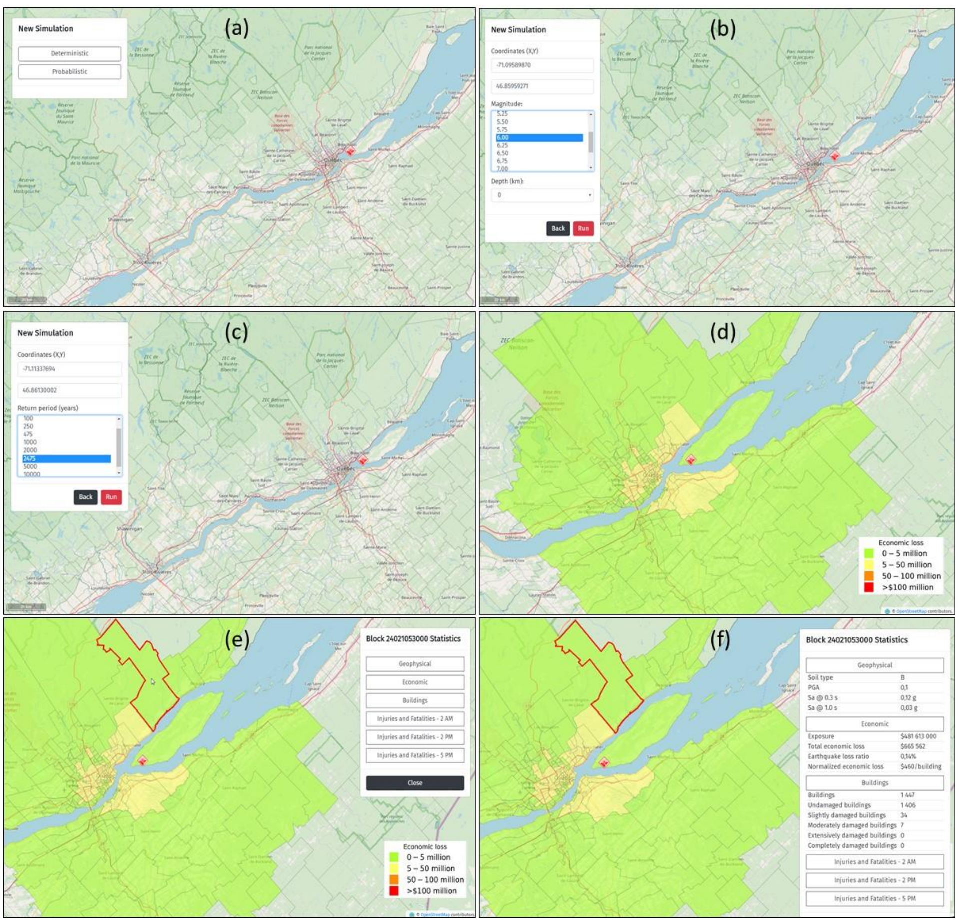

Figure 1. Example of ER2, running a M6 with 10km depth point source seismic scenario for Quebec City and respective results. The epicenter location is indicated with a red rhombus.

3 CONCLUSIONS

In this paper, a prototype web-based application for natural hazard risk assessment has been presented and the modules described. The ongoing and proactive efforts to develop the interactive web-application for seismic risk assessment tool, ER2, were presented. One of the goals of these developments is to facilitate informed decision-making and offer simplified access of the public safety community to estimates of potential physical damage, economic and social losses resulting from seismic hazards. The considered seismic risk assessment process involves the quantification of the three major input components: seismic hazard, inventory of assets at risk and respective vulnerability, and of the resulting negative impacts. The seismic hazard is defined with the earthquake magnitude, focal distance and the different types of local soil conditions at a particular location. The assets at risk, in this case, are the buildings combined with the population present in the affected area. The vulnerability represents the physical, economic and social susceptibility to damage. The probabilities of structural and non-structural damage potential are computed as a direct function of spectral accelerations at 0.3 and 1.0 seconds. The expected degree of damage and loss are obtained in terms of physical damage, economic losses as percentage of replacement costs and social losses are determined with the number of injuries and fatalities. Equipped with graphic user interface, ER2 web-application allows non-expert users from the public safety community to run otherwise complex seismic risk scenarios through a simple intuitive process.

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