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Rapid seismic risk assessment

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ABSTRACT

This paper deals with seismic risk on the Croatian territory, especially since population growth in risk-prone areas increases the potential loss due to an earthquake. The net effects of such urbanization factors are examined through the use of simulation models that estimate building inventory under possible seismic hazard expressed with peak ground acceleration. A case study of seismic risk assessments is illustrated using Croatian cities to give an overview of the overall relative risk in Croatia as developing country using general parameters from Census data. Results of a prospective analysis indicate that, for the same seismic event, the overall risk is expected to increase due to growth of population in pre-code building inventory and populated areas and cities. This relative rapid assessment presented in this paper points out which cities need detailed analysis and enables city planners to incorporate seismic risk analysis into pre-disaster emergency and land-use planning to encourage risk-reduction strategies. The validation of proposed assessment was done on L'Aquila Province based on data after L'Aquila earthquake 2009. Results indicate prediction of realistic risk for the study area based on vulnerabilities of buildings and exposure of population with relative errors of 12% and 8% respectively.

1. Introduction

An increasing number of rapidly growing urban areas are becoming more vulnerable to seismic risk in their development process [20]. The concept of risk has been introduced in disaster management and suggests that elements at risk and vulnerability should be taken into consideration in the framework of hazard and disaster management in order to reduce losses [3]. During the 20th century, more than 1100 strong earthquakes have occurred, causing more than 1500,000 casualties- most of them due to buildings collapsing, which is some 90% of direct deaths [24].

For urban zones, exposure to possible large earthquakes, certain preparedness and emergency procedures have to be organized in the event of and prior to an earthquake. Incorporation of seismic risk of facilities into a decision making framework needs procedures to quantify such risk for stakeholders. Since the quantification of the earthquake effects on the physical and social environment is required, the main element of such quantification is the building losses, which is directly related to casualties, planning of emergency response, first aid and emergency shelter needs.

According to Ramirez and Miranda [32], Homethere is one aim of current building codes: to protect life-safety and do not contain provisions that aim to mitigate the amount of damage and economic loss suffered during an earthquake. Performance-based earthquake engineering (PBEE) seeks to improve seismic risk decision-making through assessment and design methods [27]. In the case of new buildings, the basic configuration and design criteria needed to prevent catastrophic failure are well known, but the majority of the existing buildings in seismic environments do not satisfy modern code requirements. One of the possible ways for seismic risk reduction in urban areas is known building inventory and population data for earthquake-prone areas.

The evaluation of seismic risk generally includes data collection, seismic hazard assessment, vulnerability assessment as well as discipline of social and economic sciences. Seismic risk is described as the probability of loss at a given site and obtained through the convolution of exposure, vulnerability and seismic hazard [14]. Exposure is defined as the amount of human activity located in the zones of seismic hazard as defined by the stock of infrastructure in that location; hazard is defined as the probability of a certain ground motion occurring at a location; vulnerability is defined as the susceptibility of the infrastructure stock [15].

According to Villacis et al. [40] general characteristics and uses of earthquake scenarios for earthquake risk evaluation should vary depending on whether they are prepared for cities in developed or developing countries.

Developed countries have resources for accurate quantification of the expected damage with detailed risk analysis with precise description of the actions that are implemented in organization of risk management of threatened cities. However, developing countries, like

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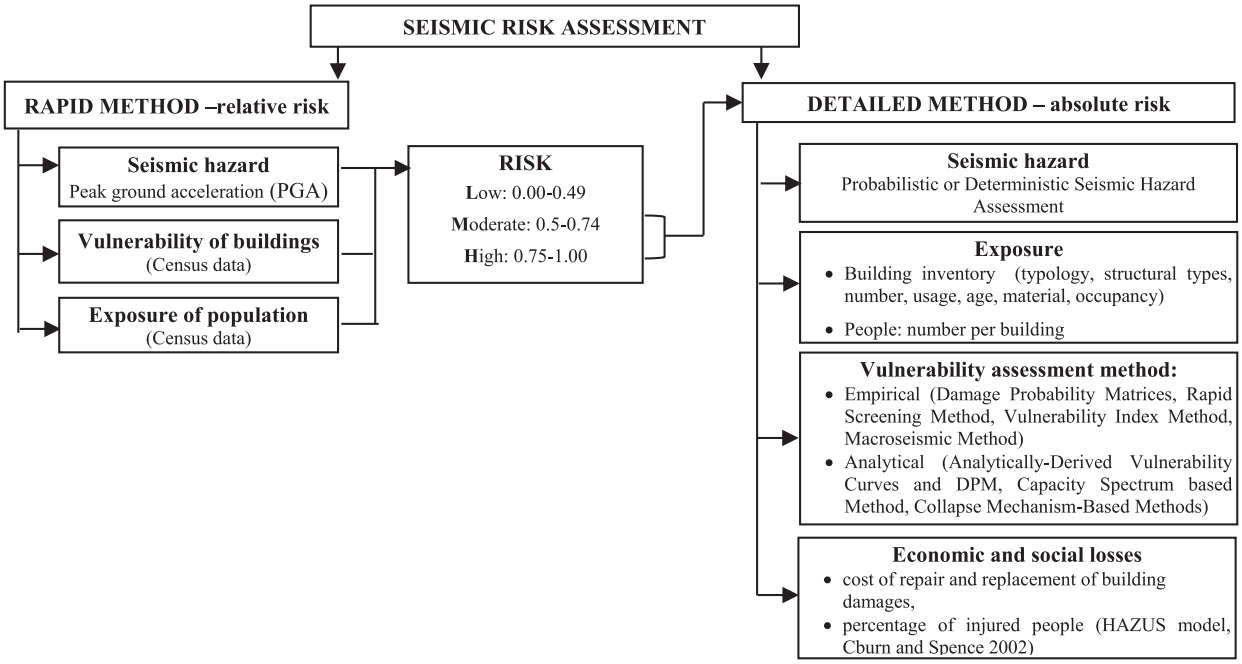

Fig. 1. Overview of seismic risk assessments: rapid vs. detailed.

Table 1
Cities with PGA $\geq 0.3g$ and $F_H > 0.98$.

City	PGA (g)	County
Imotski	0.33	Split-Dalmatia
Vrgorac	0.33	Split-Dalmatia
Dubrovnik	0.3	Dubrovnik-Neretva
Metković	0.36	Dubrovnik-Neretva
Opuzen	0.36	Dubrovnik-Neretva
Ploče	0.34	Dubrovnik-Neretva

Croatia, have very limited resources and available data with no earthquake disaster preparedness.

Accordingly, for a developing country that does not have the resources to implement all the measures in all the cities, reduction of earthquake risk at local (municipality) level is unnecessary. Therefore, at first stage, identification of problem and raise of awareness toward the social and political context for cities that are possibly threatened can be implemented by rapid relative earthquake evaluation of seismic risk, as it is proposed in this paper.

The main idea of this assessment was based on previous research done by Carreño et al. [11] and Salgado-Gálvez et al. [38] where urban seismic risk with holistic approach was developed. Foremost Cardona [8] developed a conceptual framework from a holistic or multidisciplinary approach for the seismic risk analysis of urban centers. In this method, where the risk by means of indices is achieved affecting the physical risk with an impact factor, available data about socioeconomic fragility and the lack of resilience at urban level are necessary [11].

The concept of evaluation of urban seismic risk by means of indices and based on set of factors that aggravate the physical risk, the calculation of aggravating factors using transformation functions and the calculation of weights which represent the relative importance of each factor by means of the Analytic Hierarchy Process (AHP) is the basis on which we based our method, e.g. the holistic approach developed by Cardona [8] and then continued in works of Carreño [10] and Carreno et al. [11]. However, application of this concept on new urban area requires a large number of data that are not available in all countries. Therefore, a Rapid relative seismic risk assessment is an adaptation on previous methodology that can be obtained for every country, especially developing, based only on statistical Census data for buildings and population.

The major objective of the study can be stated as:

- To develop an assessment for rapid prediction of seismic risk for an observed region based on general risk inputs: hazard data, building age data, population data.
- To explore and validate the possibility of using the developed methodology for a different region.

2. Seismic risk assessments: rapid vs. detailed

There are several state-of-the-art approaches for seismic risk assessment ([31], Hazus) and several assessments for large cities and countries in last few years [cities: Athens, Greece [17]; Almeria-Spain [33]; Barcelona-Spain [1]; Cologne-Germany [39], Lisbon-Portugal [28], Medellin-Colombia [36], Hsinchu City-Taiwan [20], Nepal [12]. All of them are detailed analysis that required a large amount of various input data, which is impossible to collect in many developing countries. Accordingly, development of rapid seismic assessment is preferable for efficient pre-disaster emergency.

Villacis et al. [40] implemented fast earthquake scenarios for risk management in developing countries, where very limited resources, data, and, in most cases, very short histories of earthquake disaster preparedness are available. They provided fast earthquake scenarios to identify the main factors contributing to the earthquake risk of cities in developing countries. Currently, the methodology for fast earthquake scenarios is being utilized by the Risk Assessment Tools for the Diagnosis of Urban Seismic Risk (RADIUS) Project, with the main goal to determine the main factors that contribute to the earthquake risk of cities in developing countries.