Seismic hazard mapping using R-CRISIS

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Abstract. This article presents methods and software used to develop a seismic hazard map. As an example, the territory of the Republic of Moldova is being studied, which is affected by subcrustal earthquakes of medium depth in the Vrancea seismic area. The elaboration of the map is based on the theoretical model of probabilistic seismic hazard assessment established and described in detail in the specialized literature. In order to facilitate and minimize errors, specialized software was used, one of this software is R-CRISIS, a software created and presented for premier in 1986 by Professor Mario Ordaz at the Institute of Engineering UNAM, Mexico and which is continuously being developed and improved. R-CRISIS allows the users to perform a big range of deterministic and probabilistic analyses through a user-friendly interface.

1. Introduction

Natural hazards represent a real challenge not only for engineers, but for entire society as well. In order to manage and have a good emergency management policy in case of natural catastrophe, every country relies on different kinds of documents, statistics and maps. In this paper is presented how a seismic hazard map could be developed using specialized software. A hazard map represents graphical delimitation of affected or vulnerable areas to a particular phenomenon. As for seismic hazard map, the definition remains unchanged, only the phenomena are known – earthquake; so, one can state that a seismic hazard map is a graphical representation of a particular territory that is divided in small areas where the ground shaking, caused by earthquake, have the same behaviour and characteristics. Ground shaking is defined in terms of some parameter, usually peak ground acceleration (PGA), spectral acceleration or macroseismic intensity (e.g., EMS-98) [1].

1.1. Uses of seismic hazard maps

Generally speaking, hazard maps could be divided into two groups: maps for regulatory purposes and maps for information purposes.
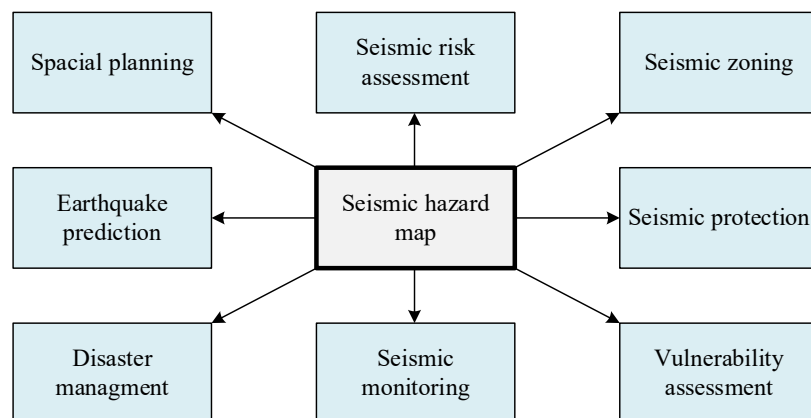

Figure 1. Applicability of seismic hazard map [2]

1.2. Seismic hazard evaluation

In present there are two methods of seismic hazard assessment: probabilistic seismic hazard assessment (PSHA) and deterministic seismic hazard assessment (DSHA). DSHA is a method for estimating location-specific seismic hazard that is affected by the maximum earthquake from the controlling sources that can influence the specific location. Probabilistic seismic hazard is detailed described in [3,4,5,6,7]. PSHA for a site is developed considering all ground motions that can occur in the specified seismic zones of any possible magnitude and/or any possible distance between source and site. The main advantage of PSHA is that it combines all of accidental uncertainties that comes from the analysis of seismic zone parameters from a future earthquake at particular site [6]. PSHA provides a probabilistic approach of a characteristic unit such as ground acceleration.

One should understand that the mapping process is the last step in hazard assessment. In order to get to this final level, we need to perform a seismic hazard assessment.

2. Software R-CRISIS

R-CRISIS is a software that works on Windows Operating System and has capability to carry out probabilistic seismic hazard analysis using a fully probabilistic approach [8]. The first version of software was issued in 1986 by Professor Mario Ordaz - the lead author and was software with a command line interface developed in FORTRAN [8]. In 2007 the program was upgraded and now provides a user-friendly environment to perform seismic hazard assessment. R-CRISIS software is logically organized in six main tabs: File, Input, GMPE Analyzer, Run, Hazard and Tools.

The work in this software can be described in few steps as follows:

- **Adding Map Data** – at this step user should have a reference map in *.sph shapefile format of region that is analysed. It should be pointed out that R-CRISIS uses the World Geodetic System 84 (WGS-84) projection system and does not make any changes of coordinate projection. In addition to the map, the program offers user to add a text file with cities that could be subjected to hazard assessment (see Figure 2).
- **Computation Site Data** – is used to define a site where the PSHA is computed. Computation can be performed for a grid with a given step or for a specific site and output is required in terms of hazard curves (see Figure 3).
- **Source Geometry Data** – intend of this panel is to provide a fast and easy way of inserting the geometry of seismic sources. Various geometric models are realized in R-CRISIS software that characterize seismic sources. In this article will be used area-plane sources that are inserted as a set of vertexes which create a plan. Line, point and grid sources are available also (see Figure 3).
- **Spectral Ordinates Data** – in this window user can define number of spectral ordinates and their fundamental periods (see Table 1)
- **Seismicity Data** – for each seismic source defined in *Source Geometry Data*, user should specify seismicity parameters. R-CRISIS, by default, assigns modified G-R seismicity model to each source (see Table 2).
- **Attenuation Data** – in R-CRISIS, ground motion prediction model could be added from a pre-defined list of existing attenuation laws or could be used a custom *.atn file, created by user.

2.1. Adding Map Data

For map data, authors had prepared 2 types of file to add in software:

- A shapefile (*.shp) of Republic of Moldova in WGS-84 system of coordinates;
- A text file (*.txt) with 5 biggest cities as follows (Name of state, name of city, longitude, latitude):
  - Chisinau District, Chisinau City,   lat *N* 47°0′59″ and long *E* 28°52′0″.
  - Balti District, Balti City,   lat *N* 47°45′41″ and long *E* 27°55′44″.
  - Cahul District, Cahul City,   lat *N* 45°54′18″ and long *E* 28°11′47″.
  - Stefan-Voda District, Stefan-Voda City, lat *N* 46°30′55″ and long *E* 29°39′47″.
  - Edinet District, Edinet City,   lat *N* 87°10′14″ and long *E* 27°18′15″.