Review and Systematization of the Available Data for Earthquake Risk Mitigation in Bulgaria Using GIS

Lyubka PASHOVA, Mihaela KOUTEVA-GUENTCHEVA, Temenoujka BANDROVA, Bulgaria

Keywords: Natural Hazards, Seismic Hazard, GIS

SUMMARY

The territory of Bulgaria is exposed to numerous natural hazards. Among the various strong geological hazards (landslides, earthquakes, erosion and sea processes, loess collapsibility due to shallow ground water and liquefaction sands) manifested and mapped for the territory of Bulgaria, a key role is assigned to the earthquake risk mitigation in the National Natural Disasters Mitigation Strategy. Seismic hazard reflects unpredictable natural process that could cause significant negative consequences, even fatalities among the population, property and infrastructure damages. Reliable risk assessment due to seismic hazard and its relevant reduction require an adequate disaster risk management approach. The integration of the numerous data sources and tools that are available at various levels of government authorities, academia and the private sector is one of the major tasks in conducting the earthquake risk estimation and a major component of the multi-hazard risk assessment towards natural hazard mitigation. Following the priorities stated in the Bulgarian Disaster risk reduction strategy (2014-2020), which is closely related to the European Horizons 2020 program priorities, this paper aims to illustrate the use of an integrated approach for systematization of the freely available information for earthquake risk mitigation in Bulgaria. Results of a comparative overview of the data (digital and hard copy maps, statistics, etc.) that might be used for earthquake risk mitigation using GIS are presented. This effort has been a part of the university UACEG-CNIP research project dealing with a conceptual model for information system for express expert evaluation of the earthquake risk over the Bulgarian territory using GIS. Selected GIS layers will be the initially set of collected maps describing the earthquake hazard available from various sources and maps of different elements exposed to risk, particularly created maps related to the building stock, population in major cities, health institutions, construction business statistics, and infrastructure. Major challenge within this effort has been combining the heterogeneous data necessary for further estimation of the earthquake disaster indices. These data have been collected from various available sources with different formats, size, standards and precision. Wide-ranging data sets are gathered to be used by risk estimation procedure, relying on a holistic indices based approach for express expert seismic risk assessment. Further development of this idea as hopefully spread out at smaller scale of Administrative territorial units in collaboration with local administrations and the potential provided by technological web-based GIS innovation platforms, that increases the utility and importance of all data to allow a better decision-making at all management levels, are discussed too.

Review and Systematization of the Available Data for Earthquake Risk Mitigation in Bulgaria Using GIS

Lyubka PASHOVA, Mihaela KOUTEVA-GUENTCHEVA, Temenoujka BANDROVA
Bulgaria

1. INTRODUCTION

The idea for reliable risk assessment due to seismic hazard and the relevant disaster risk management using the contemporary computer aided tools follows the worldwide priority of disaster mitigation and disaster preparedness within the last several decades. The international community undertakes with establishing a global culture of prevention trough the UN International Decade for Natural Disasters Reduction (1990-2000), followed-up by the Hyogo Action Plan (2005-2015) and preparation of a post-2015 framework for disaster risk reduction. The territory of Bulgaria is exposed to numerous natural hazards. Among the various strong geological hazards (landslides, earthquakes, erosion and sea processes, loess collapsibility due to shallow ground water and liquefaction sands) manifested and mapped for the territory of Bulgaria, a key role in the National Natural Disasters Mitigation Strategy is given to the earthquake risk mitigation. The estimates, based on the Indicator Issues proposed within the framework for a Disaster Preparedness Index (DPi) by David M. Simpson and Matin Katirai in 2006, qualify Bulgaria as highly vulnerable country. Seismic hazard reflects unpredictable natural process that could cause significant negative consequences, even fatalities among the population, property, and infrastructure damages. Identification risk sources, risk elements and relevant data sources, available at various levels of government institutions, academia and private sector are the first major tasks in conducting the earthquake risk estimation and a major component of the multi-hazard risk assessment towards natural hazard mitigation.

Considering the Bulgarian Disaster risk reduction strategy (2014-2020), which is closely related to the European Horizons 2020 program priorities, this paper aims to illustrate the use of an integrated approach for systematization of freely available information for earthquake risk assessment in Bulgaria. Results of a comparative overview of the data (digital and hard copy maps, statistics, etc.) that might be used for earthquake risk mitigation using GIS are presented. This effort has been a part of the university UACEG-CNIP research project dealing with a conceptual model for information system for express expert evaluation of the earthquake risk over the Bulgarian territory using GIS (Kouteva-Gentcheva, 2015). Selected GIS layers will be the initially set of collected maps describing the earthquake hazard available from various sources and maps of different elements exposed to risk, particularly created maps related to the building stock, population in major cities, health institutions, construction business statistics, and infrastructure. The intelligent possibilities for earthquake risk mitigation, based on up-to-date seismic risk estimation, is fully in line with our contemporary concern for safe society and sustainable development, and it is particularly important for the present day urban sprawl processes.

Seismic risk assessment, mitigation and management are closely tied with the spatial data compatibility. Directive 2007/2 of the the European Commission for establishing an INfrastructure for SPatial Information (INSPIRE; http://inspire.ec.europa.eu/) aims to build a main framework of developing Spatial Data Infrastructure (SDI) and to underpin rapid global access, sharing and exchange of geospatial information that support the informed decision-making and more effective action of all spheres of public life. The process of INSPIRE Directive implementation depends on the coordinated actions at the national, regional and global levels, as well as within individual organizations, in both the public and private sectors. INSPIRE Directive implementation related to Seismic risk zones are given in Annex III, Theme 12 – Natural risk zones (INSPIRE Data Specification on Buildings, 2013). Its main objectives are to produce seismic risk zones based on a methodology that shall take into account both hazard and vulnerability, and which shall be tuned on the specific conditions.

Maps have the potential to improve the disaster management process. They can resolve many perception problems and provide more clearly presented information, especially when 3D disaster information is presented on the maps (Bandrova et al, 2012). The map for early warning and crises management should be flexible, adaptive and prepared with respect to the context of the users, the type of disaster (e.g. earthquake), and the phase of disaster management. The research on these topics requires integrated efforts of researchers from many different disciplines, including cartography, computer knowledge, cognitive science, computer graphics, and human-machine interaction.

In this paper a conceptual model of integrated information database is introduced along with its components. It is followed by a comparative overview of the data (digital and hard copy maps, statistics, etc.) that might be used for earthquake risk assessment using GIS environment. Generalized scheme of the data organization process in GIS using free available data and thematic maps gathered in the framework of the university research project along with findings produced is presented. Further, discussion section containing comments on implications, limitations and future research directions and final conclusions are provided.

2. THE EARTHQUAKE RISK CONCEPT

The concept of risk can has variable meanings depending on the context either qualitatively or quantitatively. The most common definition of risk states a qualitative measure of the risk as a product of likelihood an event and consequence (Ansell and Wharton, 1992; FEMA, 2004). A quantitative definition of risk considers risk as a product of "V = vulnerability", "H = hazard" and "E = exposed elements or assets" in the equation $R = H \times V \times E$, proposed by Varnes (1984). This expression has gained international acceptance according to UNDRO (1982) and is adopted by FEMA (2004). Thus the seismic risk is understood as interaction between earthquake hazard, vulnerability of the society and exposure. United Nations/International Strategy for Disaster Reduction (UN/ISDR), for example, defines vulnerability as the "conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards'' (UN/ISDR, 2004). Considering the contemporary accepted statement that the risk management is associated with "the reaction to perceived risks", the seismic risk might be understood as product of hazard, vulnerability, exposure and capacity measures as shown in Figure 1 (Vahdat and Smith, 2010).

Traditionally, a wide range of techniques is available to estimate the seismic risk, regardless of their capability, effectiveness and degree of uncertainty. Among these techniques two major groups might be distinguished: (i) Conventional Methods, based on the predicting probable losses to a given element at risk over a specified time frame and (ii) Holistic Models, based on modelling characterisation of the risk sources through a multidisciplinary approach. Since the conventional methods target a limited audience, holistic models are suggested to cover different range of applications. Holistic models are referred to ways of describing risk as product of multiple factors in a given indicator system. These approaches are based on a common theory, which considering the qualitative seismic risk defined by the equation R = H x V x E. Moreover, all the approaches aim to measure risk and vulnerability through selected comparative indicators in a quantitative way in order to be able to compare different areas or communities (Davidson and Shah, 1998; Vahdat and Smith, 2010 and references in). In general, the risk estimation procedure starts with defining the scope of analysis and the corresponding indicators that may contribute for the risk's elements. Afterwards, a mathematical combination is employed for scaling different range of indicators and the relative importance of indicators contributing in risk is computed. The combination of scaled indicators could generate seismic risk indices which can be implemented in final stage of the procedure. The hierarchical structure of data in the common holistic concept (Birkmann, 2006) is shown in Figure 1. A quantitative measure of risk is not always possible due to a lack of data, as in this case; therefore a qualitative assessment can be applied based on expert opinion.

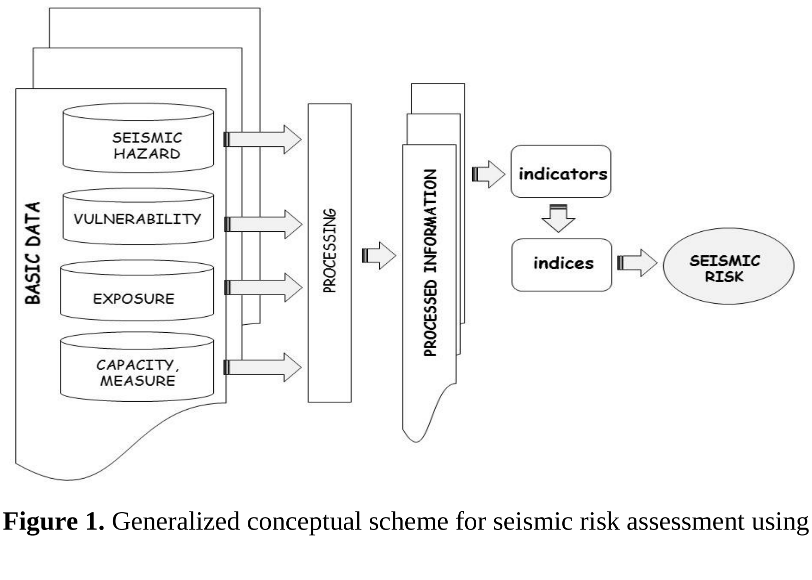


Figure 1. Generalized conceptual scheme for seismic risk assessment using holistic approach

3. CONCEPTUAL MODEL OF THE INTEGRATED INFORMATION DATASET

The present integration information dataset has been collected within the framework of the BN 164/14 UACG research project. The aim of the project is to explore and gather free available data as basic data for seismic risk assessment. Currently, in Bulgaria, still there are some difficulties in collecting, analyzing, reconciling and visualization of heterogeneous data that are scattered and the access to them often is limited. Limited access to geo-databases, lack of established National Spatial Data Infrastructure (NSDI) and relevant legal and other administrative regulatory mechanisms, undeveloped market relations in Bulgaria are extremely limiting circumstances for full usage of geoinformation (Pashova and Bandrova, 2013). These facts are reflected in a reluctance to share data and restricting access to them, included by the public institutions that are required to collect, preserve and publish relevant data already paid with public funds. Beside the specific problems related to the completeness, security, formats / standards and reliability of the geospatial data, the lack of national policy for overall management and full use of the geoinformation from the state authorities and the society is the main problem till now.

Different geo-datasets and particular information dealing with seismic hazards exist. They are maintained by different governmental, research and other institutions on national, regional and municipal level (Pashova et al., 2010). One of the typical problems, not only for Bulgaria, is the deficiency of expert knowledge for assessment and linkage of heterogeneous datasets or their appropriate visualization. Diversity in the sources, content and quality of data, their effective using and the information management are the factors which have to be considered in the development of a conceptual model of the information database for seismic risk assessment. Often, multiple versions of the same datasets exist as various institutions and authorities maintain and manage them differently. In this way overall seismic risk analysis and assessment is additionally hampered. In the process of collecting datasets and information from various sources, several difficulties arose in the initial analysis of the available maps and other materials. They can be grouped as follows:

- More than 15 maps and several atlases, including those for seismic hazard, are at various scales (sometimes it is not marked on the map), in different epochs, and from different producers;
- In many cases, the same data can be represented on the similar thematic maps but in different scale. When a map from one scale is reproducing in another, the final result may differ mainly because of vague map projection and due to not respecting the rules of cartographic generalization;
- Lack of professional qualitative and quantitative evaluation of the specialized content in the process of map preparation and their printing;
- Various map producers with or without a staff, which has professional cartographic knowledge and skills;
- Different way of retrieving information for elements of the map content, which maps are already published (by scanning and georeferencing or by digitizing);
- Several discrepancies were discovered in administrative borders (regional and municipal boundaries), road and railway networks, infrastructures, digital elevation models with different size of grid cells, and many others;

- In the process of combination and overlaying raster maps through the georeferencing tools some additional errors due to insufficient and / or unclear information, associated with different map coordinate system, scales, symbol system, accuracy, cartographic experience, etc. can be introduced.

For the purpose of our project geographic content (administrative boundaries, human settlements, train and roads networks), seismic hazard data, geology, building stock, demography, business and communication infrastructure were identified as primary categories. Furthermore, specific items were identified within each of these categories. The conceptual scheme of the collected data integrated in the project information database is shown in Figure 2.

The proposed conceptual model of information database for the purposes of express expert earthquake risk estimation consists of five thematic modules and one common “basic” data module. The multiple datasets modules contain specialized texts, maps, graphs, data tables in specific formats. The conceptual model of the information database provides functionality for input, processing, analysis and visualization of assisted elements-at-risk mapping in GIS environment. Direct Hazard presents the frequency and severity of ground shaking, to which each local area will be subjected, and the probability and extent of taking place such geological damages as ground failure, slide, and rupture caused by an earthquake in each local area. Collateral Hazard describes the frequency and severity of taking place those collateral disasters such as fire, dangerous materials release, landslides, flood, tsunami and plague in each local area. The exposure refers to all man-made facilities (e.g. buildings, infrastructure), population, economy, and the amount and type of activities associated with them in each local area, which will be affected by an earthquake. The vulnerability describes how easily and how severely the exposure of each local area can be affected by an earthquake. The conceptual scheme of the prevised comparative analyses of the collected data is shown in Figure 3. Some results of this processing are shown and discussed further in the paper.

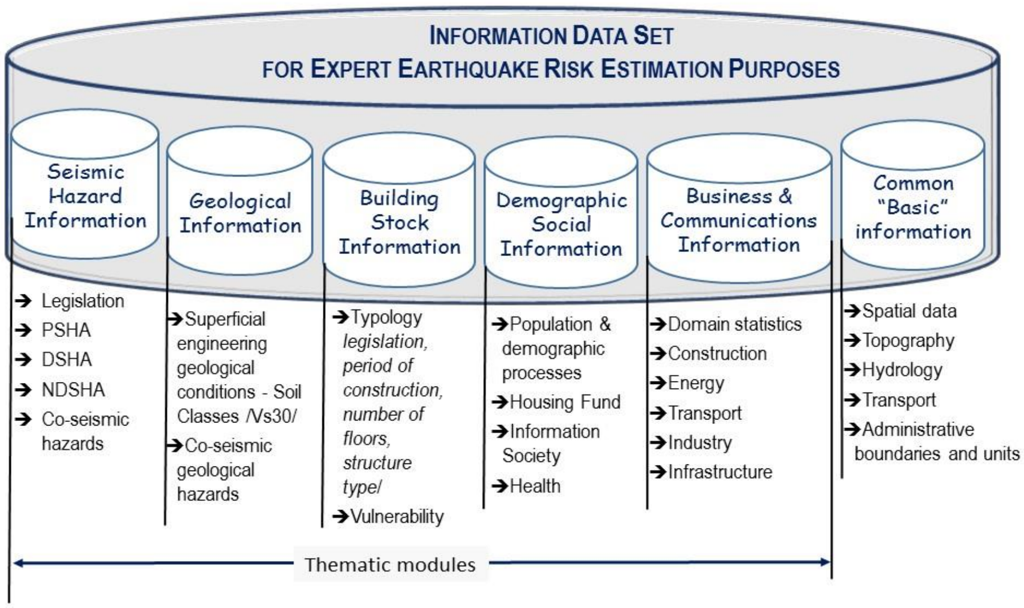


Figure 2. Conceptual model of integrated information database

3.1 Module 1: Seismic hazard and seismic action

The Seismic Hazard and Seismic Input Dataset contains mapping materials available from the official legislation documents for seismic resistant design in Bulgaria, as well as recently

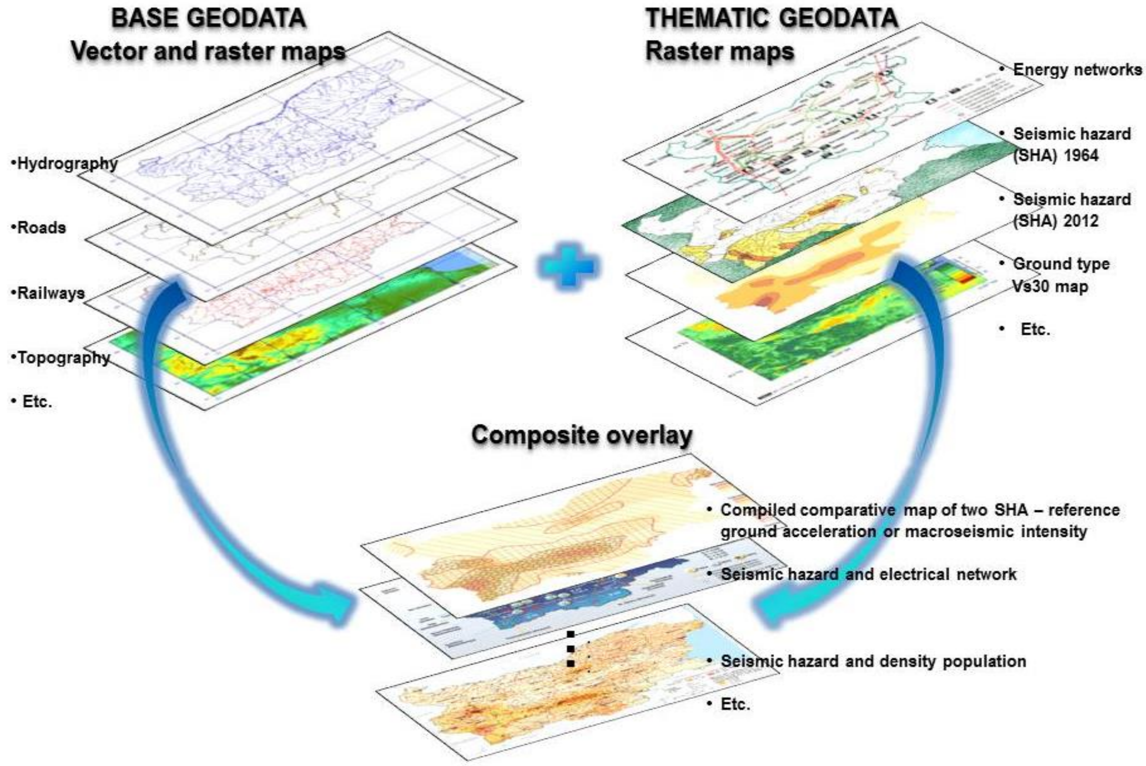


Figure 3. Conceptual scheme of the prevised comparative analyses of the collected datasets

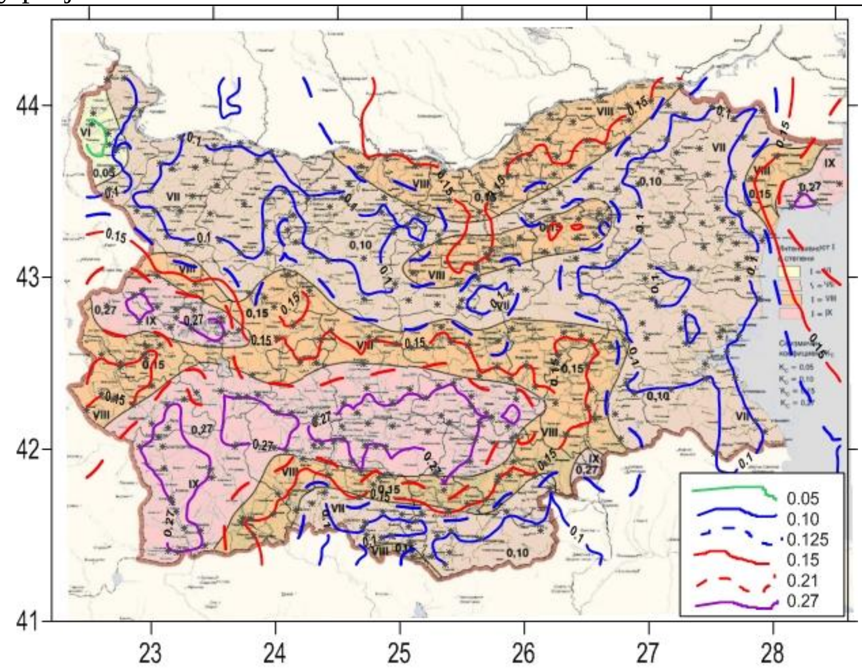
published Seismic Hazard Estimations for the Bulgarian territories, based on Probabilistic Seismic Hazard Assessment – PSHA (Simeonova et al., 2006), Deterministic SHA (CEI project 1202.136-07, 2008-2009), and Neo-deterministic SHA (Panza and Vaccari, 2000).

The comparative analysis of the maps in the current and past legislation documents for Design and Construction in Seismic Regions has shown that the development of legislation for earthquake resistance of buildings and facilities has followed the scientific knowledge development regarding the seismic hazard. Each successive revision of the building norms over time is characterized by a gradual increase in the size of the territories in which it is necessary to provide more strong seismic resistance. Currently in Bulgaria two regulations are in force: (a) Ordinance № RD-02-20-2 from 27.01.2012 for design and construction in seismic areas and (b) the Eurocodes system - EN 1998-1:2004 and BDS EN 1998-1:2005/NA: 2012. In these documents the seismic action is represented by maps of ground acceleration for different return periods and response spectral curves associated with different ground types. PSHA (Simeonova et al., 2006) provides maps in terms of peak ground acceleration and macroseismic intensity MSK-64. Maps of peak ground acceleration, velocities and displacements were published as result of the NDSHA (Panza and Vaccari, 2000). Revised macroseismic intensity map due to the strong Vrancea earthquakes become available as result of the CEI project 1202.136-07, 2008-2009. So far, all the data are available in the literature in raster format. Graphical comparisons of the reference ground acceleration maps published in Ordinance № RD-02-20-2 and BDS EN 1998-1:2005/NA:2012 was recently published by Kouteva-Guentcheva & Pashova (2015). This comparison has been only qualitative due to: (i) different levels of mapped ground acceleration in those maps, as stated in Hristoskov et al (2006); (ii) lack of access to the digital data; and (iii) insufficient published discrete data to reconstruct the maps. The provided graphical comparison indicated higher reference ground acceleration for the southwestern and south-central part of the country in the maps, that have been published in BDS EN 1998-1:2005/NA:2012. Mapping scientific curiosity pushed us to try again to prepare these maps (*not shown here*) using the published tables with discrete values of acceleration at selected points. The results are plotted in figure 4a. Using those data and modern geostatistical method of interpolation, it was not possible to reproduce the Ordinance № RD-02-20-2 map. In fact, this map was published in 1987 and most probably it was prepared using manual data interpolation and expert knowledge. We also face difficulties to redraw the BDS EN 1998-1:2005/NA:2012 map since no information has been published about the mapping data processing.

3.2 Module 2 : Engineering geology

The seismic action for engineering analysis purposes in Bulgaria encompasses the seismic hazard with choice of particular response spectra depending on the geographical location and the ground type of the construction site. The numerical values of the V_S^{30} parameter (average shear-wave velocity in the upper 30 m at a given site) are used in the BDS EN 1998-1:2005/NA:2012 to distinguish different ground types. The shear-wave velocity values are generally determined by local geological studies through traditional measurements made in boreholes. As it is expected such data are not available for large territories. Currently the only possibility to map the V_S^{30} is provided by the internet on-line USGS V_S^{30} server (http://earthquake.usgs.gov/hazards/apps/vs30/), based on a preliminary assessment and mapping of this parameter using Digital Elevation Model, which was proposed by Wald and Allen (2007, 2009). Maps must be used with great care, since mapping of local geological conditions in large scale can lead to significant error in the seismic action definition as basic input data for the seismic risk assessment, but on the other hand such information is very useful for the first order risk estimates. These data are available on a 3” x 3” grid cells. Rather raw map of the superficial engineering geological condition on a 12’ x 12’ grid cells, following the ground type classification provided by Trifunac and Brady (1975) was published in 2001 (Paskaleva et al., 2001). The map is overlayed with the custom derived V_S^{30} map of seismic site conditions for the Bulgarian territory using topographic slope as a proxy (see Figure 4b). The values of coefficients for deriving the V_S^{30} map were chosen to be the mean values between those for active tectonic regions that possess dynamic topographic relief and for stable continental regions where changes in topography are more subdued. The coefficients choice is based on the geodynamical conditions in the South-European region (Shanov and Kostov, 2015). The data fit is acceptable with regard to the major ground categories – rock, intermediate soil and weaker alluvium soils, indicated respectively with 2, 1 and 0 in Figure 4b. Another raster map of some engineering-geological elements representing the rate of seismic waves was prepared and published by the Geological Institute at the Bulgarian Academy of Sciences in 1973 under the UNESCO project – Balkan seismicity project.

a) Overlayed map of seismic hazard map and interpolated isolinies from point acceleration values, marked with asterisk



b) Overlayed map of custom derived V_s^{30} map and superficial engineering geological condition given in (Paskaleva et al., 2001)

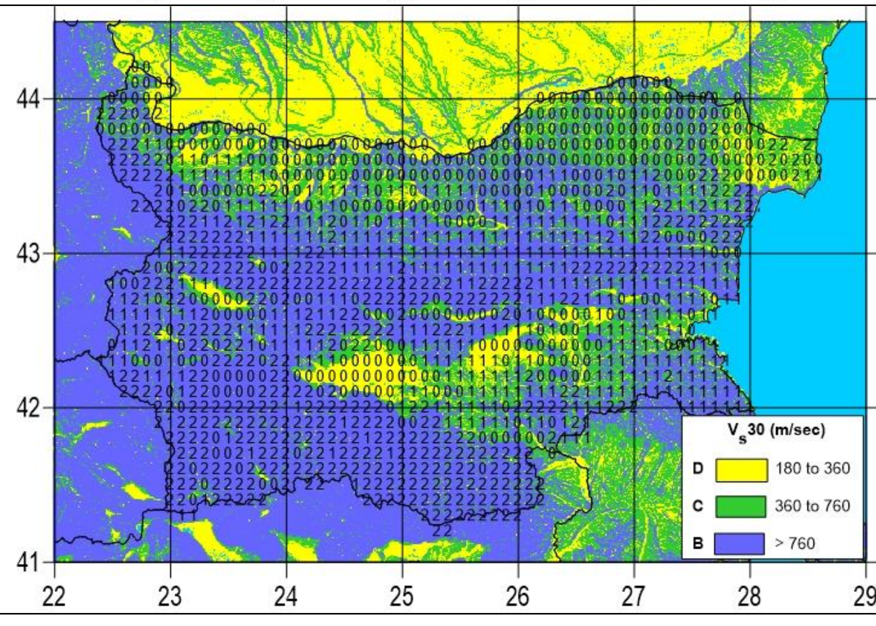


Figure 4. Two examples of compiled maps for the Bulgarian territory: (a) seismic hazard map given in Ordinance № RD-02-20-2 (2012); (b) engineering-geological elements.

3.3 Module 3: Building stock

This module contains data available from recent projects on seismic risk assessment, scientific publications and statistical published information. The INSPIRE Directive states the buildings' data as a key theme for environmental studies. The Buildings theme is a part of the reference data that is required in a Spatial Data Infrastructure to describe the landscape and for lots of mapping and communication applications. The data specifications are generated responding to the needs of user requirements in the areas of safety, environment, urban expansion and infrastructures (INSPIRE Data Specification on Buildings, 2013).

The TWG BU provides two kinds of semantic profiles: a normative core profile based on data widely available whose harmonization is required at European level (such as height, number of floors, building use and building nature, date of construction and number of dwellings, among others), and an extended profile based on data that is widely required but that is rarely available (material of facade, roof and structure, floors below ground, material of structure, official area). These data provide information describing the attributes of the elements at risk, in particular buildings, necessary for determining their vulnerability and associated fragilities. The harmonization of such data would allow intercomparable results from seismic risk analysis and loss assessment at regional and European level. Pursuant to the Law for Census of Population and Housing in the Republic of Bulgaria, in 2011 subject to the census are residential buildings. The collected information on existing buildings contains: type, location, number of floors, material of which the building is constructed, the availability of solar panels, year of construction, availability of a lift and number of dwellings in the building.

3.4 Module 4 : Demographic and social Statistics

This module is based on the data available from the National Statistical Institute (http://www.nsi.bg/). Several thematic maps are compiled – population and demographic processes, housing fund and information society (Marinova et al, 2015; *see this issue*). These maps confirm the currently ongoing process of urbanization and a downward trend in the population of working age. These factors will take a part in the earthquake disaster risk indices computing as a base for expert earthquake risk estimation. Information pertaining to the aforementioned items provides the greatest benefits when combined the existing seismic hazard maps with other information. We combined both two seismic hazard maps (Ordinance № RD-02-20-2; BDS EN 1998-1:2005/NA: 2012, T_R = 475) with the map of the population density published in Appendix II: Population grid 2011 of Bulgaria (Ahmedov and Dudova, 2014). The compiled map as a result of the latter comparison is given in Figure 5. The new thematic map, combined with the other results of the data processing, could allow the stakeholders to focus their attention on human settlements that have the greatest likelihood of victims and destructions.

3.5 Module 5: Business statistics

This module is also fully based on the data available from the National Statistical Institute (http://www.nsi.bg/). Thematic maps for two modules related to Building stock and Social statistics were prepared, and are published in this issue (Marinova et al, 2015; *see this issue*). A review of the used data has shown that the number of public and adminsitrative buildings under construction decreases significantly during the last years. Ascending trend of masonry residential buildings compared to reinforced concrete once is also clearly observed.

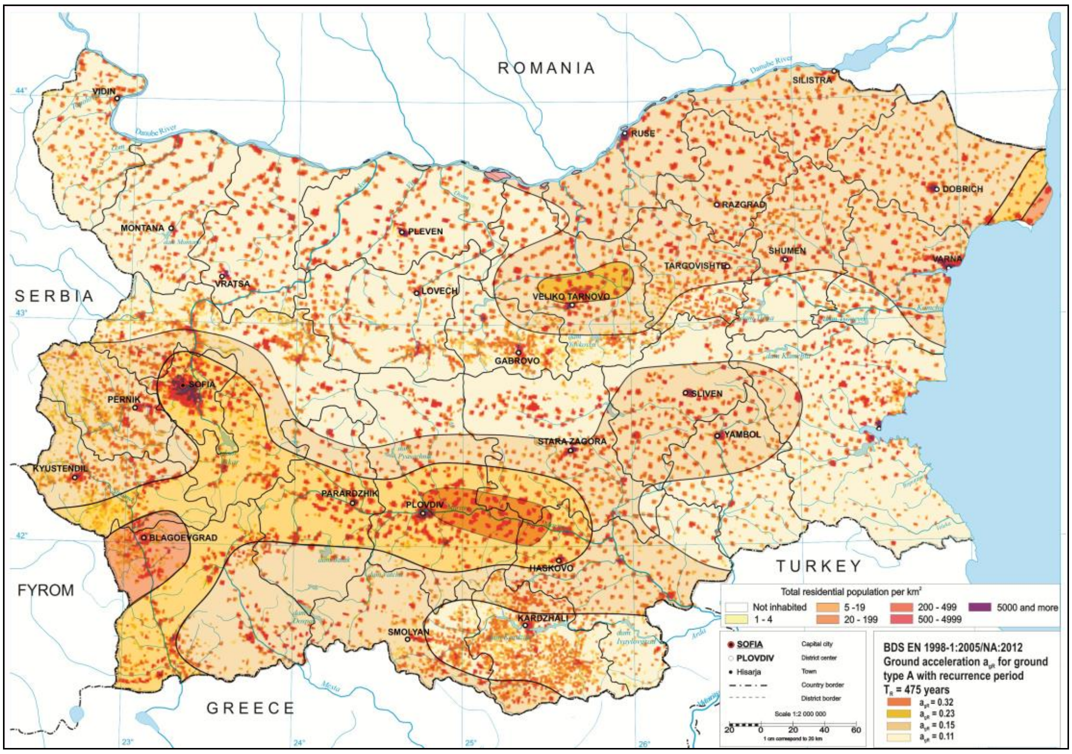


Figure 5. Overlap of maps of referent ground acceleration over the Bulgarian territory recurrence period T_R = 475 years, BDS EN 1998-1:2005/NA:2012 and density of total residential population in Bulgaria per km^2 (Ahmedov and Dudova, 2014)

3.6 Module 6: Common "basic" information

A number of spatial data themes dealing with geographical, environmental and infrastructure data have been identified. Due to many inconsistencies of the gathered maps mentioned above, the geographic information, which will be a basis for further comparisons between different maps in appropriate scale, was decided to be used. For the purposes of the UACEG-CNIP research project the Military Topographic Service provides free access to vector data type for the Bulgarian territory in scale 1:250 000. The data in shape format are as follow:

- State borders;
- Lakes and dams;
- Rivers and Danube River coastline;
- District boundaries;
- Settlements - by categories with a population of over 10,000 people;
- Classified roads - highways, roads I and II class;
- Railways - electrified and non-electrified, bidirectional and unidirectional.

Also, the digital elevation models from ASTER GDEM V2 (http://www.jspacesystems.or.jp/) and SRTM, ver. 3.0 (www2.jpl.nasa.gov/srtm/) which are publicly accessible will be used.

4. CONCLUSIONS

The assessment of seismic risk combines vast variety of information sources – from modern seismic hazard to the necessary geospatial information in broad temporal and spatial coverage. It becomes more necessary to improve sharing of information and to realize the need of serious collaborative multidisciplinary efforts to assess the available databases and their harmonization in accordance with national and European legislation. The presented results include the basic data of an information system framework. To build the model of such information system framework it is necessary to perform relevant actions for unification of maps format and attribute tables, organizing them in a common database of criteria for express expert risk assessment for large areas exposed to the seismic risk. Then, a building of the physical model in open source GIS environment is foreseen, combined with relevant adoption of the earthquake disaster risk index methodology for earthquake risk assessment. Future development of this work could be to integrate the described heterogeneous databases establishing this framework in a web-based GIS environment.

REFERENCES

Ahmedov, A. and I. Dudova (2014) Bulgarian population grid 2011. Geostatistics by mixed methods, Technical report WP1B.3 Dataset, 17p. http://www.efgs.info/geostat/1B/frontpage/appendix9-methodology-of-the-hybrid-approach-of-statistics-bulgaria.

Allen, T. I. and D. J. Wald (2009) Evaluation of ground-motion modeling techniques for use in Global Shake Map – A critique of instrumental ground-motion prediction equations, peak ground motion to macroseismic intensity conversions and macroseismic intensity predictions in different tectonic settings. U.S. Geological Survey Open-File Report 2009-1047, 114 p.

Ansell, J. and F. Wharton (1992) Risk: Analysis, Assessment, and Management. John Wiley and Sons, W. Sussex.

Birkmann, J. (2006) "Measuring vulnerability to natural hazards: towards disaster resilient societies", United Nations University Press:178-197.

BDS EN 1998-1: 2005 / NA: 2012: Eurocode 8: Design of structures for earthquake resistance - General rules, seismic actions and rules for buildings, National annexes. http://www.bds-bg.org/en/pages/page_71.html.

Bandrova, T., S. Zlatanova, M. Konecny (2012) Three-Dimensional Maps for Disaster Management, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., I-4, 245-250, doi:10.5194/isprsannals-I-4-245-2012, Melbourne, Australia, http://www.isprs-ann-photogramm-remote-sens-spatial-inf-sci.net/I-4/245/2012/isprsannals-I-4-245-2012.pdf

CEI project 1202.136-07: Central European Initiative Cooperation Activity project "Deterministic seismic hazard analysis and zonation of the territory of Bulgaria, Romania and Serbia" (Ref. No. 1202.136-07), 2008 – 2009.

Davidson R., H. Shah (1998) The Earthquake Disaster Risk Index: A holistic Comparison of Earthquake Risk in Cities Worldwide, Project "Understanding Urban Seismic Risk around the World", part of the RADIUS initiative of the INNDR Secretariat.

Simpson, D. M. and M. Katirai(2006) Indicator Issues and Proposed Framework for a Disaster Preparedness Index (DPi) Working Paper 06-03 September 2006.

Decree № 2 from 23.07.2007 for the design of buildings and structures in seismic areas. State Gazette No. 74, 09.10.2007, MRDPW.

Disaster risk reduction strategy of Bulgaria (2014), Council of Ministers of the Republic of Bulgaria, Strategy for reducing the risk of disasters, 2014 - 2020 г.

EN 1998-1 (2004) (English): Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

FEMA (2004) "Primer for Design Professionals (FEMA 389)" Department of Homeland Security Emergency Preparedness and Response Directorate FEMA Mitigation Division Washington, D.C.

Hristoskov, L., D. Solakov, S. Shanov, M. Kostov (2006) Perspectives and peculiarities of Seismic Hazard Maps elaboration as a basis for harmonization of the Bulgarian Seismic Building Code with the Europeans standards, In: Proceedings of GEOSCIENCES 2006, 17-20, BGD, Sofia, http://www.bgd.bg/.

INSPIRE Data Specification on Buildings (2013), http://inspire.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_BU_v3.0.pdf

Kouteva-Gentcheva, M. (2015) Report on the Research project BN 164/14-CNIP at the University of Architecture, Civil Engineering and Geodesy, Sofia, 50p.
Kouteva-Guentcheva, M., L. Pashova (2014) Seismic risk management and information systems, First scientific and practical conference with international participation "Project management in construction", 4 - 5 December 2014, UACEG, Sofia, Bulgaria (*in Bulgarian*), (*in print*).
National Program for Upgrading of Buildings (2005) 51p. (*in Bulgarian*)
National Strategic Plan for Building Wastes Management and Demolishment for 2011-2014 (2011) http://www3.moew.government.bg/files/file/POS/Strategicdocuments/NSPUOSR-final.pdf (*in Bulgarian*).
National Statistical Institute of Bulgaria - http://www.nsi.bg/.
Panza, G. F. and F. Vaccari (2000). Introduction: In Seismic Hazard in the Circum Pannonian Region. PAGEOPH, 157, 5-9.
Pashova, L., Pl. Zlateva, M. Kouteva-Gentcheva (2010) An approach to comprehensive information systematisation for complex risk analysis of the natural hazards, Proc. of 6th international conference "Global Changes and Regional Development, Sofia, 16-17 April 2010, Sofia University "St. Kliment Ohridsky", 30-36.
Pashova L., T. Bandrova (2013) INSPIRE Directive in Bulgaria until 2013 – results, problems and perspectives, In: Proceedings of SDI & SIM 2013 – International Conference, Skopje, FYRoM, 13-16 November, 2013, Y. Doytsher, B. Idrizi and C. Potsiou (eds.) 149 - 161. http://conf2013.geo-see.org/.
Shanov, S., K. Kostov (2015) Dynamic Tectonics and Karst. Cave and Karst Systems of the World, 2015, XI, 123 p., Springer-Verlag Berlin Heidelberg, DOI: 10.1007/978-3-662-43992-0.
Simeonova, S. D., D. E. Solakov, G. Leydecker, H. Busche, T. Schmitt (2006) Probabilistic seismic hazard map for Bulgaria as a basis for a new building code. Natural Hazards and Earth, System Science, 2006, 6 (6), 881-887.
Trifunac, M. D., and A. G. Brady (1975) A study on duration of strong earthquake ground motion, Bull. Seismol. Soc. Am. 65, 581–626.
UNDRO (1982) "Natural Disasters and Vulnerability analysis", United Nation Disaster Relief Organization, Geneva.
United Nations International Strategy for Disaster Reduction (UN/ISDR 2004) Living with Risk – A Global Review of Disaster Reduction Initiatives. 2 vols. Geneva: United Nations.
Vahdat, K. and N. J. Smith (2010) Multidisciplinary Integrated Tools in Seismic Risk Management, 18th CIB World Building Congress, May 2010 Salford, United Kingdom, Lastly visited at available at http://www.irbnet.de/daten/iconda/CIB19110.pdf
Varnes, D. J. (1984) Landslide Hazard Zonation: a review of principles and practice, UNESCO, Paris, 63p.
Wald, D. J., and T. I. Allen (2007). Topographic slope as a proxy for seismic site conditions and amplification, Bull. Seism. Soc. Am., 97, No. 5, 1379-1395.

ACKNOWLEDGEMENTS

Research project CNIP-UACG БН – 164/14 is kindly acknowledged.

BIOGRAPHICAL NOTES

Lyubka Pashova is Associate Professor in the Geodesy Department at the National Institute of Geophysics, Geodesy and Cartography, Bulgarian Academy of Sciences. She holds M.Sc. degree in "Geodesy, Photogrammetry and Cartography" and PhD Degree in Geodesy. Her research and publications focuses on topics including statistical methods for geodetic data processing, coordinate reference systems, and processing and analysis of geospatial information with GIS. She is a member of the Bulgarian Cartographic Association and of the Association for Geospatial Information in South-East Europe (AGISEE); of Editor's group of two Journals: Geodesy and Micro, Macro & Mezzo Geo Information. She leads and participated in several projects in the field of geodesy and geodynamics at national and international level. Since October 2014 she is GEO Principal Alternate of Bulgaria in the Group on Earth Observations.

Mihaela Kouteva-Guentcheva is Associate Professor in the Department of Computer Aided Engineering at the University of Architecture, Civil Engineering and Geodesy, Sofia since 2013. She has worked for more than 20 years in the Central Laboratory for Seismic Mechanics and Earthquake Engineering at the Bulgarian Academy of Sciences (BAS), later Earthquake Engineering Department at National Institute of Geophysics, Geodesy and Cartography - BAS. She holds M.Sc. degree in "Civil Engineering – Structural Engineer" and "Applied Mathematics and Informatics" and PhD in "Solid Mechanics" in field. He is Junior associate at the Abdus Salam International Centre for Theoretical Physics – SAND Group, Trieste, Italy, 2001-2008. Her research and publications are focused on topics in engineering seismology and bridging engineering seismology with earthquake engineering, including strong motion data analysis, seismic wave propagation modelling, earthquake scenarios and seismic microzonation, dynamic analysis of structures. She leads and participated in several projects in the field of seismic engineering at national and international level.

Prof. Temenoujka Bandrova is the President of the Bulgarian Cartographic Association and head of the Laboratory on Cartography and Erasmus coordinator for the Faculty of Geodesy at the University of Architecture, Civil Engineering and Geodesy, Sofia. She is Co-chair of the ICA Commission of Cartography and Children (2007-2011), a member of the Council board and a chair of Young Scientific Commission of International Society of Digital Earth (ISDE), a member of Commissions on Map Projections, on Cartography in Early Warning and Crises Management – International Cartographic Association (ICA); of the Association for Geospatial Information in South-East Europe (AGISEE); of Editor's group of the International Journal of Digital Earth, Cartographia and Geoinformatika, Croatia. She is Project manager in DataMap Ltd. where her school atlases and maps are published. She is an author of 30 school atlases and more than 80 wall maps in geography and history, approved by the Ministry of Education and Sciences for Bulgarian schools. She published more than 100 articles, reports, papers, book chapters and edited books published by Springer and ESRI Press. She is the organizer of series of 5 International Conferences on Cartography and GIS.

CONTACTS

Assoc. Prof. Dr. Eng. Lyubka Pashova
National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences
Acad. G. Bonchev Str., Bl. 3
1113 Sofia, BULGARIA
Tel.: + 359 2 9793349
Fax: + 359 2 971 3005
Email: lpashova.niggg@gmail.com
Web site: www.niggg.bas.bg

Assoc. Prof. Dr. Eng. Mihaela Kouteva-Guentcheva
Department of Computer Aided Engineering, Faculty of Structural Engineering
University of Architecture, Civil Engineering and Geodesy
1, Chr. Smirnenski Blvd.
1046 Sofia, BULGARIA
Tel. +359 889 327327
Email:kouteva_fce@uacg.bg; mkouteva@gmail.com
Web site: www.uacg.bg

Prof. Dr. Eng. Temenoujka Bandrova
Bulgarian Cartographic Association
1, Chr. Smirnenski Blvd.
1046 Sofia, BULGARIA
Tel. +359 887 832702
Email: tbandrova@abc.bg
Web site: www.cartography-gis.com