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LIST OF ABBREVIATIONS

ARSO  Environmental Agency of the Republic of Slovenia
BB    Broad Band (usually - frequency response domain of a seismic instrument)
BSHAP NATO SfP No 983054 Project acronym
DTM   Digital Terrain Model
DEMA  Danish Emergency Management Association
DPPI  Disaster Preparedness and Prevention initiative of the EU Stability Pact
DSHA  Deterministic Seismic Hazard Analysis
OHAZ  Computer Program for Seismic Hazard evaluation based on PSHA methodology and Spatially Smoothed Seismicity Approach
EMSC  Euro-Mediterranean Seismological Centre, France
EC    European Commission
GIS   Geographical Information System
GMP   Ground Motion Prediction
GPS   Global Positioning System
IGEO  Institute of Geosciences, Tirana, Albania
IPR   Intellectual Property Right
ISC   International Seismological Center, Newberry
IZIIS Institute of Earthquake Engineering and Seismology at the University "Ss. Cyril and Methodius", Skopje, FYR Macedonia
METU  Middle East Technical University, Ankara, Turkey
MSO   Montenegro Seismological Observatory
MSC   Mercalli-Cancani-Sieberg earthquake intensity scale
MSK   Scale of Seismic Intensity (Medvedev-Sponhauer-Karnik)
ML, Mw, MS, mb, Md, Mlh, Mm - different type of magnitude definition
PGA   Peak Ground Acceleration
PSHA  Probabilistic Seismic Hazard Analysis
RP    Return period of a seismic event, expressed in years
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A) INTRODUCTION

Through the history Western Balkan region countries have experienced a great number of devastating earthquakes. Obviously, this area is characterized by a high level of seismic hazard. On an average basis, every 10-15 years a destructive earthquake occurs in this region, while every 60-70 years a catastrophic one strikes the region. In this circumstance, a reliable seismic hazard assessment is an important step towards preparedness and prevention activities as well a vital base for seismic safety improvement and seismic risk management.

Figure 1. Devastating consequences of some recent big earthquakes in the western Balkan region: Shkodra town, Albania, magnitude 6.6 in 1905 (upper left); Skopje, Macedonia earthquake in 1963, with magnitude 6.1 and 1070 causalities (upper right); Banja Luka, Bosnia and Herzegovina earthquake in 1969 with magnitude 6.0 (lower left) and collapsed hotel structure in Montenegro, in earthquake of 1979, with magnitude 7.0 and 135 victims (lower right).

There were numerous important reasons for the realization of this Project "Harmonization of Seismic Hazard maps for the Western Balkan Countries" (acronym BSHAP) such are:

- Security of human lives, social and economical values, historical heritage, etc., being exposed to significant seismic hazard in this region, should be increased,
- Existing seismic hazard maps were out of date and should be updated and improved,
- Seismic, seismotectonical, geophysical and other data acquired in recent years, necessarily should be integrated and implemented in hazard assessment,
- New methodological approach and new empirical seismic models for hazard assessment were necessary to be implemented.
- Local seismic code regulations, seismic risk estimation and risk management must be based on reliable hazard maps,
- Scientific collaboration in seismic hazard analysis and seismic data exchange in the region needed improvement,
- Seismic hazard maps should be harmonized with EU standards (EUROCODE 8),
- National seismic networks needed improvement,
Young scientists had to be trained in the methodology of seismic hazard assessment through Project workshops and seminars and,

Cooperation and collaboration between partner institutions needed further fostered.

The lessons on importance of social security in case of earthquake, become most evident during last catastrophic earthquakes in the Region, such were: Skopje (Macedonia) earthquake in 1963 (Fig. 1) when besides enormous material loss of 1070 human lives were lost; in 1979 destructive earthquake in Montenegro besides 135 casualties, caused direct losses of more than 5 Billion US dollars (at the time).

The basic purpose of seismic hazard assessment today is reliable seismic risk evaluation and its management, intending to minimize losses in any large earthquake in the future.

All those important reasons gathered 12 related institutions from 6 western Balkan countries and motivate more than 48 Project key members to join in seismic hazard research activities and to reach carefully specified important Project goals, such are:

- Integrated database organized in a GIS application for the whole region: regional earthquake catalogue, seismotectonical data, focal mechanism data, morphological and geological data, etc.
- Regional seismogenic model,
- New seismic hazard maps, compatible to EU standards - as a base for seismic safety improvement, seismic risk management, and seismic design codes upgrade,
- Improved capacities and instrumentation of existing seismic monitoring networks in the region,
- Improved scientific collaboration between the participating countries and institutions,
- Trained young scientists in earthquake hazard related topics,
- Publishing and dissemination of the major Project results.

We are acknowledging our great thankfulness to all parties that had additionally supported the realization of this Project, especially to the:

- Science for Peace Programme that had recognized the importance of the stated Project goals and provided all means to realize these activities,
- DPPI/SEE Stability Pact that made significant efforts to gather all interested parties and encourage them to propose joint project. In addition, DPPI supported several meetings during the preparation and in the initial phase of Project.
- ARSO supported this project by organizing its’ first Workshop in Ig, Slovenia, made the national earthquake catalogue data available and provided significant professional expertise in OHAZ implementation and training.
- Albanian GeoSciences Institute from Tirana, together with ARSO, made huge contribution by making the OHAZ software available for BSHAP Project seismic hazard assessment, with great personal efforts of Prof. Neki Kuka to upgrade this software.
- DEMA which donated MSO by 35,000 EUR to fully equip one of the permanent GPS stations in geodynamic network of Montenegro.
- EUR-OPA Major Hazards Agreement and “European Center on Vulnerability of Industrial and Lifeline Systems” for organizing the Workshop in Skopje, December 2007.
B) SCOPE AND OBJECTIVES OF THE PROJECT

Project “Harmonization of Seismic Hazard Maps for the Western Balkan Countries” was realized by the leading seismological and earthquake engineering institutions from seven Balkan countries: Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Serbia and Turkey. Twelve institutions from the Region took part in its realization with 48 key scientific members and its’ institutional staff.

Project achieved numerous important results, valid for all the countries involved, as well as for the whole Western Balkan Region:

- Improved cooperation between all the institutions in the western Balkan region involved in seismic hazard assessment and seismic risk reduction,
- Improved cooperation with similar EU institutions,
- Improved technical capacities and seismic monitoring performances in all national seismic networks of the western Balkan countries,
- Established real-time seismic data exchange between national seismic networks,
- Assessment of the harmonized and reliable seismic hazard maps for the whole western Balkan region,
- Introduction of the NATO SPS Programme benefits to many governmental, scientific and public institutions,
- Advocacy in favor of seismic risk mitigation public education, etc.,
- Fostering other NATO SIP Projects,
- Young scientist professionally trained in the course workshops and dedicated trainings,
- Fostered further cooperation and collaboration between partner institutions.

Project recognized many important end users to implement the achieved results:

- National civil protection agencies,
- Agencies for physical and urban planning,
- Ministries responsible for seismic safety improvement and seismic risk management in all countries involved in the Project,
- Authorities for seismic design code legislation,
- National seismic networks,
- Seismological, geological and geophysical institutions in the Region,
- Insurance companies and
- The broad community – as final end user of reliable hazard maps implemented in physical planning, building design and construction of earthquake resistant structures.

Project launching: Podgorica 2nd October 2007
C) REALIZATION OF THE PROJECT

The BSHAP Project proposal was elaborated by efforts of Montenegro Seismological Observatory, as the leading partner institution, in close cooperation with other project partners.

The project was managed by:

- NPD, Prof. Sinan Akkar, PhD in Civil Engineering Earthquake Engineering Research Center, Dept. of Civil Engineering, Middle East Technical University, Ankara, Turkey and
- PPD, Prof. Branislav Glavatovic, PhD in Geophysics, Director of Montenegro Seismological Observatory, Podgorica, Montenegro

collaborating with Co-Directors of the participating countries:

- Prof. Ismail Hoxha, PhD in Geoinformatics, Project Co-Director Institute of Geosciences, Polytechnic University of Tirana, Albania
- Vlado Kuk, MS in Geophysics, Project Co-Director Department of Geophysics, Faculty of Sciences, University of Zagreb, Croatia
- Amer Zoranić, B.S. in Political Sciences, Project Co-Director Ministry of Civil Affairs, Sarajevo, Bosnia and Herzegovina
- Prof. Mihail Garevski, PhD in Civil Engineering, Project Co-Director Institute of Earthquake Engineering and Engineering Seismology at the University "Ss. Cyril and Methodius", Skopje, Republic of Macedonia,
- Svetlana Kovacevic, MS in Geology, Project Co-Director Seismological Survey of Serbia, Belgrade, Serbia.

The project activities were grouped into logic units – working packages. The experienced professionals were in charge of leading the specific package activities – such were the cases of catalogue compilation or OHAZ implementation, while in most of other activities partners performed activities according to the agreed approach.

Most of the coordination activities, planning of joint workshops and meetings were done by MSO, as the leading project partner. The workshops/meetings had been equally arranged and hosted over the participating institutions and upon the mutual agreements, and having in mind the easiest travel connections.

All Minutes, reports from conferences attended and regular reporting to SfP Programme were prepared by MSO and timely delivered. For the visibility of actions the Project Web has been established and maintained by MSO staff.

The Project Launching Meeting took place in Podgorica, Montenegro on October 2nd, 2007.

Coordination, planning of activities, know-how transfer, and methodology to be applied, were realized during the Workshops:
Workshop, Ljubljana, 7-9 November, 2007 was the first Workshop of the Project "Harmonization of Seismic Hazard Maps for the Western Balkan Countries" was held in Ig, Ljubljana covering: Hazard software analysis (OHAZ), Spatial smoothing seismicity, Seismic source zones delineation and characterization and Earthquake catalogue unification. Partially granted by: Administration of the Republic of Slovenia for Civil Protection and Disaster Relief and Stability Pact/DPPI.

Workshop, Skopje, 17-18 December, 2007 was organized with the principle tasks - to synchronize national earthquake catalogues and to discuss seismic zones affecting the region under the study.

Workshop, Dubrovnik, March, 2008. The workshop was dedicated to analysis of seismic instrument bid, discussion and decision-making on selection of seismic instrumentation. The final national drafts of earthquake catalogues with threshold magnitude 3+ were reported. The First version of Unified regional earthquake catalogue was presented. The comparative analysis of fitness of existing empirical ground motion models to recorded strong motion data in the Region has been discussed.

Workshop, Budva, Montenegro, December, 2008 covered discussion and decisions on: Overview of the current Project results; Earthquake catalogue declustering, completeness, format; Ground motion predictive models; Purchasing GIS software (MapInfo); Development of OHAZ - Hazard assessment software; Seismic source zone delineation and characterization.

Workshop, Banja Luka, Bosnia and Herzegovina, October, 2009. The workshop covered topics of: Overview of the Project progress; Earthquake catalogue - final version; Development of OHAZ - Hazard assessment software; GIS thematic maps and final decisions for the last Project year implementation.

Workshop, Ohrid, Macedonia, 27-28 May, 2010 was a joint workshop of the groups for identifying the seismic sources, their characteristics and hazard computation. The groups discussed: approach to create joint seismotectonic model, conversion of the unified catalogue into suitable Mw magnitude, errors in last catalogue edition, recent GMP equations, alternative hazard software, and exercise into OHAZ software.

In addition,

- Training in GIS (MapInfo Professional 9.5) was organized by the Seismological Survey of Serbia and held in April, 2009 in Divcibare, Serbia with participation of representatives of the partner institutions from all countries involved in the Project.

Two more meetings of Co-Directors were organized to adopt the guidelines for Project progress:

- Ohrid Working Group Meeting: May 27 – 28, 2010
- Tirana: Co-directors Meeting Oct. 29, 2010
• Meeting of the Co-Directors, Sarajevo, Bosnia and Herzegovina, April, 2010. The following topics were discussed: deployment, malfunction and repair of instruments, establishment of task group for identifying earthquake sources and their characteristics and group in charged for PSHA analysis, empirical scaling relationships for magnitude unification in earthquake catalogue, collaboration with SHARE project, etc.

• Meeting of the Co-Directors, Tirana, Albania, October 29, 2010 organized to discuss earthquake catalogues, seismic zones, application of GMPE models, unified coordinate system for GIS application, etc.

Upon the request, which on behalf of the Project was submitted by NPD, the SfP Office approved half-year extension for the delivery of results.

• The hazard assessment results and input parameters were presented and discussed on the Conference that took place in Zagreb, Croatia on May 12-13, 2011. Upon the in detailed result analyses the opinion was made that the final improvements should be introduced. In agreement with the SfP office common decision was achieved to extend the project activities for additional six month.

• The final project results were presented during the Closing Conference held in Ankara, Turkey on October 24, 2011.

BSHAP Project was structured in 9 interconnected working packages, realized in accordance to stated time-frame.

1. **Compilation of earthquake catalogue data**
   1.1. Earthquake catalogue completion
   1.2. Unification of magnitude scale

2. **Seismic source modelling**
   2.1. Seismotectonical elaboration
   2.2. Recurrence of earthquakes inside the identified seismic sources
   2.3. Modeling of seismic sources using smoothed seismicity approach

3. **Determination of GMP models**
   3.1. Investigation of available GMP models
   3.2. Comparison of results from different GMP models

4. **Seismic hazard assessment**
   4.1. Preparation and testing of input database
   4.2. Computation of hazard probabilities

5. **GIS implementation**
   5.1. Preparation of GIS background and thematic maps
   5.2. Elaboration of hazard GIS maps

6. **Equipment purchase and deployment**

7. **Software purchase**
   7.1. Accelerogram analysis software
   7.2. GIS software

8. **Project coordination activities and issuing information and results in the Project**
   8.1. WEB site preparation
   8.2. Web maintenance, Workshops, coordination and dissemination of the results
   8.3. Presentation and dissemination of the final hazard results

9. **Training of young scientists**
Scientific research activities performed by collaborators of 14 institutions from six countries of the western Balkan region, that are mostly devoted to the seismological monitoring, earthquake phenomenology exploration and earthquake engineering activities, gathered in this NATO SfP Project, after three and a half of years resulted with many direct, but also indirect benefits. Namely, direct, very valuable achievements are related especially in improvement of the capacity of all national seismic networks in the Region, but also in producing new seismic hazard maps harmonized for the whole region, as well as with the European standards and experience in this field. New valuable knowledge and experience in seismic hazard assessment methodology and a lot of other related topics, that were accepted by numerous young scientists in the Region is of precious.

But, as a very valuable result of the Project we also reached the conviction on some important scientific topics that should be much better resolved and explored only in the future, because of it complexity and lack of data for now, such as much more extensive study of seismotectonics, as well as seismic tomography and geodynamic modeling of the region. These scientific findings in the future could bring greatly better light to all unexplained and incompletely understood geological, geophysical and seismological question in this part of the Mediterranean rim and Carpatho-Balkanian arch and its interaction with the surroundings orogen systems. This will certainly result in much better knowledge for seismic hazard assessment and of course – for seismic risk management in this seismically prone Region.

This Project brought also very valuable professional experience and improved greatly a good spirit of full regional cooperation and strengthened professional and personal relationships in the seismological community of the whole western Balkan region.

In this part of the Report, we presented new probabilistic seismic hazard maps for all the BSHAP Region, by implementing a new computation methodology based on the smoothed-gridded seismicity approach and on a logic tree, to fully characterize the seismic hazard and its associated uncertainties.

1. GEODYNAMIC AND TECTONIC FEATURES OF THE WESTERN BALKAN REGION

There are a lot of strong scientific evidences that in a geological and geodynamic sense the mountain belts of Dinarides, Hellenides, and Taurides were created as a polyphase orogen, representing the coalescence of three subduction zones since Mesozoic times (for inst. Selley et al. 2005, Schmid et al. 2008, etc). The existence of these subduction zones is supported by the occurrence of two distinct oceanic sutures, preserved as the ophiolitic suites of Vardar and the Sub-Pelagonian units, which represent two separated branches of the Mesozoic Tethyan Ocean and the present oceanic subduction of the Ionian Sea.

In the Balkans, the Rhodope, and the Serbo-Macedonian massifs, structural and stratigraphic data indicate interplay of compressional and extensional tectonics. A Cretaceous to Eocene compressive deformation was followed by the generation of Eocene grabens. A later (possibly Miocene) compression inverted and uplifted these grabens, but it was followed by extensional tectonics that have affected the Balkan peninsula since Pliocene times, determining the northwest-trending normal faults and the related east–west right-lateral and north–south left-lateral transtensive transfer faults. Northeastwards-directed subduction is continuing along the eastern side of the Adriatic, in the Ionian Sea underneath the Mediterranean Ridge, and on the northern side of the Levantine Sea, i.e. in the eastern Mediterranean beneath Cyprus (Fig. 3).
According to this geodynamic scenario, during the compressive events associated with north-eastwards directed subduction, basement rocks (both continental and ophiolitic slices) in western Anatolia and the Aegean Sea were uplifted and eroded. Later extension caused subsidence in the area, and the basement slices were partly covered by continental and marine sediments.

During its development, the Aegean extension migrated south-westwards (Fig. 4). The Aegean rift affects the Aegean Sea and all of continental Greece, and it can be followed to the east, where it is widely expressed in Turkey, and to the north-west in Bulgaria, Macedonia, Albania, Serbia and Bosnia (Selley et al. 2005).

At the same time, from the Oligocene to the present, to the north, the Pannonian basin developed as the back-arc of the Carpathians subduction, but migrating eastwards, and affecting mainly eastern Austria, Slovenia, Croatia, Hungary, and Romania. Therefore, in the central part of the former Yugoslavia, the Pannonian and Aegean rifts meet with opposite directions of migration.

The present-day configuration of tectonic units suggests that a former connection between ophiolitic units in West Carpathians and Dinarides was disrupted by substantial Miocene-age dislocations along the Mid-Hungarian Fault Zone, hiding a former lateral change in subduction polarity between West Carpathians and Dinarides (Schmid et al. 2008). The SW-facing Dinaridic Orogen, mainly structured in Cretaceous and Paleogene times, was juxtaposed with the Tisza and Dacia Mega-Units along a NW-dipping suture (Sava Zone) in latest Cretaceous to Paleogene times.

Earth crust velocity field in the western Balkan region determined by results of permanent GPS observation on rather dense network, indicates very complex geo dynamic scenario ongoing in this area (Figure 5). Namely, it is obvious from great number of recent kinematical solutions of GPS time series (Hefly 2007, Papazachos 2002, Pinter at all. 2004, Grenertzy and Kenyeres 2004 etc.) that there is no any uniform migration of the segments of the Earth crust in this region. Namely northern part of Apenine platform and stations western of the Montenegro, Serbia and Hungary, are moving to the North, relatively to the stable Euroasian platform, by velocities of 4-7 mm per year. All eastern GPS stations (in Hungary and central and western Serbia) express much smaller horizontal velocity vectors (only 1-2 mm/year) and they are mostly easterly oriented. The horizontal velocity vectors in Montenegro are oriented to the North mostly and are, as well, of very small intensities (around 1 mm/ year).
Figure 4. Major tectonic and geological units of the western Balkan and the surrounding regions of the Carpathians, Dinarides and Hellenides (Schmid et al. 2008).

The most southern GPS stations in Montenegro (Podgorica and Dračevica) express obviously effects of local tectonical features and probably some post earthquake tectonic stress relaxation - related to the big 1979 earthquake in Montenegro. Finally, the area covering eastern Serbia, southern Romania, Bulgaria and eastern Albania show strong south-east and southern orientation of the horizontal velocity vectors relative to the stable Euroasia platform, with the intensities of 3-6 mm/year. This non-homogenius horizontal velocity field implicates creation of complex geodynamic and tectonical consequences, what result in forming of complex orogens features as well as active tectonics in the Region.

It is obvious that the Adriatic and western Balkan regions play very important role in shaping the neotectonics of the whole southern and central Europe. Recent numerous geodetic studies (for inst. Pinter et al. 2004, Papazachos 2002, Hefty 2007, Grenertz and Kenyeres 2004, etc.) almost universally conclude that the Adriatic lithospheric unit currently is moving independent of both Eurasia and the Africa/Nubia. But, much less agreement can be found regarding the precise locations of the boundary of Adria.

Aldough the Adriatic Sea is generally surrounded by compressional faults and earthquake focal mechanism to the north, extension along the axes of Appennines and transpressional deformation in the Dinarides, regional maps drawn by different workers document suprisingly wide range of different oppinions delineating the margins of Adria. The region to the northeast of Adria, encompassing the Eastern Alps, the northern Dinarids, the Panonian basin, experienced one or more episodes of lateral extrusion during the Tertiary. The continuing motion of Adria appears to be driving active, although slower extrusional processes today.
Figure 5. Intraplate velocities (ITRF2000) as a result of combination of regional and local velocity fields in the frame of stable Euroasia (Hefty 2007): EPN, CERGOP, CEBAPER, ALPMED, CRODYN, BULREF, HGRN, SGRN, Papazachos (2002) and Glavatović et al (2011).

2. SEISMICITY OF THE REGION

The South Eastern part of Europe is the most seismically active region on the continent, and consequently the region with the highest seismic hazard and risk in Europe. Unfortunately, the level of earthquake research capacity, as an average, is far below the European practice. Some countries involved in the BSHAP project still perform seismological observations at non adequate level, which is far away that should be especially for the purpose of seismotectonic studies and proper characterization of at least main active faults. These circumstances obviously are not quite satisfactory for seismic hazard evaluation.

So, relatively sparse seismological networks until recently in the region and limited cross-border seismic data exchanges before this Project generated a lot of doubts in seismotectonical interpretation and understanding of phenomena of seismic and geodynamic processes in the region. Despite the fact that this part of the Balkan Peninsula, compared to the rest of Europe is characterized by very high earthquake hazard and risk (Fig. 6), seismological and seismotectonical research are still poorly resolved. This Region during several last decades was just occasionally involved in some valuable seismological studies, such as UNDP/UNESCO "Seismicity of the Balkan Region" (1972-1976) or "Seismic risk Reduction in the Balkan Region" (1983-1986). It means that more than 20 years there were no any extensive regional study at the western Balkan of the topics related to the earthquake phenomenology, seismic monitoring, seismotectonics and seismic hazard assessment. One of newer, COST Action-625 Project “3D monitoring of active tectonic structures” (2000-2003) was only partially realized and opened more questions than it solved.

Results of the quoted former projects, international earthquake catalogues are combined with national data related to historical and contemporary seismic activity to compile unified BSHAP Project Earthquake Catalogue. Eventually, it showed up that there are large differences in the contents of the national earthquake catalogues, mostly regarding the completeness, the time span covered by reliable data, quality of earthquake parametric solutions, especially in recent years, etc.
Figure 6. Seismicity of the western Balkan region expressed as a map of earthquake epicenters (based on a compiled earthquake catalogue from published regional and national catalogues data in the Region).

Well documented historical data on seismic activity in this Region, as well as the information based on instrumental records, indicate that the western Balkan region is a scene of relatively often devastating and occasionally catastrophic earthquakes occurrence. The most affected area is without any doubt – the whole Adriatic coastal area, covering mostly a belt around 15 kilometers wide, both on-shore and similar off-shore (Fig. 6). Seismicity in this zone is mostly connected with strong overthrusting neotectonic process of so called Pindos-Budva-Cukali zone.

The similar may be stated for the zones of collision Carpathians with Serbo-Macedonian belt, (during ancient and in modern times), as well as in the central and southern Albanides and some distributed and isolated seismic sources in the central and inner Dinarides (such as Banja Luka zone for example) (Fig. 6).

Several times in the documented period of time, the Western Balkan region has been hit by earthquakes with 10 degrees Mercally (MCS) or up to 7.7 Richter magnitudes, and many times by earthquakes resulting with 9 degree MCS intensity scale.
2.1. Improvement of Seismic Monitoring Networks in the Region

The equipment purchased in the framework of the BSHAP Project, as the Project direct benefit, is extreme added value for the improvement of the complete seismic monitoring capacity of the western Balkan region, as it for all of the national seismic and strong motion networks of the countries involved in the Project.

As a resume of the seismic equipment upgrade, the specified total numbers of seismic broadband stations and strong motion stations that were purchased and installed through the BSHAP Project, by the national network, are given in the Table 3. 13 broadband seismic stations and 36 strong motion stations were established. Besides that, additional valuable equipment for operation of seismic stations was implemented (seismic signal digitizers, seismic sensors, communication devices, etc.), as well as several computers and software (mostly GIS MapInfo and Vertical Mapper).

Table 3. Resume of seismic equipment upgrade

<table>
<thead>
<tr>
<th></th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seismic BB stations</strong></td>
<td></td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>5</td>
</tr>
<tr>
<td>Croatia</td>
<td>5</td>
</tr>
<tr>
<td>Montenegro</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13</td>
</tr>
<tr>
<td><strong>Strong motion stations</strong></td>
<td></td>
</tr>
<tr>
<td>Albania</td>
<td>10</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>7</td>
</tr>
<tr>
<td>Croatia</td>
<td>2</td>
</tr>
<tr>
<td>Macedonia</td>
<td>13</td>
</tr>
<tr>
<td>Montenegro</td>
<td>3</td>
</tr>
<tr>
<td>Serbia</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>36</td>
</tr>
</tbody>
</table>

The distribution of this instrumentatation at the field is displayed on the map given in Fig. 7.

For the seismic equipment purchase was spent around 344,000 EUR, what makes 54 % of the NATO SIP award of 638,000 EUR to the Project. Selection of specific technical solutions of equipment was made in accordance with the choice and needs of the participating partners, through the tender bid.

These 36 new stations (seismic and strong motion) equipped with modern seismic instrumentation, improved significantly the capacities to detect and process seismic events in the western Balkan region and in ranging surroundings.

In additional, the Protocol on seismic exchange of data collected through this instrumentation, and the possibility to use these data - not only for urgent purposes when a major earthquake strikes, but also for scientific research of seismotectonical and geodynamic processes in the Region, gave additional value to this precious contribution of the NATO SfP No. 983054 project.
2.2. Protocol on Seismic Data Exchange

In the framework of the NATO Science for Peace Project No. 983054, all institutions involved in the Project, wishing to improve already existing cooperative mutual professional and scientific relationships, especially to enhanced real-time seismic data exchange, have made a Protocol on understanding. The objective of the cooperation was to advance science and technology, capacity building in the stated fields, to improve quality of urgent earthquake hypocenter parameters determination, to enrich existing national seismic databases for the purpose of scientific research of the Earth crust structure, its seismotectonical and geological features, as well as to study focal mechanism of the earthquakes in the region.

The protocol intended to establish cooperation margins enabling the above institutions to pull their resources towards advancement of science and the application of obtained results without disadvantaging either party.

Subject to technical availability and the approval of the directors of stated seismological institutions, the cooperation is expected to be carried...
out by each of the contracting parties through the following activities:

- Exchange of real time seismic data in a convenient data format;
- Education of new generation of scientists;
- Joint implementation of human capacity building activities (workshops, trainings, seminars, specialists courses) in the fields of particular interest;
- Identification of areas of potential research and cooperation;
- Co-partnership in the national, regional and international projects;
- Exchange of expertise;
- Joint authorship of publications in scientific journals and proceedings.

Based upon the interest shown in the stated fields of cooperation activities, all parties have agreed that the mode of mutual cooperation may be organized in one of the following manners:

1. Establishment of virtual seismic network by mutual providing of real-time or near real-time seismic data for the purposes of common interest;
2. Establishment of joint projects of common interest financed and supported by the governments of participating countries and/or other public and private institutions and organizations; and,
3. Establishment of joint bilateral or multilateral projects of common interest supported by United Nations agencies, the Commission of European Communities, or any other agencies and institutions with the same specific interest.

3. SEISMOTECTONIC DATA

The evaluation of seismogenic capacity of the seismogenic fault system and its mapping is a very complex task, usually realized using all relevant seismological, geological, geophysical, paleomagnetic, paleoseismological, geodetical, etc. data. This evaluation should result in geometry of active fault, level its activity expressed as the maximum expected magnitude that fault can produce, type of faulting, kinematical properties, as well as the directions of predominant tectonic stresses responsible for its activity.

Until recently, no serious regional active faults mapping project existed in the western Balkan region. A breakthrough initiative came from the COST Action-625 project “3D monitoring of active tectonic structures”, when a task group was focused on the compilation of a “Map of active faults of the Adria region”.

For this reasons, a special effort was made by the national research groups gathered in the BSHAP Project, trying to make a step forward in the determination of evident or potentially active tectonic faults that can produce future earthquakes relevant for the content of seismic hazard map of the Region. The resulting compiled map of six separate partial solutions for all the countries involved in the Project is presented in the Figure 9.

Analysis of spatial and kinematical parameters of tectonic faults - the average fault length, its' orientation, type of faulting, etc. through all delineated seismotectonic zones in the BSHAP region, shows specific similarity pattern and evident influence of some tectonic units in the broader region. Namely:

- The influence and interaction of Alpine orogen and tectonic belt is evident in northern zones in Slovenia, Austria and partially in Croatia. It is characterized by existence of reverse faults with fault lines extending in the direction North-East – South West, with average azimuth of fault lines 65-85° (with relative weight of 0.1-0.3). Strike slip faults (50-90%) are dominant for this part of the Region, with prevailing 35° and 330° azimuth direction.
- Outer Dinarides are mostly characterized by thrust faulting style (85-100%) stretching practically parallel to shore line. Only small part of strike slip tectonic structures are present along the coast (up to 10 %), as well as negligible normal faulting stile (5% in the most southern Adriatic zones).
• Similarly, the Inner Dinarides are mostly (35-100%) shaped by active reverse faulting with azimuth of strike line of 285° - 315° in Bosnia and Herzegovina and Montenegro, and 310°-330° in Croatia. The presence of the reverse faulting decrease getting far away from prominent Dinarides napes and turn to dominantly normal faulting style with azimuths of 45°-55° but 285-320 directions, as well. The relative occurrence of normal fault types has the broad range - weight 10-100% depending to different zone.

• Pannonian basin (continental ridge) are mostly (50-70%) defined by strike slip faulting style with some presence of reverse faults. The most southern part of Panonian basin - the V-shaped Peripannonian basin portion, is clinched between inner Dinarides and Carpathians. It is characterized by the blocky structure formed by existence of intersected strike-slip faults of dominant ESE-WNW and NE-SW orientation.

• Going westward the influence of Carpathian orogen geodynamic causes existence of thrust faulting of dominantly 340°-350° directivity, by relative factors of 10-20%, whilst the presence of strike slip is still mostly prominent by 10-80%.

• Zones in Eastern Albania, Macedonia and Greece are mostly defined by the influence of normal faults – majority of them in directions of 160°-180° and 325°-350°. The small influence of strike slip faults (10-20%) is present.

• The Western Albania zones are characterized by reverse faulting – at the range 40-50 % stretching along the coastal shore (165°), while the appearance of strike slip faults is in range of 15% of total tectonic activity. The influence of normal faulting style is present in ranges 30-40% - in this case very close to the major directivity of thrust fault type.

Figure 9. Traces of mostly seismic active faults as defined and integrated in the framework of the BSHAP Project for the BSHAP region and the faults defined through the COST Action-625 Project “3D monitoring of active tectonic structures”. Seismotectonic zones as defined for the seismic hazard assessment using OHAZ software were presented by blue dashed lines.
3.1 Tectonic stress field

Relatively large number of earthquake focal mechanism solutions published up to now, reveals that thrust and strike-slip faulting predominate in the western Balkan region (Figure 10). The map of the horizontal projection of pressure axis derived from focal mechanism solutions (World Stress Map Rel. 2008, Helmholz Centre Potsdam, combined with Herak & Herak 2009 and Glavatović, 2011), as shown in Figure 10, indicates predominantly S-N to SW-NE lined tectonic compression. These results are consistent with the character of stress field produced by counter-clockwise rotation of the Adriatic microplate around the pole in north of Italy (as suggested by e.g. Anderson and Jackson [55], Grenertzy and Kenyeres 2004, etc), and the push of the African plate from the south.

![Figure 10. Maximum compressional directions (P-axis) derived from earthquake focal mechanism solutions, published by World Stress Map Rel. 2008 (Helmholz Centre Potsdam) combined with Herak & Herak (2009) and Glavatović (2011) solutions for group of stronger earthquakes in the Region, indicating dominant stress field direction (left) and common focal mechanism solution as a result of EMA (Earthquake Mechanisms of Europe, 2008) research for the whole northern Adriatic coastal area (right).](image)

4. SEISMIC HAZARD ASSESSMENT METHODOLOGY

For the assessment of seismic hazard, two methodologies can be used: deterministic analysis (Deterministic Seismic Hazard Assessment - DSHA), and probabilistic analysis (Probabilistic Seismic Hazard Assessment - PSHA).

The deterministic methods attempt to characterize the maximum earthquake that can be generated by a certain tectonic fault and can affect a specific site or a given structure. All the variables that enter into the calculations are treated in a deterministic approach, and based on the hypothesis that the future seismicity of the region shall be the same as the one observed on the past. That means that in the future we’ll not observe earthquakes causing greater impact compared to those of the past. For this reason, it is necessary that the deterministic methods should be supported by detailed knowledge of the activity of the active tectonic faults and depends entirely from the available data, which, in many cases are incomplete and not reliable.

The first step in a DSHA is the identification of all seismic sources. Further, the maximum earthquake for every source, as well as the closest distance of the site to each source, is characterized. The selected maximum magnitude and the closest distance are used with the Ground Motion Predictive Models (GMPM) of the region, or the so called – attenuation models, in order to calculate the ground motion parameters for every identified source. The scenario
representing the highest level of the ground motion parameter is adopted as the controlling earthquake (Kramer, 1996). Since the attenuation models are always associated by a certain uncertainty, characterized by the standard deviation of the relevant regression equation, the resulting ground motion parameter carries out a certain error as well, so it represents also a random variable.

The probabilistic methods (PSHA) take into account all the possible scenarios that can take place in a site/region of interest, their appearance in space, time and quantity is a random variable. A probabilistic function that characterizes the likelihood of the event and its characteristics associated every process. All these uncertainties are taken into consideration during the assessment of seismic hazard and the result is described as a random quantity with a specific probability distribution. More specifically, the probabilistic seismic hazard assessment consists on evaluation of the probability, that within a given period of time, a specified level of the parameter characterizing the ground motion is exceeded.

The probabilistic methods have already found a broad area of applications in seismology for the analysis of seismic processes related to the appearance of the earthquake phenomena and ground motion analysis. Their main advantage consists on the fact that the parameters which characterize the ground shaking on a specific site are accompanied with probabilistic values that describe the likelihood of their appearance. Further, characterizing quantitatively the uncertainties of the parameters assessment, it is possible to perform the analysis and the comparison of the alternative models, since the sensitivity analysis of the results obtained against different parameters are possible. This is very important, taken into consideration the absence of the high quality data and the stochastic behaviour of the processes under analysis.

Nevertheless, probabilistic methods have their limitations, as well. For example, the extrapolation of the obtained results for periods of time larger than those covered by the existing historical data, or for magnitudes larger than those observed, might produce erroneous results in case of insufficiency of data. Another limitation is observed when the observed processes do not satisfy the hypothesis which are on the base of the relevant probabilistic models, such as the Poissonian character of the process, its stationarity, etc.

Among the methods used today for the assessment of seismic hazard, with no doubt, the most widespread is the probabilistic approach (PSHA). The basic steps for the implementation of PSHA are (Kramer, 1996):

- Identification and characterization of the seismic sources. Every source should correspond a probabilistic distribution that describes the earthquake occurrence in any point inside it. The definition of the zonal sources is based on the evaluation of the seismotectonic framework, on the observed past seismicity, as well as on the considerations for the stationarity in time and space of the seismic activity.

- Characterization of the seismicity within every source zone, that means the determination of the frequency-magnitude relationship, as well as the maximum possible magnitude for every seismic source.

- Definition of an adequate model to predict the required ground motion parameter that describes the amplitude attenuation (acceleration, velocity, spectral ordinates, etc.) as a function of distance, magnitude, soil conditions, faulting mechanism, etc.

- Assessment of the probability that a specified level of any ground motion parameter can be exceeded within a certain period of time, taking into account the random nature of earthquakes and the uncertainties associated with their size and position, as well as the ground motion generated by them.
4.1. Modeling of the earthquake occurrence and magnitude characterization

Geological studies indicate that the characteristic earthquakes in the range of the rare events with large magnitudes are manifested more frequently than could be expected by the G-R relationship. In order to consider this phenomenon, a more complex recurrence function is proposed, the so-called characteristic earthquake law. For small magnitudes, this relation is governed by the seismicity data employing magnitude exponential distribution, whereas for large magnitudes, by the geological data nearby the characteristic earthquake employing the uniform distribution.

The recurrence relation constitutes the backbone of the PSHA, because it provides the instrument to predict the rare, more destructive big earthquakes, based on the observational data of small, more frequent earthquakes. The leading, intended hypothesis is to use this relation obtained by the historical data, for the prediction of the future seismic events.

Earthquake catalogue is the most basic prerequisite for any kind of earthquake hazard estimation. Unfortunately, even the best catalogues extend into the past only for an order of thousand years, and only for the most destructive events. The problem of reliability of catalogue entries pertaining to ancient earthquakes is also an important issue.

Probabilistic seismic hazard assessment (PSHA) relies in large part on the assumption that seismicity of the past is representative of the future earthquake activity in a region. This is a strong statement, and should be valid in all of its aspects: magnitude-frequency relation, spatial distribution of foci, focal mechanisms, temporal distribution, etc., should all be stationary in time, to provide basis for extrapolation into the future.

In the case of seismic hazard, nearly all preconditions to apply extrapolation are violated – the time-span of data (catalogues) is often shorter than average return periods of large earthquakes, catalogues are far from being homogeneous (in time, space and magnitude), earthquakes do not obey the Poissonian model (foreshocks and aftershocks), and seismicity is not stationary.

The most important seismicity research in the region has been done in the framework of the so called Balkan Project in the 1970-es, which resulted in an authoritative and representative catalogue for the Balkan region [14], and which still provides – especially its historical part – the basis for any serious seismicity research. This effort was followed by Shebalin et al. [26], who compiled the catalogue for the SE Europe for the period from 342 BC until 1990 AC. Also, Karnik’s European catalogues published in 1968 and 1971 [27, 28] is very valuable. In absence of recent local earthquake data, catalogues are often supplemented from the global ones maintained by, e.g. NEIC, ANSS, or ISC [29–31].

4.2. The BSHAP earthquake catalogue

Having in mind the first goal of NATO SIP 983054 Project (BSHAP) assessment of new seismic hazard maps for the region (and thus ensuring seismic hazard harmonization -within the region as well as compatibility with the European standards) the first task was compilation of a representative earthquake catalogue. All available data supplied by the authorities from the participating countries, and the publicly available datasets were implemented.

The catalogue data were analysed in two phases.

4.2.1 First BSHAP catalogue

In the first phase, the catalogue data automatic compilation and analysis was performed by Prof M. Herak, Department of Geophysics, Faculty of Sciences University of Zagreb, Croatia.

The compiled earthquake catalogue was result of merging 12 separate catalogues data with magnitude threshold 3.0:

- National catalogues contribution from 6 participating countries (Serbian catalogue with the M3.6 magnitude cut-off),
- Slovenian complete catalogue,
- Greek catalogue (with magnitude cut-off M4.5)
- Romanian earthquake catalogue,
- Italian catalogues available on the internet [33] or recently published [34]
- Hungarian catalogue by Zsiros [23]
- Catalogue for the SE Europe, Shebalin et al. [32]
- Advanced National Seismic System (ANSS) catalogue [30].

All catalogue data were considered to have local magnitude $M_L$. National catalogues had been merged and then declustered (i.e. foreshocks and aftershocks were removed) by using the temporal and spatial windows whose size increase with the main-shock magnitude according to Table 1.

Table 1. Windowing parameters used to decluster catalogues. For $M < 3.0$ and $M > 7.0$, the parameters are estimated by log-linear extrapolation. $D_w$ – radius of circular window; $T_w$ – duration of aftershocks; $T_{w, foreshocks}$ – duration of foreshocks.

<table>
<thead>
<tr>
<th>$M$</th>
<th>$D_w$(km)</th>
<th>$T_w$(days)</th>
<th>$T_{w, forshocks}$(years)</th>
<th>$M$</th>
<th>$D_w$(km)</th>
<th>$T_w$(days)</th>
<th>$T_{w, forshocks}$(years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>20.0</td>
<td>25.0</td>
<td>0.0684</td>
<td>5.2</td>
<td>45.7</td>
<td>190.1</td>
<td>0.5206</td>
</tr>
<tr>
<td>3.2</td>
<td>21.6</td>
<td>30.1</td>
<td>0.0823</td>
<td>5.4</td>
<td>49.3</td>
<td>228.7</td>
<td>0.6260</td>
</tr>
<tr>
<td>3.4</td>
<td>23.2</td>
<td>36.2</td>
<td>0.0990</td>
<td>5.6</td>
<td>53.2</td>
<td>275.0</td>
<td>0.7528</td>
</tr>
<tr>
<td>3.6</td>
<td>25.1</td>
<td>43.5</td>
<td>0.1190</td>
<td>5.8</td>
<td>57.3</td>
<td>330.7</td>
<td>0.9053</td>
</tr>
<tr>
<td>3.8</td>
<td>27.0</td>
<td>52.3</td>
<td>0.1431</td>
<td>6.0</td>
<td>61.8</td>
<td>397.6</td>
<td>1.0887</td>
</tr>
<tr>
<td>4.0</td>
<td>29.1</td>
<td>62.9</td>
<td>0.1721</td>
<td>6.2</td>
<td>66.6</td>
<td>478.2</td>
<td>1.3092</td>
</tr>
<tr>
<td>4.2</td>
<td>31.4</td>
<td>75.6</td>
<td>0.2070</td>
<td>6.4</td>
<td>71.8</td>
<td>575.0</td>
<td>1.5743</td>
</tr>
<tr>
<td>4.4</td>
<td>33.9</td>
<td>90.9</td>
<td>0.2489</td>
<td>6.6</td>
<td>77.4</td>
<td>691.5</td>
<td>1.8932</td>
</tr>
<tr>
<td>4.6</td>
<td>36.5</td>
<td>109.3</td>
<td>0.2993</td>
<td>6.8</td>
<td>83.5</td>
<td>831.6</td>
<td>2.2767</td>
</tr>
<tr>
<td>4.8</td>
<td>39.4</td>
<td>131.5</td>
<td>0.3600</td>
<td>7.0</td>
<td>90.0</td>
<td>1000.0</td>
<td>2.7379</td>
</tr>
<tr>
<td>5.0</td>
<td>42.4</td>
<td>158.1</td>
<td>0.4329</td>
<td>min($D_w$) = 20.0 km, min($T_w$) = 25.0 days, $T_w / T_{w, forshocks} = 5.0$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All events occurring within time $T_w$ after the main-shock, and within $D_w$ km from its epicentre were declared aftershocks, and were removed from the catalogue. The foreshocks were identified using the same spatial windows, but with 5 times shorter time span. The particular window sizes used are the result of experience in years of analyses of Croatian seismicity and turned out to produce the main-shock catalogues whose complete parts are Poissonian at least on the 0.95 level of significance when tested by the Anderson-Darling or the $\chi^2$-tests. They are intermediate between the values suggested by Gardner and Knopoff, [35] and Knopoff [36].

The resulting main-shock catalogues were merged, and duplicate events were identified as those whose epicentres are closer than $\Delta R$, their occurrence times are less than $\Delta T$ apart, and their magnitudes differ by $\Delta M$ or less (Table 2).

Table 2. Maximal distances between epicentres ($\Delta R$) and differences of origin times ($\Delta T$) and magnitude ($\Delta M$) between pairs of main-shocks from different catalogues to be declared duplicates, as a function of time. Actual values are obtained by interpolation.

<table>
<thead>
<tr>
<th>Year</th>
<th>BC</th>
<th>1500</th>
<th>1700</th>
<th>1850</th>
<th>1920</th>
<th>1990</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta R &lt;$</td>
<td>100 km</td>
<td>100 km</td>
<td>50 km</td>
<td>50 km</td>
<td>50 km</td>
<td>45 km</td>
<td>45 km</td>
</tr>
<tr>
<td>$\Delta T &lt;$</td>
<td>10 days</td>
<td>5 days</td>
<td>1.5 days</td>
<td>2 h</td>
<td>1 min</td>
<td>1 min</td>
<td>1 min</td>
</tr>
<tr>
<td>$\Delta M &lt;$</td>
<td>3.0</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
As a rule the preference was given to the record from the authoritative catalogue (the catalogue from the country where the epicentre is located). For Bulgaria, data were taken entirely from other contributing catalogues, including the global ones. In case of events in the border regions, the coordinates, origin times and magnitudes were computed as weighted averages of all contributing data, and weights were assigned depending on the distance from the respective border. After removing duplicate events, the catalogue was declustered once again. No manual checks of the data were performed.

The first BSHAP catalogue contains 10819 records for earthquakes (main-shocks only) with magnitudes $M \geq 3.0$ from the period 480 BC - 2008 AC, within the latitudes 39.0-47.5°N and longitudes 12.5-24.5°E. Figure 11 shows epicentres colour-coded to indicate their catalogue of origin.

Further on, the completeness analysis was performed for a set predefined threshold magnitudes, obtaining the “staircase” graphs for each country separately - as a check, and for the whole region.

Knowing the completeness interval for each magnitude class, the $b$-value and the normalized reference activity rate ($N_r$) in the Gutenberg-Richter recurrence relationship

$$\log N = \log N_r - b(M - M_r)$$  \hspace{1cm} (1)

was estimated by the maximum-likelihood method using the algorithm proposed by Weichert [44]. In (1), $N$ is the activity rate, i.e. the annual number of earthquakes per standard area (equal here to 10,000 km$^2$) with magnitudes greater or equal to $M$, $M_r$ is arbitrarily chosen reference magnitude ($M_r = 3.5$ here), and $N_r$ is the corresponding activity rate.

Figure 11. BSHAP earthquake catalogue (release version F) represented as the map of epicentres (main-shocks only).
The estimated frequency-magnitude distribution closely follow the log-linear relationship (1) for small magnitudes, and that the resulting $b$-values are 'normal' (close to 1), which indicates that completeness thresholds have been determined reasonably well.

The same procedure was applied to the BSHAP data for every node in a grid (22 × 22 km) covering the whole area under study. In order to ensure large enough number of earthquakes within each circular window during computation of recurrence parameters, its radius was allowed to vary between $r = 30$ km and $r = 150$ km, until it contained at least 50 earthquakes within their respective time interval of complete reporting.

The year of onset of complete reporting for the four magnitude levels are shown in Figure 12, which presents rather consistent picture, clearly identifying regions (Slovenia, NW Croatia, southern Hungary and central Italy) with comparatively more complete catalogues than the rest of the region.

Having established the spatial completeness pattern of the catalogue, it was straight-forward to compute geographical distribution of the $b$-value and the activity rate $N_t$ by using Weichert’s [44] maximum likelihood approach. The map of calculated $b$-values for the BSHAP region is represented in Figure 13 with the resulting standard deviation of data. The $b$-value is mostly found to be in the interval 0.75—1.10, which are normal values found all over the World. No clear regularity is obvious – the active regions of southern Dinarides, the Apennines or Central Slovenia are characterized by lower than average values, indicating higher proportion of large-events and the same is true also for the areas of the lowest seismicity (southern Adriatic Sea, Slavonia, Hungary, northern and eastern Serbia). Values about $b = 1.0$ or higher are characteristic of Istria and Pokupsko in Croatia, the Central Adriatic Sea, and the belt along the Dinarides, Albanides and Hellenides stretching from the Lika area in Croatia, along central Bosnia and Herzegovina to Montenegro, Albania and Greece.

Figure 12. Initial years of complete reporting for magnitudes $M = 3.0$, 3.5, 4.0 and 4.5. Circles are epicentres of earthquakes with magnitude exceeding $M = 3.5$. 

Figure 13. The map of calculated $b$-values for the BSHAP region with the resulting standard deviation of data.
Figure 13. a) Map of the b-value in the Gutenberg-Richter relation for the western Balkan region derived from the BSHAP earthquake catalogue data; b) Standard error of the b-value. Epicentres of main shocks are presented by open circles.

The calculated earthquake activity rate for magnitude threshold 3.5 ($N_{3.5}$) is presented on Figure 14 and expressed as the number of earthquakes expected to occur in 10 years period on an area of 10,000 km$^2$ (100 $\times$ 100 km) around any point on the map.

For the constraining of maximum possible magnitudes the informative Map of maximum magnitudes that occurred in the period 1500-2009 within 25 km of each grid point of BSHAP investigation area was created (Figure 15).

The provided First BSHAP catalogue analyses made insight into some of the fundamental parameters needed for seismic hazard assessment. For instance, it seemed reasonable to define seismic source zones so that recurrence parameters do not change abruptly within any of them, thus ensuring their homogeneity which is difficult to assess a priori. Maps as presented in Figures 13 and 14 and 15 were created for a purpose of more direct use, in the course of PSHA - using zoneless or the smoothed seismicity approach (e.g. papers by Frankel [45], Frankel et al. [46], Lapajne et al. [47]).
4.2.2 Final BSHAP catalogue

With the main intention to harmonize the indispensable fields required for seismic hazard (date and time origin, epicenter location) and all the available data for better magnitude characterization, including the database of ISC (Ms, mb), CMT catalog of Harvard, EMMA database, and RCMT catalogs provided by INGV and ETHZ - for the investigated area, the final BSHAP catalogue in the extended format was generated. Still with a lot of missing data, every project partner should be able to complete its extended form later for its country.

The Final BSHAP catalogue is manual check-out of full national and available catalogues compilation. It has been compiled by: Li. DUNI, Dept. of Seismology, Institute of Geosciences from Tirana, Albania, in the frame of the BSHAP Project, based on the following earthquake catalogues:

TIR-Tirana, Albania
BLY-Banja Luka, Bosnia and Herzegovina
SAR-Sarajevo, Bosnia and Herzegovina
SOF-Sofia, Bulgaria
ZAG-Zagreb, Croatia
NOA-National Observatory of Athens, Greece
UOA-University of Athens, Greece
THE-University of Thessaloniki, Greece
BUD-Budapest, Hungary
ROM-Roma, Italy (CPTI04)
SKO-Skopje, Macedonia
PDG-Podgorica, Montenegro
BUC-Bucurest, Romania
LJU-Ljubjana, Slovenia
BEO-Belgrade, Serbia
SHE-Shebalin & Leydecker catalogue (1998)
ANSS-ANSS Online Catalogue
EMSC-CSEM-EMSC center
ISC-International Seismological Center
CMT and RCMT evaluations have priority over other catalogues
KRN-Karnik 1996 Catalogue
NEIS-NEIC/NEIS catalogue, USA
HRV-CMT Harvard Catalog
INGV-Regional Centroid Moment Tensor RCMT (INGV)
ETHZ-RCMT from Zurich.
EMMA- EMMA database, Version 2

Unlike the first BSHAP catalogue version, the national catalogues had been merged and then the multiples removed. The BSHAP catalogue contains total number of 13341 earthquakes events with magnitude larger than 3.5 occurred within the area 12.5-24.5°E longitude and 38.0-47.5°N latitude. Events are ranging for the period 510 BC-31/12/2010.
Criteria to merge the available catalogues were:
- The project partner’s catalogues have priority over other catalogues.
- The events occurred in the border areas were located consulting the respective partners. However, epicenter re-location at the border area still remains problematic.

4.3. Magnitude unification

Unfortunately, seismological institutions of the region report the information regarding the earthquakes size in different magnitude scales (\(M_L, M_S, m_b, M_W\), etc.). For the historical events they use the epicentral intensity, \(I_o\), and later convert it in \(M_S\) or any other equivalent magnitude, using regression models with \(I_o\) and other focal parameters as input (Karnik, 1996). For the instrumental period, usually the earthquake size is expressed in terms of local magnitude, \(M_L\). But the instrumentation and procedures used for \(M_L\) determination are rather different, thus the \(M_L\) magnitudes reported by different centers cannot be considered as equivalent. Hence, it is not possible to define a unique regional relation converting \(M_L\) to \(M_W\) or to any other magnitude scale. Therefore local relations have to be used.

Because at present almost all Ground Motion Predictive Models (GMPM) use moment magnitude as one of the explanatory variables, it is indispensable to have a homogenous unified earthquake catalog in terms of \(M_W\), for both historically known and the instrumentally recorded events. The \(M_w\) estimation was preceded by a detailed statistical investigation regarding the relationships between different magnitude scales used by the seismic networks of the region, with a view to check the magnitude consistency reported by the above mentioned agencies with the \(M_w\) magnitude obtained by the centroid moment tensor solutions (Harvard CMT catalogue, PDE catalogue) or from RCMT solution (INGV, ETHZ).

Converting of \(M_{SK}, M_S\) and \(m_b\) to \(M_w\)

The converted, or re-estimated macroseismic magnitudes from Karnik and Shebalin catalogues, were converted in \(M_w\) using the relevant regression relations of Scordilis (2006):

\[
\begin{align*}
M_w &= 0.80 \cdot M_{SK} + 1.31 & 4.0 \leq MSK < 5.4 & (1) \\
M_w &= 0.70 \cdot M_{SK} + 1.80 & 5.4 \leq MSK < 6.3 & (2) \\
M_w &= 1.04 \cdot M_{SK} - 0.33 & 6.3 \leq MSK \leq 8.1 & (3)
\end{align*}
\]

\(M_S\) and \(m_b\) magnitudes reported in the bulletins of ISC are converted in \(M_w\) using equations presented in the Table 4. These relations are derived recently (August 2011), using all the data available for the BSHAP area till April 2011 in the bulletins of ISC for \(M_S\) and \(m_b\), and in the catalogues of Harvard, INGV and ETHZ for \(M_w\). Two regression models are applied, the quadratic and rational. The fit is the same for both models, but the rational model is simpler and fits better for the small events. As can be easily seen from the Table 4 and the figures 16 and 17, the present regional regression relations fits the data in the BSHAP area, more closely than the relevant relations derived globally by Scordilis (2006).

<table>
<thead>
<tr>
<th>Regression model (M_w=b_0+b_1\times M+b_2\times M^2)</th>
<th>Number of events</th>
<th>Determination coefficient, R2</th>
<th>Stand. dev. of regression, se</th>
<th>Application Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M_w=3.948 - 0.177M_S + 0.08626M_S^2)</td>
<td>293</td>
<td>0.903</td>
<td>0.175</td>
<td>3.0≤MS≤7.0</td>
</tr>
<tr>
<td>(M_w=5.887 - 1.433mb + 0.25512mb^2)</td>
<td>367</td>
<td>0.872</td>
<td>0.197</td>
<td>3.5≤mbs≤6.2</td>
</tr>
<tr>
<td>(M_w = \frac{1}{(b_0 + b_1 \times M)})</td>
<td></td>
<td></td>
<td></td>
<td>3.0≤MS≤7.0</td>
</tr>
<tr>
<td>(M_w = \frac{1}{(0.31304 - 0.024282Ms)})</td>
<td>293</td>
<td>0.176</td>
<td></td>
<td>3.5≤mbs≤6.2</td>
</tr>
<tr>
<td>(M_w = \frac{1}{(0.40266 - 0.041342mb)})</td>
<td>367</td>
<td>0.198</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Converting of M<sub>L</sub> to M<sub>w</sub>

To enable conversion to M<sub>w</sub> of the local magnitudes M<sub>L</sub> calculated by the seismological centers of the region, we updated the empirical relations derived in 2010 (Duni et al., 2010), using an extended datasets for the BSHAP area, accepting as reference the moment magnitude reported by Harvard CMT solutions (Dziewonski et al., 1981) and the regional moment tensor solutions reported by INGV (Rome) and ETHZ (Zürich) till May 2011. About 500 CMT/RCMT solutions for medium-strong events in the BSHAP area, varying from M<sub>w</sub>=3.75 to MW=6.9, are used to derive the local relations converting the local magnitudes M<sub>L</sub> to M<sub>w</sub>.

The summary results are presented on the Table 5 and Figure 18. The method used is that of errors-in-variables regression.
Table 5. Correlative relationships between moment magnitude Mw and local magnitude ML.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Regression equation $M_w = b_0 + b_1 \cdot M_L$</th>
<th>Number of events</th>
<th>Determination coefficient, $R^2$</th>
<th>Stand. dev. of regression, $se$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tirana</td>
<td>$M_w = 1.423 + 0.768M_L$</td>
<td>91</td>
<td>0.687</td>
<td>0.273</td>
</tr>
<tr>
<td>Pogdorica</td>
<td>$M_w = 0.690 + 0.900M_L$</td>
<td>55</td>
<td>0.921</td>
<td>0.166</td>
</tr>
<tr>
<td>Zagreb</td>
<td>$M_w = 0.489 + 0.853M_L$</td>
<td>29</td>
<td>0.735</td>
<td>0.283</td>
</tr>
<tr>
<td>Belgrade</td>
<td>$M_w = 0.414 + 0.938M_L$</td>
<td>26</td>
<td>0.855</td>
<td>0.218</td>
</tr>
<tr>
<td>Skopje</td>
<td>$M_w = 0.684 + 0.907M_L$</td>
<td>19</td>
<td>0.742</td>
<td>0.273</td>
</tr>
<tr>
<td>Thessaloniki</td>
<td>$M_w = 0.383 + 1.010M_L$</td>
<td>109</td>
<td>0.830</td>
<td>0.220</td>
</tr>
</tbody>
</table>

Figure 18. Relationships between moment magnitude Mw and the local magnitude, ML.

4.4. Data completeness with time and catalogue declustering

The BSHAP catalogue can be considered complete from magnitude Mw 4.0.

Figure 19. Magnitude completeness of final BSHAP catalogue
Completeness levels are estimated from the earthquake catalog, by using the cumulative number of events versus time graphs, in order to evidence slope changes, assuming that the most recent change in slope occurs when the data became complete for magnitudes above the reference (Gasperini and Ferrari, 2000).

By making use of the cumulative number versus time graphs (Figure 20), we identified magnitude intervals: 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5 and 7.0. The described catalogue can be considered complete since:

<table>
<thead>
<tr>
<th>Year</th>
<th>for earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>$M_W \geq 4.0$</td>
</tr>
<tr>
<td>1955</td>
<td>$M_W \geq 4.5$</td>
</tr>
<tr>
<td>1905</td>
<td>$M_W \geq 5.0$</td>
</tr>
<tr>
<td>1830</td>
<td>$M_W \geq 5.5$</td>
</tr>
<tr>
<td>1600</td>
<td>$M_W \geq 6.0$</td>
</tr>
<tr>
<td>1400</td>
<td>$M_W \geq 6.5$</td>
</tr>
<tr>
<td>1150</td>
<td>$M_W \geq 7.0$</td>
</tr>
</tbody>
</table>

Declustering procedure follows the same rules already applied in First BSHAP catalogue version. Instead of time and space rectangular window frame filtering (Table 1) the polynomial regression of 4-th order has been applied to fit the same constrains, expressed as follows.

\[
DX_{\text{max}}[\text{km}] = 13.62376 - 4.6758 \cdot M_w + 3.1428669 \cdot M_w^2 - 0.4115956 \cdot M_w^3 + 0.04010185 \cdot M_w^4
\]

\[
DT_{\text{max}}[\text{days}] = 1449.8806 - 1429.3413 \cdot M_w + 528.79571 \cdot M_w^2 - 86.982819 \cdot M_w^3 + 5.61304210 \cdot M_w^4
\]

The filtering process reduced the number of events, present in full Final catalogue, from total of 13,341 earthquakes to 5,722 main events (above 3.5 Mw magnitude). The 5,722 of foreshock and 7,619 aftershock earthquakes were extracted.

Figure 21 shows the comparison of activity rates (number of events - since year 1900, per year and per 10,000 sq. km) calculated for the First version of the BSHAP earthquake catalogue (left) and the Final one (right). The activity distribution pattern is similar; activity rates are a bit lower in case of the Final catalogue as the result of rejection of some doubtful events.
Figure 21. Comparison of earthquake activity rates (the number of events per year and per 10,000 sq. km since year 1900) calculated for the First version of the BSHAP earthquake catalogue (left) and the Final one (right).

Figure 22. Gutenberg-Richter relationship recurrence parameters (coefficients: a - left and b - right), calculated for the Final main BSHAP catalogue

Seismicity parameters

Reliable evaluation of the seismic hazard is strongly dependent on the accurate estimation of seismicity parameters, such as the magnitude-frequency relation coefficients (a- and b-values in G-R relation), the mean annual rate of seismic activity $\lambda$, the completeness level of the seismic data $M_{min}$ above which the earthquake catalogue can be considered to be complete, and the regional maximum magnitude $M_{max}$. Seismic activity rate is estimated using the double truncated exponential recurrence relationship, in order to confine the range of magnitudes, eliminating the contribution of very small earthquakes at the lower end and unrealistic high magnitude earthquakes at the high end:
\[ \lambda_m = \lambda_m^\text{ \_exp} \frac{\exp[-\beta(m - m_0)] - \exp[-\beta(m_{\text{max}} - m_0)]}{1 - \exp[-\beta(m_{\text{max}} - m_0)]}, \quad m_0 < m < m_{\text{max}} \]

- \( \lambda_m \): the mean annual number of earthquakes with \( M \geq m \).
- \( \lambda_{m_0} \): the mean annual number of earthquakes with \( M \geq m_0 \).
- \( m_0 \): minimum magnitude with engineering interest.
- \( m_{\text{max}} \): maximum magnitude that can be generated in a seismic source.

The recurrence statistics (\( a \)- and \( b \)-values, \( \lambda_{m_0} \)) are obtained from analysis of the BSHAP catalog, using a MLE method that accounts for variable completeness (Bollinger et al. 1993; Weichert 1980, Berril and Davis 1980). This estimation is repeated for each of the source zone (about 70) identified from the seismotectonic analysis of the BSHAP region.

The doubly-truncated G-R exponential model is characterized by three parameters: \( \lambda_m \), \( b \), and \( m_{\text{max}} \). After their assessment, a final manual check and tuning is applied for every source zone, inspecting carefully how the model obtained fits the respective observed data. This procedure enables an accurate calculation of the seismicity rates.

4.5.1. Assessment of maximum magnitude

The size of the largest expected earthquake, \( M_{\text{max}} \), is one of the most critical parameters, with large impact into seismic hazard assessment, at least for large return periods. It is region dependent, and very difficult to be estimated, because the physical significance of \( M_{\text{max}} \) is poor and the corresponding database statistically very limited. Various methods are described in the literature to estimate \( M_{\text{max}} \), however, there is not a general consensus in this regard. Some authors recommend estimation of \( M_{\text{max}} \) based on release of accumulated energy in the course of long periods of time, or on the basis of the well documented faults length (Wells and Coppersmith, 1994). Other authors prefer to apply statistical models (Kijko, 2004; Kagan, 2006).

The dominant scientific opinion is that \( M_{\text{max}} \) should be estimated from tectonic or geological principles rather than by examination of earthquake catalog data that spans a time period that is only a fraction of the recurrence times of the largest modeled events. Meanwhile, there exist some general principles that are widely recommended (Giardini et al., 2004) such are:

- The maximum magnitude, \( M_{\text{max}} \), should be relatively large, because big earthquakes may have very large return period that sometimes exceeds 10,000 years and probably are not evidenced in the historical or geological documents.
- The estimation of \( M_{\text{max}} \) to some extent should reflect the uncertainties that associate this parameter.
- \( M_{\text{max}} \) should not differ too much among the different zones; this reflects the conviction that there are not fundamental differences between tectonic regions that would justify a different behavior in regard to the expected maximum magnitude.

For the estimation of \( M_{\text{max}} \) the historical-parametric approach of Kijko-Selevoll (1989, 1992) was used, based on the observed seismicity. Except the above mentioned principles, during the calculations we took into account the previous evaluations based on geological considerations of seismogenic potential of seismotectonic zones (Aliaj et al., 2004). These estimations are used for the seismic hazard calculation. The maximum magnitude ever observed in the region is \( M_{\text{max}} = 7.7 \) for the entire historically and instrumentally documented period.

Maximum magnitude within a given seismogenic zone (or a larger region) may also be estimated by statistical methods using only seismic catalogues. For instance, Kijko [62] proposed a generic equation for the estimation of the maximum earthquake magnitude which may be used under various assumptions about the statistical magnitude distribution or the available information regarding past seismicity.
Figure 15 shows maximum magnitudes of earthquakes which occurred in the period 1500 - 2009 within 25 km of each grid point. Maps like this one, going back into the past several hundreds of years can be useful in constraining maximum possible magnitudes inferred from fault lengths and other geological information. When used together with maps presenting other recurrence parameters (like those in Figures 13 and 14) they can provide a solid basis for delineation of areal seismic source zones. For the areas with no available geological information, $M_{\text{max}}$ can even be defined using only seismological data, as the maximum observed magnitude within a seismogenic zone increased by $\Delta M$, which has to be defined taking into account the tectonic setting and the time span of complete reporting of the strongest events in the catalogue.

4.6. Ground Motion Prediction Models

Ground-motion prediction equations or attenuation relations are generally the component with the largest influence on the seismic hazard assessment. They relate the source characteristics of the earthquake and the peculiarities of the seismic wave’s propagation path with the ground motion at the site of interest. The ground-motion prediction is usually quantified in terms of a median value (which is a function of magnitude, distance from the earthquake source, style of faulting, and other factors) and a probability density function, of PGA or spectral accelerations. Ground Motion Predictive Models (GMPE) are usually developed from the statistical analysis of strong-motion records available for the given region.

Due to the absence of regional strong-motion data, an indigenous ground-motion model is not available for the Balkan region. In these circumstances it is necessary to consider ground-motion predictive models developed for regions with similar geological and tectonical features, or models accepted and used worldwide, such as those generated recently by the NGA project in USA (EERI, 2008) or recommended by a scientific working group on GMPEs which can be used in the Project SHARE (Seismic Hazard of Europe).

Based on the evaluation of the SHARE project (Segou and Akkar, 2010) on the validity and ranking of the different GMPEs which can be used in the Europe, the selected GMPEs for this study are the pan-European model derived by Akkar and Bommer (2010), the global models of Boore and Atkinson (2008) and Cauzzi and Faccioli (2008), as well as the Italian ground-motion model proposed by Bindi et al. (2009). These models are valid for active shallow crustal regions; the seismotectonic setting suitable for the BSHAP area. The seismic hazard outputs obtained from these models are combined according to a weighting scheme implemented in the logic-tree approach.

In the following is presented a brief description for each of the GMPEs chose to be used for the BSHAP project:


$$\log_{10} Y = a + b_1(M_w - M_{\text{ref}}) + b_2(M_w - M_{\text{ref}})^2 + (c_1 + c_2(M_w - M_{\text{ref}})) \log_{10} \sqrt{R^2 + h^2} + e_i s_i + f_j f_j$$

where $Y$ is the response variable (maximum between horizontal components); $M_{\text{ref}}$ is a reference magnitude; $R$ is the distance; $h$ is the pseudodepth (km); $S_i$ with $i=1,2,3$ are dummy variables that assume either the value 0 or 1 depending on soil type (rock, class C0: $S_1=1$ and $S_2=S_3=0$; shallow alluvium, class C1: $S_2=1$ and $S_1=S_3=0$; deep alluvium, class C2: $S_3=1$ and $S_1=S_2=0$); $F_j$ are dummy variables that take either the value 0 or 1 depending on the style of faulting (normal fault: $F_1=1$ and $F_2=F_3=0$; strike-slip: $F_2=1$ and $F_1=F_3=0$; reverse fault: $F_3=1$ and $F_1=F_2=0$); $e_i$ and $f_j$ are the site and the style-of-faulting coefficients, respectively. Two different set of regressions were performed, considering either the epicentral distance ($Re_p$) or considering $R_{jb}$ for $M \geq 5.5$ and $Re_p$ for smaller magnitudes.


$$\ln(y) = f_w(M) + f_d(R,M) + f_f(F) + f_S(S),$$
Here, $y$ is the response variable; $f_m(M)$, $f_d(R,M)$, $f_f(F)$ and $f_s(S)$ are magnitude, distance, faulting mechanism and site amplification functions, respectively.

The magnitude scaling is given by:

$$f_m(M) = \begin{cases} 
  e_3(M - M_h) + e_6(M - M_h)^2, & M \leq M_h \\
  e_7(M - M_h) + e_8(M - M_h)^2, & M > M_h 
\end{cases}$$

where $M_h$ is the “hinge magnitude” for the shape of magnitude scaling.

The distance function is given by:

$$f_d(R,M) = [c_1 + c_2(M - M_{ref})] \ln(R/R_{ref}) + c_3(R - R_{ref}) + c_4(M - M_{ref})(R - R_{ref})$$

where $R = \sqrt{R_{JB}^2 + h^2}$, $R_{JB}$ is the Joyner-Boore distance in km.

The influence of fault type is characterized by the following equation:

$$f_f(F) = e_1U + e_2SS + e_3NS + e_4RS$$

where $U$, $SS$, $NS$, $RS$ are dummy variables used to denote unspecified, strike-slip, normal-slip, and reverse-slip fault types, respectively (Table 5).

The site amplification can be considered using the following model:

$$F_s(S) = F_{lin} + F_{NL}$$

where $F_{LIN}$ and $F_{NL}$ are the linear and nonlinear terms, respectively.

### Table 6. Dummy variables for different fault types

<table>
<thead>
<tr>
<th>Fault Type</th>
<th>U</th>
<th>SS</th>
<th>NS</th>
<th>RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unspecified</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Strike-slip</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Thrust/reverse</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

The coefficients $e_i$ ($i=1, \ldots, 8$), $M_h$, $c_i$, $c_5$, $c_6$, $M_{ref}$, $R_{ref}$ and $h$ are determined by regression analysis (Boore and Atkinson, 2007, 2008). Their values for PGA, PGV and PSA (for 5% damping) corresponding to 21 periods, (from 0.01-sec up to 10-sec), as well as the details concerning determination of $F_{LIN}$ and $F_{NL}$ can be found in the relevant papers (Boore and Atkinson, 2007, 2008).

3. Akkar & Bommer (2010):

$$\log(y) = b_1 + b_2M + b_3M^2 + (b_4 + b_5M) \log \sqrt{R_{JB}^2 + b_6^2 + b_7S_S + b_8S_A + b_9F_N + b_{10}F_R}$$

where $y$ is given in cm/s$^2$.

$b_1 = 1.04159$, $b_2 = 0.91333$, $b_3 = -0.08140$, $b_4 = -2.92728$, $b_5 = 0.28120$, $b_6 = 7.86638$, $b_7 = 0.08753$, $b_8 = 0.01527$, $b_9 = -0.04189$, $b_{10} = 0.08015$, $\sigma_1 = 0.2610$ (intra-event) and $\sigma_2 = 0.0994$ (inter-event).

The formula utilizes three site categories:

- Soft soil $S_S = 1$, $S_A = 0$.
- Stiff soil $S_A = 1$, $S_S = 0$.
- Rock $S_S = 0$, $S_A = 0$.

Three faulting mechanism categories may be specified:

- Normal $F_N = 1$, $F_R = 0$.
- Strike-slip $F_N = 0$, $F_R = 0$. 34
Reverse $FR = 1$, $FN = 0$.


$$\log_{10}(y) = a_1 + a_2 \cdot Mw + a_3 \cdot \log_{10}(R) + a_B \cdot S_B + a_C \cdot S_C + a_D \cdot S_D$$

where $y$ is in m/s$^2$, $a_1 = -1.296$, $a_2 = 0.556$, $a_3 = -1.582$, $a_B = 0.22$, $a_C = 0.304$, $a_D = 0.332$ and $\sigma = 0.344$ for horizontal PGA.

Use four site categories based on Eurocode 8:
- A Rock-like, $V_{S30} \geq 800$ m/s. $S_B = S_C = S_D = 0$.
- B Stiff ground, $360 \leq V_{S30} < 800$ m/s. $S_B = 1$, $S_C = S_D = 0$.
- C $180 \leq V_{S30} < 360$ m/s. $S_C = 1$, $S_B = S_D = 0$.
- D Very soft ground. $V_{S30} < 180$ m/s. $S_D = 1$, $S_B = S_C = 0$.

4.7. Estimation of ground motion parameters

If we denote with $\lambda_i(m_0)$, the mean annual number of events with magnitude greater than $m_0$ in the seismic zone $i$, then the mean annual number of events from this source, that on a certain site induce a seismic intensity greater to a specified value $u$, can be calculated by:

$$P(U > u) = \sum_{i=1}^{n} \lambda_i(m_0) \cdot P(U > u),$$

where $P(U > u)$ indicates the conditional probability of the occurrence of a higher intensity compared to a specified value $u$, when it is known that the vector $x$ take place.

Let us suppose that the study area is influenced by $n$ seismic sources. Supposing the earthquake occurrence processes on these zones are independent to each other, the mean annual number of events from all sources that generate a seismic intensity greater than a given value $u$, can be estimated based on the aggregation property of $n$ independent Poisson processes:

$$\mu_u = \sum_{i=1}^{n} \mu_i(u) = \sum_{i=1}^{n} \lambda_i(m_0) \int \int F_{M_i}(m) \cdot f_{R_i}(R) \cdot dm \cdot dR \quad (2)$$

The quantity $\mu_u$ is called the annual rate of exceedance. As it can be seen, the annual rate of exceedance for a given value of ground motion parameter is taken by aggregating the contributions of all individual sources that can influence on the given site.

If the earthquake recurrence process in every source zone is a stationary Poissonian process, then the probability that in a certain site, a specified level $u$ of seismic intensity to be exceeded at least once during the time period $T$, is given by:

$$P_T(U > u) = 1 - e^{-\mu_u T} \quad (3)$$

For $T=1$ year, the equation (3) gives the annual exceedance probability of the level $u$ of the ground motion, at least once in one year:

$$PE(u) = P_T(U > u) = 1 - e^{-\mu_u} \quad (4)$$

The reciprocal of the annual probability of exceedance gives the return period $RP_u = 1/PE_u$.

Applying the equation (2) for a series of values $u_i$, $i = 1, ..., n$, the corresponding series $\mu_{u_i}$ is obtained, that can be used to set up the seismic hazard curve for the given site, which represents the relationship between the annual rate of exceedance and the ground motion parameter. The seismic hazard curve is further used for determination of the ground motion value that corresponds to the chosen value of the return period.
Usually, in the engineering practice is required to evaluate seismic hazard for a time duration (for example, 50 years) that corresponds to the lifetime of the structure to be designed. Under the Poisson hypothesis, we’d have:

\[
P_E(t(u)) = 1 - [1 - P_E(u)]^t
\]

(5)

where \( P_E(t(u)) \) is the probability of exceedance of the \( u \) level of the ground motion during \( t \) years. From the formula (5), it is not difficult to calculate the annual probability of exceedance, \( P_E \), when the hazard \( P_E \) for \( t \) years is given:

\[
P_E(u) = 1 - [1 - P_E(t(u))]^{1/t}
\]

(6)

For example, 10% probability of exceedance in 50 years corresponds to the annual probability \( P_E = 0.002105 \), or to the return period \( R_P = 475 \) years.

The independency of the events in a Poissonian process often doesn’t comply with the reality. In fact, if an earthquake is result of a sudden release of an energy accumulated gradually in the earth’s crust, it is evident that the time series of these events cannot be considered as Poissonian processes. However, if the foreshocks and aftershocks are discarded and only the main events are taken into consideration, then it could be reasonable to accept the process as a Poissonian one.

5. PROBABILISTIC SEISMIC HAZARD ASSESSMENT

In the process of probabilistic seismic hazard assessment, two main requirements are usually problematic:

- Earthquake catalogue completeness and
- The need to specify seismic source zones.

The second requirement often needs the expertise of many independent groups of specialists in order to create different models of seismic sources that in many cases are too subjective. In fact, the mean annual rate of seismic activity varies from one point to another, and it is a function of the geographical position. In the context of the seismic source zones method, each of them is associated with a unique, constant seismic activity rate within the zone, expressed in terms of mean annual number of events exceeding the threshold engineering magnitude inside it. Assumption that seismicity within a seismic zone is uniform often is conflicting with the spatial distribution of the earthquake epicenters. On the contrary, this geometry appears structured and can be characterized by a fractal distribution.

For that reason, the zoneless approach is obtaining increasing consensus in the framework of the seismic hazard studies (Frankel, 1995; Woo, 1996; Crespo and Martin, 2002; Martin et al., 2002; National Seismic Hazard Maps program in USA, USGS 1996, 2002-2003, 2008). Here, the seismicity rate is considered a spatial random variable, and not presumed as constant within different seismotectonic zones. The zoneless methods operate beyond the seismotectonic zoning concepts and avoid all the subjectivism in the delineation of the seismic source zones. The method represents a consolidated alternative for the seismic hazard assessment and is based on the models of seismic activity that derives directly from the earthquake catalogue.

Between various probabilistic zoneless methods in use, the smoothed-gridded methodology developed by Frankel (1995) was used in the BSHAP project, which is the official method for the assessment of seismic hazard in USA. This methodology has been used to compile the national seismic hazard maps in the 1996 and 2002-2003 editions (Frankel et al., 1996, 2000, 2002), and is used recently for the preparation of the new edition of the 2008 (Petersen et al., 2008). The method still follows the basic approach established by Cornell in 1968, but no delineation of seismic sources is needed.

The general methodology include four different classes of earthquake source models (Petersen et al., 2008): (1) smoothed-gridded seismicity, (2) uniform background zones, (3) geodetically derived source zones, and (4) faults. The first two models are based on the earthquake catalog
and characterize the hazard from earthquakes between about M=5 and M=6.5-7.0. The geodetically derived source zones are used to derive the hazard between M=6.5 and the largest potential earthquake in a region. In most cases, the faults contribute most to the hazard for earthquakes larger than M=6.5.

Random seismicity-derived sources account for two types of earthquakes: those that occur off known faults, and moderate-size earthquakes that are not modeled on faults. The gridded-seismicity models are based on historical earthquakes and account for the expectation that future large, damaging earthquakes will occur near previous small and moderate-size earthquakes (Frankel, 1995). Uniform background zones account for the possibility of future random seismicity in areas without historical seismicity and establish a floor to the seismic-hazard calculations. Special zones allow for local variability in seismicity characteristics within a zone (for example, changes in b-value, changes in maximum magnitude M_max, and uniform seismicity characteristics). These models are combined to account for the suite of potential earthquakes that can affect a site.

Seismicity rates are determined by counting earthquakes in each grid cell with dimensions 0.1 degree in latitude and longitude, and adjusting for completeness, giving a maximum-likelihood estimate of the local rate (Frankel, 1995). A two-dimensional spatial Gaussian function is used to smooth the gridded rates. Choices of smoothing parameters (correlation distance) are based on judgments about earthquake location uncertainties and spatial trends observed in historical seismicity. The resulting \( \lambda \)-grid gives the annual rate of earthquakes with magnitude greater or equal to the lower-bound magnitude of the earthquake catalogue.

The Frankel's method was improved by Lapajne et al., (1997, 2003), including into calculation the seismotectonic characteristics of the region. Smoothing of seismicity rates is performed in two stages. First, a circular (Gaussian) smoothing is carried out to account for errors in the earthquake epicenter location. After that, an elliptical rupture-oriented smoothing is performed, following the orientation of the earthquake generation tectonic faults in the region. Choices of elliptical smoothing parameters are based on the supposed size (length and width) of the tectonic faults, estimated according to the maximum possible magnitude of the region. The fault type, strike and the weight of a certain faults in a seismotectonic zone are specified in a separate seismotectonic file, together with the vertices coordinates of the zone. Incorporation of the seismotectonic data enables application of the ground motion attenuation relations using the shortest distance to the causative fault and not only the epicentral distance. The impact of the strong historical earthquakes on the seismic hazard is taken into account by adding in the analysis seismicity models that are based in the energy released.

The hazard is calculated for potential earthquakes at each grid cell. Earthquakes smaller than M=6.0 are characterized as point sources at the center of each cell, whereas earthquakes larger than M=6 assume hypothetical finite vertical or dipping faults centered on the source grid cell. Lengths of the finite faults are determined using the Wells and Coppersmith (1994), or user defined relations, accounting for the related faulting style. Based on the smoothed seismicity rates and applying appropriate ground-motion predictive models, the annual rate of exceedance of the specified level for a given ground motion parameter, and finally the relevant value corresponding to a given return period specified by the user is calculated. The adopted approach considers different alternatives about fundamental hypothesis on input parameters to account for and to propagate uncertainties in the model, within a logic-tree framework.

Quantification of active tectonic faults was performed for every seismotectonic zone delineated in the whole BSHAP region and the near surroundings, as it was presented in Figure 9. For all the explained reason the smoothed-gridded methodology for this assessment was chosen and all the calculation has been performed using an upgraded version of the computer code OHAZ 6.0 (Zabukovec, Kuka et al., 2007).

5.1. The results of seismic hazard assessment

At first, the seismicity rates are determined at every grid cell within [12.5°-24.5°E, 38°8 first, the seismicity rates are determined at every grid cell within [12.5°-24.5°E, on.re exefixed at \( M_w=4.0 \), and adjusting this value using a maximum likelihood method (Weichert, 1980) that
accounts for variable completeness. Then, the adjusted earthquake rates are spatially smoothed using a two-dimensional Gaussian smoothing operator with correlation distance 20 km, and an elliptical smoothing oriented according to the main tectonic faults within the identified seismotectonic zones.

Hazard curves that depict the annual frequency of exceedance at given ground-motion levels are calculated at the cells included within a smaller grid (13.0°-23.2°E, 39.5°-5.6°). To calculate hazard from a particular source, we apply a doubly-truncated exponential magnitude-frequency distribution, with b-value corresponding to the relevant zone. The lower bound magnitude \( M_{\text{min}} \) is fixed at \( M_W = 4.0 \), while \( M_{\text{max}} \) varies according to the respective zones from 5.6 up to 7.5.

![Probabilistic seismic hazard map for the BSHAP region for horizontal PGA, with the return period of 95 years, for hard rock conditions (Vs30 ≥ 800 m/sec).]
Calculations are accomplished using four PGMEs:

- Bindi et al. 2009 (Bi09),
- Akkar and Bommer 2010 (AB10),
- Boore and Atkinson 2008 (BA08),
- Cauzzi and Faccioli 2008 (CF08).

For simplicity, we have nominated these models as AB10, Bi09, BA08 and CF08, respectively.

Assessment is applied for rock conditions, with 800 m/sec shear-wave velocity in the upper 30 m of the soil section. The maximum source-site distance and the magnitude range used, were chosen in accordance with their magnitude-distance domain: $D_{\max} = 100$ km and $5 \leq M \leq 7.5$ for Bi09 and AB10; $D_{\max} = 200$ km and $5.0 \leq M \leq 7.5$ for BA08; $D_{\max} = 150$ km and $5 \leq M \leq 7.5$ for BA08. The mean values were calculated as the weighted average of the estimations taken using the four aforementioned GPMEs. The accepted final weighting scheme is $w_1 = 0.3$ for AB10 model, $w_2 = 0.3$ for the Bi09, $w_3 = 0.2$ for the BA08 and $w_4 = 0.2$ for CF08 model.

Figure 23. Probabilistic seismic hazard map for the Western Balkan Region (BSHAP) for horizontal PGA, with return period 475 years, for hard rock conditions ($V_{s30} \geq 800$ m/sec).
Based on the results taken according to the above mentioned procedure, the probabilistic seismic hazard maps that characterize the spatial variability of maximum horizontal acceleration (PGA) were compiled. In compliance with EC8 standards, the hazard was calculated for two characteristic return periods: 95 and 475 years, which correspond to the exceedance probabilities of 10\% in 10 years and 50 years, respectively (Figures 22 and 23).

Maximum horizontal acceleration (PGA), in case of 10\% exceedance probability in 50 years (475 years return period) varies from 10-15 \% of g in the region of central and inner Dinarides and Vardar-Morava rift zone, to more than 30 \% at the peri-Adriatic zones, especially at the south-western part of Albania (Fig. 23).

The results of this seismic hazard estimate is consistent to many other previous studies of seismic hazard, such are Giardini (1999) (GSHAP - Global Seismic Hazard Assessment Program), Musone (1999), Husebye (2005), Duni and Kuka (2010), Kuka et al. (2003), Glavatovic (1985), etc.

Upon the discussions of hazard results the common conclusions on hazard assessment are stated as follows:

- The new PSHA for the Western Balkan Countries builds upon extensive research and database compilation carried out over the last three years by the institutions participating in the BSHAP project. Hazard assessment is based on the smoothed-gridded seismicity approach.
- The seismic hazard maps derived in this project are a good basis to characterize the seismic hazard of region. The results of BSHAP PSHA will help the national authorities, public and private institutions, civil emergencies agencies, etc. for urban planning, disaster preparedness, etc.
- However, they should not be considered as national documents for design building codes. Every country, based on the new seismological database (BSHAP catalogue) and the present seismotectonic zones delineation and characterization, the methodology and experience from BSHAP project, as well as the present maps, have to improve the seismic hazard assessment for the relevant territories.

Moreover, the recommended improvements of the seismological and seismotectonic databases are foreseen as:

- Completing the BSHAP catalogue with events $M_W \geq 3.5$ (better for $M_W \geq 3.0$); eliminating of possible inaccuracies; completing of the extended database in format we already have defined and agreed.
- Improving of the BSHAP seismotectonic database (some zones are too small and difficult to estimate reliably the seismicity parameters, especially for the low seismicity areas).
- Identifying and characterization of the large faults in the BSHAP region, which have generated earthquakes with $M_W \geq 6.5$; combining the smoothed gridded seismicity with the fault generated seismic hazard.
- Creating of the strong motion database for the BSHAP area; deriving a GMPE model - more adequate for our region.
6. CONCLUSIONS

NATO SfP Project 983054 (BSHAP) successfully reached all planned goals. Moreover, this Project brought valuable professional experience to all of 14 participating institutions from six countries involved. It greatly improved the spirit of full regional cooperation and strengthened professional and personal relationships in the seismological community of the whole Western Balkan region.

In this Report we presented scientific results – the new generation of probabilistic seismic hazard maps for all the BSHAP Region assessed by implementation of computation methodology based on the spatially smoothed seismicity approach and on a logic tree, to fully characterize the seismic hazard and its associated uncertainties.

The results are expressed in terms of peak horizontal acceleration (PGA) for 95, and 475 years return periods, that correspond to probability of exceedance of 10% in 10 years, and 10% in 50 years, respectively. The assessment has been carried out for rock conditions with average velocity of shear waves $V_S \geq 800$ m/sec in the upper 30 meters of soil section (classified as soil type A according to Eurocode 8 soil definitions). Thus, the presented results are in agreement with the Eurocode 8 standard for seismic zonation and aseismic design. Based on these results, seismic hazard maps that characterize the spatial variability of PGA with probability of exceedance of 10 % in 10 years, and 10% in 50 years, have been estimated.

As the conclusion, we express our confidence that this Project represents a new achievement on the methodology and the practice of seismic hazard assessment in the western Balkan region. The project results set the basis for a modern policy of earthquake risk mitigation in the region. The obtained results can be used by the national and local authorities, as well as the interested organizations and individuals involved in spatial planning and management, earthquake-resistant structure design, etc. We recommend establishment of a new national building code for all these countries, which should reflect the new hazard model. This will ensure the smooth integration of state-of-the-art knowledge and it will respond to changing needs of the user community.

Apart from the seismic hazard maps, the results of BSHAP project provided a significant number of details across the whole of this parameter space of BSHAP, whose content was also assessed in conformity with the seismic potential of these territories.

However, the progress in our understanding of the earthquake process as well as the collection of new data and the development of innovative approaches is far from its end. The dense seismological monitoring network in the region has been just recently established and greatly improved by the contribution of the BSHAP Project. These improvements will also lead to the necessity for further upgrading of these seismic hazard maps, in accordance with new data and new developed methodologies.
7. REFERENCES


[16] Earthquake catalogue for S. R. Croatia (Yugoslavia) and neighbouring regions for the years 1986 and 1987 / D. Herak, S. Cabor // Geofizika, 6, 101–121.


Seismic hazard mapping methodologies / I. D. Gupta // This issue, 2009.


Bulletins of International Seismological Center (ISC), http://www.isc.ac.uk/search/bulletin/index.html

Catalogue of earthquakes in Bosnia and Herzegovina with M=>4 for the period 1386-2007. Republic Hydrometeorological Service Republic of Srpska, Seismological Department


Duni, Ll., Kuka N., Bozo L., Begu E., “An upgrade of the microzonation study for the Centre of Tirana City”, in “Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics”, San Diego, California, May 24-29, 2010.

Duni LL., Kuka Sh., Fundo A., Towards a New Seismic Hazard Assessment of Albania, 14-th European Conference of Earthquake Engineering, 30/08-09/2010, Ohrid, Macedonia.


Glavatovic B. 1985. Seismic hazard map of Montenegro, as a basic component for Physical Plan of Montenegro (in Montenegrian). Seismological Observatory of Montenegro.


Jordanovski, L. (2002). “Prilog B:Katalog na zemljotrecite od P. Makedonia i podracjata do 100 km od granicata clyceni pred 1900 godina, IzVII MSK-64 (Katalog 1)”. Excerpt from the study of seismic zoning of Macedonia, (personal communication).


Mihailov, C. and Panceva, B. (1985). "Distribution of maximum acceleration for the territory of Kosovo".


National Earthquake Catalogue of Republic of Macedonia (Extract), Seismological Observatory Skopje, Faculty of Natural Sciences, University “Ss Cyril and Methodius” Skopje, Republic of Macedonia.

National Earthquake Catalogue for the territory of Montenegro (extract), Montenegro Seismological Observatory, Podgorica, Montenegro.


Romplus - Romanian national earthquake catalogue, Bucharest, Romania.


At the end of the project realization, there are evident the considerable results which already find implementation in regular practice of institutions involved. In addition, broader impacts to communities are expected.

The most distinct among the already implemented results of project is institutional capacity building. Speaking of capacity building BSHAP Project significantly influenced technical capacity improvements of institutions as well as knowledge transfer education and training of professional staff.

- During the course of this Project a significant funds were allocated to upgrade the existing seismic networks. More than 55% of the overall Project budget has been spent on equipment. For an example – the improvement in particular network (measured by number of deployed instruments) depend on previous development stage: the number of weak motion instruments increased by 100% in national seismic network of Bosnia and Herzegovina, approximately by 30% in MSO network, etc. Number of strong motion instruments in Serbia was doubled due to procurement in the framework of BSHAP project and in Albania and Macedonia increased significantly.

- Institutional IT capacities were significantly upgraded. Digital era of seismic instruments posed additional requirements in field of data transmission, acquisition, processing, storage and dissemination. All of these become available through purchase of digitizers, computers and software. Final proof of this implementation is the real – data seismic exchange that is established between participating institutions upon the mutual agreement to sign The Protocol on Multilateral Cooperation in Seismic Data Exchange (June, 2008).

- As the PSHA computation tool which applies the Poisson probability distribution, the OHAZ software was upgraded and implemented in the final hazard assessment.

- Unified GIS database was established using the “MapInfo 9.5” and “Vertical Mapper” software. Along with the software, institutions got the opportunity to learn about GIS, geographical projections, software features and implement it - not only as mapping tool, but importantly – as the tool to compare different data types that geographically refers to the area of interest.

- Trainings, study stays, knowledge exchange, and the purchase of literature led to staff professional development that resulted in publication of scientific papers, presentations and finally improved cooperation with broader scientific community.

- Through publications and printed material and Final conference the new regional hazard maps become broadly available to engineering community, physical and urban planners, disaster prevention institutions, foreign investors. Insurance companies and numerous other subjects interested in seismic hazard and risk analysis.

In respect to expected consequences of project results:

- As the short-term we are planning to make National presentations of project results to interested parties, in charged Ministries and Engineering chambers and raise public awareness to subject of seismic safety and especially of enhancing of Eurocode introduction into engineering practice.

- Since the seismic hazard analysis is the field of investigations we are expecting continuation of cooperation between the participating institutions in this issue as well as on the other already established subjects. Moreover in broadening the cooperation to other questions of seismological investigations but to the questions of seismic risk mitigation as well.
• The long term consequence of this project is the enforcement of obtained hazard maps into national Annexes of seismic zonation and seismic safety technical norm upgrade, as stated in the Project objectives.

Regional research Project “Seismic Hazard Harmonization in Europe” (SHARE) financed in the framework of FP7 Programme was launched in the middle of 2009 and MSO was appointed as the regional partner for the BSHAP Region. All the BSHAP participants were invited by MSO and SHARE to took the role in the SHARE activities.

The collaboration between BSHAP and SHARE was limited by the decision of BSHAP participants of Dubrovnik Meeting (March 2008) not to allow BSHAP earthquake catalogue to be used for any purposes untill the end of the Project. Until now, nobody expressed the interest.

To avoid blacking the BSHAP region in the SHARE seismic hazard maps, MSO prepared a separate regional earthquake catalogue using its own data and all the published catalogue data, as well as additionally realized seismotectonic research and made it available for SHARE, as well as the results of a separate seismotectonic study of the Region.
As a general conclusion related to the realization of the NATO SfP Project “Harmonization of Seismic hazard Maps for the Western Balkan Countries” (BSHAP), it can be shortly noted that besides successfully reached all main goals, for all 14 participating institutions and six countries involved, this Project brought very valuable professional experience, but also it improved greatly a good spirit of full regional cooperation and strengthened professional and personal relationships in the seismological community of the whole western Balkan region.

The NATO SfP Project 983054 was proposed for financing to NATO in the Framework of the Science for Peace Programme by the midst of 2007. Upon the recommendation of the Environmental Security Advisory Panel, and on behalf of the NATO Science for Peace and Security Committee, the project is approved for financing in June 2007.

The indicative granted award to THE BISHAP NATO SfP Project 983054 in summary was 638.000 EUR, or by partner institutions as follow (expressed in EUR):

- Middle East Technical University, Ankara, Turkey 45.000
- Montenegro Seismological Observatory, Podgorica, Montenegro 105.000
- University “St. Cyril and Methodius”, Skopje, FYR Macedonia 97.000
- Seismological Institute, later Institute of GeoSciences, Tirana, Albania 96.000
- Ministry of Civil Affairs, Sarajevo, Bosnia and Herzegovina 100.000
- Seismological Survey of Serbia, Belgrade, Serbia 98.000
- Department of Geophysics, Faculty of Science, University of Zagreb 97.000

The total of 344.000 EUR were spent for purchasing seismic instrumentation and other equipment for the Project purposes, what make 54 % of the total amount awarded. For software purchase, around 20.000 EUR were used and for the stipends of young researchers and training around 30.000 in total for all the countries involved.

Regarding the seismic hazard maps for the western Balkan region, as one of the crucial outputs of the BSHAP Project, we consider that it can be accepted as a basic, but also a significant step towards improving seismic safety and implementing the Eurocodes into national practice of all countries involved in the BSHAP Project.

Nowadays when Euro-Atlantic integrations are the major task for the Balkan region itself, we are aware that achievements reached in the Project gave significant contribution to our national authorities.

The Science for Peace Programme of the NATO provided as with the opportunity and means to realize the significant tasks that we had put in front of us.

This was the suitable framework to cooperate in, easily managed, with clearly stated propositions, but yet flexible enough to understand the specifics of limitations that are outcome of this not-so-widely populated scientific branch. We experienced full understanding for the specific requirements that particular institutions had in respect to choice of - not so numerous manufacturers of seismic equipment.

The cooperation with SfP Office was very efficient and we are thankful for their support during the process of Project proposing as well as during all work on this Project.
After three and half year’s progress and upon the finalization of stated tasks and Project objectives above named institutions would like to express gratitude to NATO Science for Peace Programme for the provided opportunity to accomplish here presented results.

As an additional conclusion, we express our confidence that this Project represents an achievement on the methodology and the practice of seismic hazard assessment of the western Balkan region, and set the basis for a modern policy of earthquake risk mitigation in the region. The obtained results can be used by the national and local authorities, as well as the interested institutions and individuals involved in spatial planning and management, earthquake-resistant structure design, etc. We recommend establishment of a new national building code for all these countries, which should reflect the new hazard model. This will ensure the smooth integration of state-of-the-art knowledge as well as response to changing needs of the user community.

However, the progress in our understanding of the earthquake process as well as the collection of new data and the development of innovative approaches is far from its end. The dense seismological monitoring network in the region has been just recently established and greatly improved by the contribution of the BSHAP Project. These improvements will lead also to the necessity for upgrading these seismic hazard maps, in accordance with new data and new developed methodologies in the meantime.
ANNEX 1: List of Project Co-Directors and key members of the Project teams

A) MONTENEGRO
1. Prof. Branislav Glavatović, PhD, Director of the Seismological Observatory of Montenegro
3. Mr. Velija Šupić, M.S. Geologist, Seismological Observatory of Montenegro
4. Ms. Ljiljana Vučić, B.Sc, Mathematician, Seismological Observatory of Montenegro
5. Mr. Marin Čavelić, BS in Electronics, Seismological Observatory of Montenegro
6. Mr. Vladan Dubljević, MS, Director of the Geological Institute of Montenegro.

B) ALBANIA
1. Prof. Ismail Hoxha, PhD, Institute of Geosciences, Tirana
2. Prof. Neki Kuka, PhD, Mathematician, Institute of Geosciences, Tirana
3. Prof. Llambro Duni, PhD, Seismologist, Institute of Geosciences, Tirana
4. Dr. Rexhep Koçi, PhD, Geologist, Institute of Geosciences, Tirana
5. Dr. Enkela Begu, PhD, GIS & RS specialist, Institute of Geosciences, Tirana
6. Mrs. Irena Ymeti, MSc, GIS & RS specialist, Institute of Geosciences, Tirana
7. Mr. Edmond Dushi, MSc, Seismologist, Institute of Geosciences, Tirana
8. Mr. Rrezart Bozo, MSc in informatics, Institute of Geosciences, Tirana

C) BOSNIA AND HERZEGOVINA
1. Mr. Amer Zoranić, Expert B.S., Ministry of Civil Affairs
2. Mr. Ivan Brlek, Center for Seismology, Federal Meteorological Institute, Sarajevo
3. Mr. Rusmir Gorusanin, sc. assistant, Center for Seismology, Federal Meteorological Institute
4. Prof. Dr. Hazim Hrvatovic, Geological Faculty, Sarajevo
5. Ms. Vesna Sipka, Hydrometeorological Institute of Republic of Srpska, Sector for Seismology
6. Ms. Snjezana Cvijic, BS, Hydrometeorological Institute of Republic of Srpska, Sector for Seismology
7. Mr. Sveto Vrhovac, Electronic eng., Hydrometeorological Institute of Republic of Srpska, Sector for Seismology

D) CROATIA
1. Mr. Vlado Kuk, MS, Faculty of science, Geophysical department
2. Prof. Marijan Herak, PhD, University of Zagreb, Faculty of Science, Dep.of Geophysics
3. Prof. Dr. Davorka Herak, University of Zagreb, Faculty of Science, Dep.of Geophysics
4. Dr. Snježana Markušić, University of Zagreb, Faculty of Science, Dep.of Geophysics
5. Mr. Krešimir Marić, MS, University of Zagreb, Faculty of Science, Dep.of Geophysics
6. Mr. Ivo Allegretti, MS, University of Zagreb, Faculty of Science, Dep.of Geophysics
7. Mr. Ivica Sović MS, University of Zagreb, Faculty of Science, Dep.of Geophysics
8. Mr. Krešimir Kuk BS, University of Zagreb, Faculty of Science, Dep.of Geophysics
9. Ms. Ines Ivančić, BS,University of Zagreb, Faculty of Science, Dep.of Geophysics
10. Dr. Vladimir Golijat, University of Zagreb, Faculty of Science, Department of Geology.

E) MACEDONIA
1. Prof. Mihail Garevski, PhD, Director of the IZIIS-Skopje
2. Prof. Zoran Milutinovic, PhD, IZIIS-Skopje
3. Dr. Snezana Stamatovska, PhD, IZIIS-Skopje
4. Dr. Dragi Dojcinovski, IZIIS-Skopje
5. Mr. Slobodan Micajkov, BS in Informatics, IZIIS-Skopje
6. Dr. Lazo Pekevski, Seismological observatory, PMF, Skopje
7. Ms. Radmila Salic, MS, IZIIS-Skopje
8. Ms. Irena Gjorgjeska, MS, IZIIS-Skopje
9. Mr. Goran Jekic, MS, IZIIS-Skopje.

F) SERBIA
1. Ms. Svetlana Kovacevic, MS, Seismological Survey of Serbia
2. Ms. Slavica Radovanovic, MS, Director of the Seismological Survey of Serbia
3. Mr. Branko Dragicevic, BS, Seismological Survey of Serbia
4. Mr. Vladan Kovacevic, B.Sc., Seismological Survey of Serbia
5. Dr. Miodrag Petrovic, Seismological Survey of Serbia
7. Ms. Branka Veselinovic, BS, Geologist, Seismological Survey of Serbia
8. Mr. Stepa Petrovic Cacic, BS, Geophysicist, Seismological Survey of Serbia
9. Mr. Goran Kronic, BS, Geophysicist, Seismological Survey of Serbia
10. Mr. Dejan Valcic, BS, Electronic engineer, Seismological Survey of Serbia
11. Prof. Mira Petronijevic, PhD, Faculty for Civil Engineering University of Belgrade
12. Prof. Radmila Pavlovic, PhD, Faculty of mining and geology, Department for geology
13. Assist. Prof. Branislav Trivic, PhD, Faculty of mining and geology, Department for geology
14. Sasa Colic, assistant, Faculty of mining and geology, Department for geology.

G) METU - Middle East Technical University (METU), Ankara –Turkey
1. Assoc. Prof. Sinan Akkar, PhD, Middle East Technical University, METU, NPD
2. Prof. Güney Özcebe, PhD, Middle East Technical University, METU, Advisor
3. Assist. Prof. Tolga Yilmaz, PhD, Middle East Technical University, METU.
**ANNEX 2: List of publication resulting from the Project and publications given to the broader society via press of the NATO SfP Project 983054**

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<th>No.</th>
<th>Printed papers and documents (in accordance with the time of publishing)</th>
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<td>List of Presentations to scientific /broader society</td>
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<tr>
<td>1</td>
<td>B. Glavatovic (2007). Harmonization of Seismic Hazard Maps for the Western Balkan Countries – Project Plan Presentation. BSHAP Launching Meeting, Podgorica, Montenegro</td>
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<td>7</td>
<td>J. Mihaljevic (2009). SIP – 983054 Project presentation and SIP Programme opportunities. Workshop “Between equals” on public debate with environmental NGOs organized by Alfa-Net, Ulcinj, Montenegro</td>
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<td>11</td>
<td>B. Glavatovic (2010). Active faults, earthquake and seismic zone data for Montenegro. Regional Meeting WP3 of FP7 SHARE Project “Seismic Hazard Harmonization in Europe”, Podgorica, Montenegro</td>
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<td>12</td>
<td>B. Glavatovic, J. Mihaljevic (2010). Active faults, earthquake and seismic zone data in Montenegro, 14 ECEE, BSHAP Session. Ohrid, Macedonia</td>
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<td>14</td>
<td>J. Mihaljevic (2010). MSO: institution, seismic monitoring, projects, and hazard and risk analyses in Montenegro. The Civil Military Emergency Preparedness (CMEP) Interagency Workshop and Table Top Exercise, Danilovgrad, Montenegro</td>
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<td>16</td>
<td>B. Glavatovic (2010). NATO SPS Opportunities: Experience Through the Balkan Seismic Hazard Project. Budva Conference on NATO’s support to crisis management</td>
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<td>18</td>
<td>J. Mihaljevic (2010) Harmonization of Seismic Hazard Maps for the Western Balkan Countries - Lessons Learned &amp; Results. EUROMED and PPRD South Programme Training Workshop on Earthquakes, Roma, Italy.</td>
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Press review:

**Government of Montenegro announcement related to the visit of NATO SPS officials to Montenegro during BSHAP Project launching:**

During the visit to Montenegro, Dr. Chris de Wispelaere, Director of NATO Science for Peace and Security Programme met Foreign Affair Minister Mr. Milan Rocen.

Minister of Foreign affairs, Mr. Milan Rocen, spoke earlier today to Mr. Chris de Wispelaere, Director of NATO Science for Peace and Security Programme.

Mr. Wispelaere is visiting Montenegro on the occasion of Kick of Meeting of three-year project “Harmonization of Seismic Hazard Maps for The Western Balkan Countries”. Project will realize Montenegro Seismological Observatory in coordination with experts from Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and NATO member countries Turkey, Greece and Slovenia.

Minister Rocen expressed his pleasure with fact that Montenegro is chosen to be the leading country partner in the project of common interest to the region and that it is going to be implemented in partnership with NATO. Emphasizing the importance of regional cooperation he pointed out the significance of this Project to Montenegro.

Minister Rocen uttered the expectations that this Project will further promote the civil-scientific component of North Atlantic Treaty Organization, which is relevant as much as it is the political and military dimension of the Alliance.

Mr. Wispelaere had positively valued the leading role of Montenegro in implementation of this regional project with primary goal to reduce seismic risk. He confirmed the willingness of NATO SIP Programme to closely cooperate with Montenegrin institutions on issues of NATO’s civil-scientific role.

Minister Rocen and Mr. Wispelaere agreed that the common interest of NATO and Montenegro is to foster stability and safety of the region through implementation of similar projects.

"DAN", daily news:

**NATO HELPS AGAINST EARTHQUAKES:**

Montenegro Seismological Observatory had formally announced the start of the of the project «Harmonization of Seismic Hazard Maps for the Western Balkan Countries» that is going to be realized with the support of NATO «Science for Peace and Security Programme». Besides Montenegro Seismological Observatory as the leading partner, a number of referent geophysical and seismological institutions from Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, and Serbia will take part into the project realization. This is the first project that NATO supports on the territory of Montenegro.
Minister of foreign affairs of Montenegro Mr. Milan Rocen along with the NATO «Science for Peace and Security Programme» director Dr. Chris De Wispelaere officially launched the project. –The work of our experts with their NATO colleagues on the project of common interest will contribute to better relations and understanding, exchange of information, adoption of best standards, and in such a way, to stability and security of our countries and to our speedy road to EU and NATO, said Mr. Rocen.

Mr. Chris De Wispelaere pointed out that NATO is not only the military organization. Only a very limited number of people are aware of the fact that NATO has a third dimension, based on Article 2 of the North Atlantic Treaty, which explicitly highlights NATO’s role to develop peaceful and friendly international relations and to promote conditions of stability and well-being. Indeed, implementing this third dimension has resulted in the creation of NATO’s Science Programme, said Mr. De Wispelaere.

The present invitees, among them a substantial number of diplomatic chore, have been also addressed by Mr. Zoran Begovic, deputy minister of internal affairs, as well as by representative of DPPI of Stability Pact for Southern Europe and NATO Project Co-directors Dr. Sinan Akkar from Turkey and Dr. Mihail Garevski from FYR Macedonia.

"Pobjeda", daily news:

FIRST NATO PROJECT IN MONTENEGRO:

Minister of foreign affaires of Montenegro Mr. Milan Rocen, along with the NATO «Science for Peace and Security Programme» director Dr Chris De Wispelaere have launched the three years Project «Harmonization of Seismic Hazard Maps for the Western Balkan Countries». Representatives and experts of this program, representative of Disaster Prevention and Preparedness Initiative for Southern Europe of Stability Pact, Co-directors of Project as well as representatives of diplomatic chore were present at the launching ceremony.

Out of total planed Project budget( 640 000 EUR) more than half will be invested in instruments, 22% in the training and 13% for the workshops. Slovenia will participate with expertise and will also organize the first Project workshop in Ig, Ljubljana.

Minister Rocen emphasized that through this project countries of the region will collaborate with NATO in domain of security and stability – in preparedness and the prevention from earthquake disasters, what may be considered not only as security matter but may have broader economical and political sense. However, realization of this Project represents the another prove of Montenegrin capacities, own commitments to regional and Euro-Atlantic integrations, and also the final proof of our strategic goal of cooperation with NATO – said Minister Rocen.

"DAN", daily news October 3, 2007

NATO’S THIRD DIMENSION

Dr. Chris De Wispelaere said that NATO’s third dimension is based on Article 2 of the North Atlantic Treaty, which explicitly highlights NATO’s role to develop peaceful and friendly international relations and to promote conditions of stability and well-being.

This “third dimension” is not pointed only to the NATO countries but, especially from the beginning of nineties, to partner countries and Mediterranean Dialogue countries. In that way it becomes possible to create the cooperative network of more than fifty nations.
Project director Dr. Branislav Glavatovic emphasized the importance of harmonization of seismic hazard maps in the region, as the quality base to upgrade technical provisions in construction the earthquake resistant buildings. In addition significant improvement in seismic instrumentation that will be achieved as well as the cooperation between referent institutions in the region.

Deputy minister of internal affairs Mr. Zoran Begovic and the head Emergency Management Sector said that planned goals are in the line with the concept of Montenegro.

National Strategy for Emergency Management and that quantification of seismic hazard will lead to seismic risk assessment in the region.

"Vijesti", daily news:

**BETTER EARTHQUAKE PREVENTION:**

The realization of the project «Harmonization of Seismic Hazard Maps for the Western Balkan Countries», with the Montenegro as the leading partner country, should lead to reduction of seismic risk in the region - is what was stated on the official launching of the this project.

Three years activities will be supported by NATO «Science for Peace and Security Programme» wit the goal to present the methodologically improved seismic hazard maps for the region. Establishment of a consistent seismic database and Deployment of new stations for seismic monitoring are other important goals of the Project.

Twelve seismological institutions from the region will participate in the project realization, whose planned budget is 641 900 EUR.

On yesterday's official launching ceremony Minister Milan Rocen said that this project is the another proof of Montenegrin commitment to the Region and to Euro Atlantic integration. NATO «Science for Peace and Security Programme» director Dr Chris De Wispelaere emphasized that NATO realizes and supports important activities that contribute the general security.

Mr. Zoran Begovic, deputy minister of internal affairs, confirmed that Government of Montenegro have shown the adequate treatment of the disaster management issue through implementation of the document Nacional Strategy for Emergency Management as well as with the establishment of Emergency Management Sector And Civil Security in the frame of Ministry of internal affairs.

Project Co-directors Mihail Garevski from FYR Macedonia, pointed out that Project is very important from the stand point of view that EU countries are apt to use unique civil engineering provisions. - Since all of project participating countries tend to join EU, it is very important to establish seismic hazard maps accordingly.

**Monthly magazine "NATO-MONTENEGRO Vijesti" publication**

A special edition of the monthly magazine "NATO-MONTENEGRO Vijesti", published on the beginning of 2008, was devoted to the SIP BSHAP Project, explaining all Project goals and importance for the western Balkan Region on several pages.
Conference "NATO and Youth", Podgorica

On 16 and 17 March 2011 a conference "NATO and Youth - Possibilities for Youth in the framework of NATO" took place at the Faculty of Law in Podgorica.

Conference was organized by NATO CPE and Coordination team for Implementation of Communication Strategy for Euro-Atlantic Integration of Montenegro, Slovenian Embassy in Montenegro and Government of Montenegro.

Speakers at the conference were the representatives of the Republic of Slovenia, Montenegro and NATO Headquarters in Brussels. The aim of the conference was to inform high school and university students, as well as the Montenegrin public on possibilities NATO gives to young people.

Internet presentation of the BSHAP Project

For the purpose of the BSHAP Project visibility, the Web site: www.wbseismicmaps.org was developed and hosted by Montenegro Seismological Observatory, following the NATO SIP recommendations and Project document. Initially, the information about participating institutions, the main Project objectives and approaches, all ongoing and planned activities as well as important documents and news, were published on the website. Over the past three and a half years, the Project progress reports and meetings minutes, workshop presentations, posters and papers were regularly uploaded on the dedicated website pages.

Through the Project website, dissemination of the BSHAP results to the scientific community in order to ensure European-wide visibility of the Project outcomes is accomplished. Also, the new results and several maps of seismic hazard assessment for the Western-Balkan region, as well as final Project report were published on the website.
Some clips of the Web presentation of the BSHAP Project: www.wbseismicmaps.org, consisting of 20 pages.
## ANNEX 3: INVENTORY RECORDS

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