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WHY ARE EARTHQUAKE HAZARD MAPS OF IRAN DIFFERENT?

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ABSTRACT

The Iranian plateau formed by the active tectonics of the Alpine-Himalayan belt, is situated between the Eurasian and Arabian plates. The plateau is considered as one of the most seismically active regions in the world and is faced with different earthquakes each year. Active tectonic conditions, different faults and seismic sources and a large population in earthquake-prone areas makes it necessary to perform more considerations and scientific studies in order to analyze the seismic hazards and risks. Earthquake hazard analysis is a useful tool in seismic hazard mitigation strategies. The first generations of seismic hazard zoning maps in Iran were developed based on the deterministic approach for calculation of maximum intensities (e.g. Neghabat and Liu, 1977; Berberian and Mohajer-Ashjai, 1977; Mohajer-Ashjai and Nowroozi, 1978; Berberian, 1981) and then by using the probabilistic approach for calculation of peak ground accelerations (e.g. Bozorgnia and Mohajer-Ashjai, 1982; Nowroozi and Ahmadi, 1986; Tavakoli and Ghafory-Ashtiany, 1999; Moinfar et al., 2000; Mäntyniemi et al., 2007; Gholipour et al., 2008; Iranian seismic code for buildings, 4th edition in 2012; Zaré, 2012; Hamzehloo et al., 2012; EMME project, 2014; Mousavi-Bafrouei et al., 2014; and Karimiparidari et al, 2014. The scope of this paper is to compare the earthquake hazard models in Iran with special regard to the seismicity and uncertainties. In this respect, the development history and re-evaluation hazard studies in Iran is presented.

Keywords: Seismic Zoning Map; Earthquake; Iran.

1. INTRODUCTION

From seismotectonic point of view, the Iranian Plateau is exposed to high seismic activity (Fig. 1) and is greatly influenced by the continental convergence and active crustal shortening between the African, Arabian and the Indian plates to the NE and northward with respect to the Eurasian plate. Accordingly, the geodetic, seismic and tectonic studies in the region confirm the existence of a complex active tectonic framework with high deformation rates, a part of which expresses in terms of destructive earthquakes with magnitude over 7.0 e.g. the 1909 Silakhor (M_w.7.3), 1930 Salmas (M_w.7.1), 1962 Bou'in-Zahra (M_w.7.1), 1968 Dasht-e-Bayaz (M_w.7.4), 1978 Tabas (M_w.7.4), 1990 Manjil (M_w.7.4),1997 Ghaen (M_w.7.3), 2013 Savaran (M_w.7.8) and 2017 Ezgeleh (M_w.7.3).

Earthquake hazard analysis is a useful tool in seismic hazard mitigation strategies. Reliable seismic hazard studies depend on having a robust earthquake catalog, good knowledge of tectonic conditions and relevant attenuation model applied for the hazard analysis. The better input for hazard analysis results in more reliable the parameters and the seismic hazard assessments. The uncertainties associated with the seismic hazard analysis and level of success of the methodology should be also treated. The scope of this paper is to compare the earthquake hazard models in Iran with special regard to the seismicity and uncertainties. In this respect, the development and re-evaluation of and seismicity parameters and seismic hazard studies in Iran are presented with a special reference to seismicity data and seismic source characteristics as well as uncertainties in methods.

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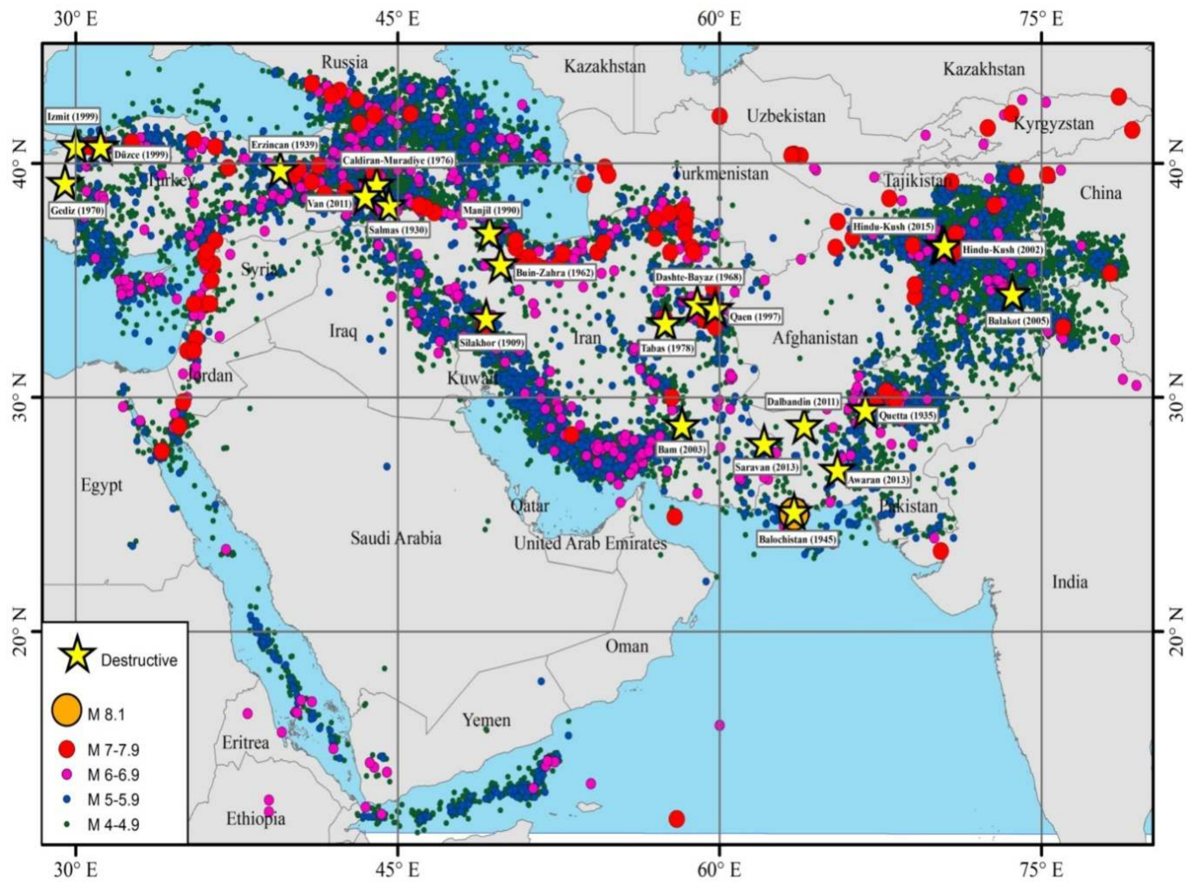


Figure 1. Seismicity map of the Middle East region before declustering represented by epicenters of earthquakes ($4 \leq M_w$). Yellow stars indicate some of the destructive seismic events (with $6.5 \leq M_w$) during the last century. Source of data: EMME earthquake catalogue (Zare et al., 2014).

2. EARTHQUAKE HAZARD MAPS OF IRAN

The seismic hazard zoning maps of Iran have been developed using seismicity and active tectonic data since the mid-1970s. The analysis have been expressed using different seismic parameters. The studies to determine the level of seismic hazard in Iran were established using active fault maps, iso-intensity maps of major earthquakes, seismotectonic map (e.g. Nowroozi, 1976; Berberian, 1976a; Berberian, 1976b; Nogol Sadat, 1993; Ramazi, 1995; Tavakoli, 1996; Mirzaei et al., 1998; Zare and Memarian, 2000; Mojarab et al., 2014) as well as an earthquake catalog of Iran (Ambraseys and Melville, 1982; Berberian, 1994; Moinfar et al, 1994; Mirzaei et al., 1997; Shahvar et al., 2013; Karimiparidari et al.,2013).

Continuous improvement in providing earthquake catalogs, defining seismotectonic provinces and intensities has led to evolution of the hazard analysis. The first generation of seismic hazard maps were developed based on the deterministic approach in terms of maximum intensity levels. Then, by progress in data completion and methods, the probabilistic approaches in terms of peak ground accelerations were proposed (Cornell, 1968; Algermissen et al., 1982). Most of the probabilistic seismic hazard analysis (PSHA) involve several steps as below:

- Definition of the nature and locations of earthquake sources.
- Seismicity and frequency-magnitude relationships for the sources.
- Attenuation of ground motion with distance from the sources.
- Determination of exceedance probability at given sites.

Since mid-70's by 2015, dozens seismic hazard analysis have been carried out for Iran, employing different data and methods (Table 1). In this section, some of the most important seismic hazard zonings in Iran during the last four decades are explained. The trend of such zoning studies started by deterministic approaches, continued by probabilistic approaches and finally is under consideration in terms of spectral zoning maps. It is tried to depict the development history of seismic hazard zoning in Iran which starts from 1977 by Neghabat and Liu and terminates to the last updated version carried out by Karimiparidari et al (2014).

Table 1. Databases, methodology and output parameters used in different earthquake hazard zoning studies of Iran.

M_R= magnitude on the Richter scale; I_{Max}= maximum intensity; I_{obs}= observed intensity; I_{prob}= probable intensity; PGA_i= peak ground acceleration with i-year return period; SA_i= spectral acceleration with i-year return period.

Study	**Year**	**Earthquake Catalog**	**Uncertainty Calculation**	**Hazard Parameter**
Neghabat and Liu	1977	1900-1970; 4.0≤M_R	No	I_{20} - I_{100} - I_{500} - I_{2500}
Berberian and Mohajer-Ashjai	1977	400 BC-1900; 6.0≤ M_R 1900-1977; 3.0≤ M_R	No	I_{Max}
Mohajer-Ashjai and Nowroozi	1978	1900-1977; 5.3≤M	No	I_{obs} , I_{prob}
Berberian	1981	400 BC-1900; 6.0≤ M 1900-1980; 3.0≤ M	No	I_{prob}
Bozorgnia and Mohajer-Ashjai	1982	1900-1981	No	PGA_{20} - PGA_{50}, PGA_{100} - PGA_{150}, PGA_{200} - PGA_{500}, PGA_{1000} - $PGA_{10,000}$
Nowroozi and Ahmadi	1986	1900-1976	No	Mean return periods for several magnitudes, I_{prob}, PGA
Tavakoli and Ghafory-Ashtiany	1999	Pre1900 1900-1997	No	PGA_{75} - PGA_{475}
Mäntyniemi et al.	2007	734 BC-1900; 4.0≤M 1900-2002; 4.0≤M	YES	PGA_{475}
Gholipour et al.	2008	850-1900; 5.5≤ M 1900-2007; 3.5≤ M	YES	PGA_{75} - PGA_{475}, PGA_{1000} - PGA_{2475}, SA_{75} - SA_{475} - SA_{1000}- SA_{2475}
Iranian seismic code for buildings (4th edition)	2012	400 BC-2011; 4.5≤ M	No	PGA_{475}
Zaré	2012	734 BC-1900; 4.0≤M 1900-2012; 4.0≤M	YES	PGA_{475}
Hamzehloo et al.	2012	Pre-1900 1900-2012	No	PGA_{475} - PGA_{2475} SA_{475} - SA_{2475}
Yazdani and Kowsari	2013	700 BC-1900; 5.0≤M_s 1900-2011; 5.0≤M_s	YES	Probability of exceeding a magnitude of 6.5 over 50 and 100 years
EMME project	2014	1250 BC-2006; 4.0≤M_w	YES	PGA_{475}
Karimiparidari	2014	3rd millennium BC-2010; 3.5≤M_w	YES	PGA_{475}

The first generations of seismic hazard zoning maps in Iran were developed based on the deterministic approach for calculation of maximum intensities. In 1977, Neghabat and Liu prepared an earthquake microzonation analysis of Iran. They initially divided the geological area of Iran into four seismic regions including the Zagros folded belt, the Rezaiye-Esfandagheh orogenic belt, the central and southeast Persia and the Alborz ranges. Each of the four regions were divided into several sub-regions as earthquake source zones in order to be analyzed separately. The earthquake database of their analysis comprised of the instrumental mainshocks with Richter magnitude greater or equal to 4, recorded during 1900-1970. Then, the probability of the maximum earthquake intensity for each independent zone was determined based on different statistical and probabilistic relationships such as Gutenberg-Richter reoccurrence relation, arrival rates and attenuation functions and the seismic hazard method developed by Cornell (1968). Finally, by synthesizing the results of the four mentioned geological regions, a general isoseismic contour map was presented for the entire country in terms of the Modified Mercalli intensity corresponding to various return periods of 20, 100, 500 and 2500 years.

In the same year, Berberian and Mohajer-Ashjai (1977), prepared another seismic hazard map of Iran based on the deterministic estimate of the maximum intensity, adding other available data such as historic earthquakes, effects of the major Quaternary and active faults of the country. Their paper presents a deterministic estimate of the maximum intensity levels to be expected in different parts of Iran.

Mohajer-Ashjai and Nowroozi (1978) used thirteen available isoseismal maps of Iranian major earthquakes, reports of historical damages, distribution of moderate and large earthquakes and post Quaternary faults and volcanoes to construct two intensity zoning maps for Iran. The first map was prepared on the basis of observed and calculated intensities in which 5 zones were introduced. The second map consisted of probable intensity zones which were calculated assuming seismic activity of post-Quaternary faults.

Berberian (1981) also depict a seismic hazard zoning map in terms of intensity in which the values were not expressed as the maximum possible intensities but the most probable intensities. Looking at the map reveals that the third zone with maximum intensity covers the region of Quaternary faults and the area associated with past destructive earthquakes.

Up to this time, most of the seismic hazard studies were concentrated on deterministic estimation of the intensity parameter. Since then, by progress in data collection and statistical methods, the probabilistic approach was employed to calculate the probable peak ground accelerations. The PSHA method takes all possible earthquake occurrences and ground motions into account to calculate a combined probability of exceedance that incorporates the relative frequencies of occurrence of different earthquakes and ground-motion characteristics.

The first probabilistic hazard analysis in terms of PGA versus annual risk and return period was carried out by Bozorgnia and Mohajer-Ashjai in 1982. For this purpose, they used a catalog of 2346 recorded instrumental events during 1900-1981 in Iran. they also modeled a total number of 324 seismic sources from which 304 were fault segments and 20 were area sources. They finally presented the probable PGA in 25 major cities of Iran corresponding to 20, 50, 100, 150, 200, 500, 1000 and 10,000 years return periods.

Nowroozi and Ahmadi (1986) also conducted a PSHA for Iran using seismotectonic province model and compiled and statistically treated earthquake data of each province. They first calculated the coefficients of a log-linear and a log-quadratic magnitude frequency relationship and estimated the PGA for a set of return periods and epicentral distances and noted the substantial variations in return periods for a given earthquake magnitude.

Another important seismic hazard zoning for the country has been produced as an attachment of the Iranian seismic code for buildings (known also as the Standard No. 2800). Until now, four editions of the Standard 2800 have been published and updated in 1988, 1999, 2007 and 2012, respectively. All maps have been prepared based on the study on relative seismic hazard zoning using different seismic, tectonic and geology data. Last version of this map was published in 2012 for which a comprehensive study on some disciplines, or revision of some important aspects was carried out. For instance, a new fault map was compiled in the scale of 1:1,000,000 in which 700 faults with over 20 km in length were identified meanwhile magnetic basement lineaments were removed. A refined and updated catalogue of the Iranian earthquakes including historic to 2011 events was compiled with the expertise judgments. On the basis of combination of these updated data, a hazard map was produced which divides the country into four zones with design base accelerations of 0.35g, 0.30g, 0.25g, and 0.20g (Fig. 2-a). The defined zones are rated as very high, high, moderate, and low hazard, respectively. This map indicates that about 70% of the area in the map corresponds to 0.30g (high hazard) zone.

Tavakoli and Ghafouri-Ashtiani (1999) prepared two seismic hazard maps of Iran in the forms of iso-acceleration contour lines and hazard zoning using PSHA method on the basis of three kinds of data: earthquake database, seismotectonic provinces and attenuation relationships. In their study, the computer program SEISRISK III was applied to calculate the PGA. Accordingly, the two mentioned maps (contour lines and zoning) were originally presented on 1:5000000 scale. these maps indicated that the minimum and maximum accelerations ranged from 15% to 48% g. The highest PGA were predicted to be 0.45g and 0.3g for return periods of 475 and 75, respectively, encompassing North Tabriz, North Tehran and Dasht-e-Bayaz fault zones. The lowest PGA were predicted to be less than 0.35g and 0.2g for return periods of 475 and 75, respectively, for a narrow NW-SE band from Urumiyeh to Esfahan and in the Central Lut zone. It is notable that the calculated PGA is corresponding to the maximum horizontal acceleration in bedrock level and the PGA on surface soil level should be then calculated for each region using proper attenuations relations and soil profiles. Their results were then also published in the Global Seismic Hazard Assessment Program (GSHAP, 1999) (Fig. 2-b).

Mäntyniemi et al. (2007) used a new method called "parametric-historic" (Kijko and Graham, 1999) to map PGA, PGV and PGD. This method does not require any definition of seismic sources and/or seismic zones and permits the use of both incompletely reported historical and complete instrumental earthquake catalogs as input data, considering the inherent magnitude errors and uncertainties of earthquake locations. Mäntyniemi et al. (2007) used 3345 earthquake mainshocks on the M_w scale in the time span of 734-2002 which was compiled by Zare (2002). Using the data and employing the Iranian attenuation relationship given by Zare et al (1999), final seismic hazard map was prepared which specified a 10% probability of exeedence of the given horizontal PGA values for an exposure time of 50 years, corresponding to a returm period of 475 years. The soil category of rock and stiff sediments was assumed. The new map does not show such strong elongation of contours as previous works that are based on assumptions of seismotectonic units. In this new one the resulting PGA values are lower than those of previous works which can be resulted from a different methodology.

In 2008, with regard to earthquake hazard mitigation program and retrofitting of structures, infrastructures and lifelines, a new detailed seismic hazard analysis project was proposed by the President Deputy Strategic Planning and Control of Iran. The project was divided into 7 phases for which six different regions of the country containing the Greater Tehran, Alborz, northwestern Iran, eastern Iran, central Iran and south of Zagros were considered for seismic hazard analysis for which their results will be further combined to derive a unique map for the country. Up to now, the first phase of the program (the Greater Tehran) has been published under the consideration of the faculty of engineering, University of Tehran (Gholipour et al, 2008). The next two phases (Khorasan and Azarbaijan regions) are currently being done under consideration of the Geological Survey of Iran. In addition, with respect to significant importance of the plan, the responsibility of monitoring the plan was assigned to the road, housing and urban development research center. In the first phase for the Greater Tehran region, available surface/subsurface geophysical, seismological, geotechnical, geodetic and hydro geological characteristics of the project area was first evaluated. The analysis resulted in preparing a seismic hazard map in which maximum acceleration of an earthquake with a determined occurrence probability is presented. Keeping in mind the different kinds of uncertainties for earthquake size and location and future triggering, the analysis has been performed for events of 2%, 5%, 10% and 50% occurrence probabilities in 50 years and for different soil profiles including 150, 255, 525, 760 and 1070 m/s shear wave velocities. In addition, uniform seismic response spectra and simplified uniform spectra for 475-year and 2475-year return periods were also presented.

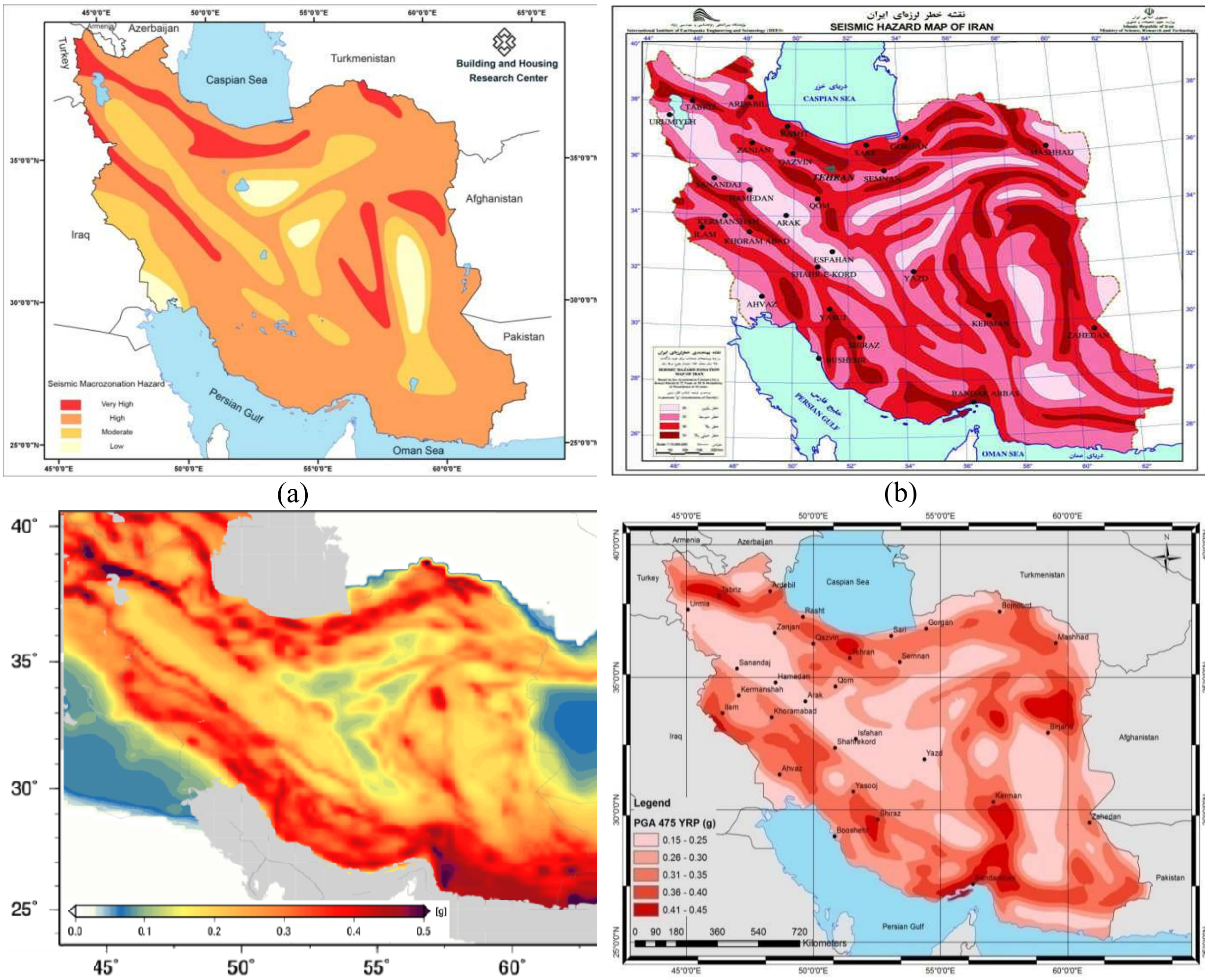
Zare (2012) introduced a new map based on new seismic source determination. The determination of seismic source zones were performed using the up-to-date geophysical and geodetical measurements. The new data showed that the revision in seismic hazard zoning maps in local and regional (nation-wide) scale is necessary. In his study, new map was prepared according to new seismic source data and parametric method.

Hamzehloo et al. (2012) also developed new seismic hazard maps for Iran based on probabilistic earthquake hazard analysis. As the first step, necessary data were provided. The IIEES catalogue, which is based on the reports from International seismological institutes, and reports from Ambreseys and Melville (1982) were used, considering moment magnitude (M_w) in all calculations. In this respect, the authors estimated the seismicity parameters and the return period for different earthquake magnitudes using the Kijko (2000) method which makes it possible to combine the information of the historical part of earthquake catalog with those of the instrumental part. The method is based on assumption of the Poisson occurrence of earthquakes with the activity rate of λ and the doubly truncated Gutenberg- Richter distribution. On the basis of geological and seismological studies, Hamzehloo et al. (2012) found 25 source zones in which seismicity parameters were estimated after omitting foreshocks and aftershocks from the catalogue. In addition, four attenuation relationships (Ghasemi et al., 2009; Boore et al., 1997; Campbell and Bozorgnia, 2003; Abrahamson and Silva, 1997) were also considered. They also presented the disaggregation and uniform hazard plots showing the contribution of hazard for major cities in Iran.

Yazdani and Kowsari (2013), for the first time, used time-independent Bayesian probability method to assess seismic hazard in Iran. The earthquake database they used in the prior estimation contained 140 historical and 495 instrumental events. *"The Bayesian approach was applied to calculate the probability that a certain cut-off magnitude would be exceeded at certain time intervals in different regions of Iran"* (Yazdani and Kowsari, 2013). The results for the cut off magnitude of 6.5 indicated that the highest probability of seismic hazard exists in the Alborz, Kopeh-Dagh, Bandar-Abas, Kerman, and Zagros regions. The seismic hazard was assessed to be lowest for the Esfahan–Sirgan region, the Arabian Platform, the Persian Gulf, and Kavir in Central Iran. Based on their results, the comparison of results between the Bayesian method and previous seismotectonic models of Iran revealed the ability of the Bayesian method to identify seismotectonic provinces based on earthquake data alone.

Recently, a comprehensive earthquake seismic hazard analysis was performed in the framework of EMME (Earthquake Model of the Middle East Region) project (Fig. 2-c). The EMME Project is a regional project of the umbrella GEM (Global Earthquake Model) project. The PSHA approach and the existing source models were revised or modified by the incorporation of newly acquired data. More importantly, the most distinguishing aspect of the EMME project from the previous ones is its dynamic character. This very important characteristic is accomplished by the design of a flexible and scalable database that will permit continuous update, refinement, and analysis. In 2013, a part of the project was finished and new seismic hazard maps were released.

The most recent seismic hazard map of Iran was developed using the most recently comprehensive data and a PSHA approach by Karimiparidari et al. (2014) (Fig. 2-d). In this regard, a homogeneous earthquake catalog of Iran developed by Karimiparidari et al (2013) was used, which includes the Iranian events in terms of uniform moment magnitudes (M_w) with the range of M_W 3.5–7.9 from the 3rd millennium BC to April 2010. Until now, this catalog seems to be the most comprehensive data, since it covers a wide time span of earthquake history and contains of uniform scaled magnitudes. Karimiparidari et al., (2014) used new seismic source models and seismotectonic zoning map of Iran (Karimiparidari et al., 2011). This seismotectonic models were developed based on the latest data of active tectonic, topography, magnetic intensity and seismicity catalog. These new maps divide the area of Iran into 27 seismotectonic zones and demonstrate two models for linear and regional seismic sources. Modification and computation local coefficients of the space-time windows in the well-known window algorithm developed by Gardner and Knopoff (1974), was also performed in the research by Karimiparidari et al., (2014). To modify the space-time windows, the well-documented events of Iranian earthquake catalog in the time period of 1972 to 2008 were used. The data contains 21 different sequences of mainshocks and aftershocks with the magnitude of the mainshocks ranged between Mw 5.4 and 7.1. The updated temporal and spatial windows were applied to the seismic catalog in different seismotectonic zones of Iran. After declustering, the seismic catalogs were found to follow a Poisson distribution in all studied zones based on the results of the statistical Kolmogorov-Smirnov test. The same test on times between successive declustered events shows that the inter-event times of all catalogs follow an exponential distribution. Following the removal of foreshocks and aftershocks, magnitude of completeness of each seismotectonic zone was established for the entire time span of the catalog. They also made a comparison study on available strong motion attenuation relations to select proper models and weight them in a logic tree. In this respect, six attenuation models (including Ghasemi et al., 2009; Zafarani and Soghrat, 2012; Boore and Atkinson, 2008; Akkar and Cagnan, 2010; Ambraseys, 2005) which had the best coincidence to the Iranian data were used to conduct the PSHA. In this respect, for each seismotectonic zone, very lower level of its seismicity was considered as the background seismicity. Frequency of earthquakes was attributed to each zone using the ratio of the uncovered area by sources to the total area of zone. In the following, seismicity parameters were calculated and the probabilistic source-based approach established by Cornell in 1968 was followed by different branches defined in logic tree. Accordingly, a grid network with 0.2*0.2 square kilometers cells in the area of study was taken into account and seismic hazard zoning map of Iran with 475-year return period was prepared using CRISIS2007 software and Kriging interpolate method.



(a) (b)

(c) (d)

Figure 2. Seismic hazard zoning map of Iran in terms of PGA_{475} by (a): Iranian seismic code, 2012; (b): Tavakoli and Ghafouri-Ashtiani, 1999; (c): EMME project, 2014; (d): Karimiparidari et al., 2014.

3. CONCLUSIONS

The seismic hazard zoning maps are developing in Iran using seismicity and active tectonic data since the mid-1970s. During the first years of this four decades, studies mostly focused on deterministic earthquake intensity approaches. By development of strong motion data, attenuation relations and probabilistic methods, probabilistic maximum acceleration approaches were replaced to the deterministic intensity method. Most of the recent seismic hazard analysis studies and projects were conducted based on PSHA method, meanwhile some other mathematical/statistical algorithms were rarely used.

Although the deterministic and probabilistic PGA methods are efficient, some other modern seismic hazard analysis approaches are currently proposed in the world such as spectral analysis, neo-deterministic and realistic acceleration approaches. Some tools have been provided during the 10 recent years such as defining spectral attenuation models by different researches (e.g. Khademi, 2002; Ghodrati Amiri et al., 2007; Zaré et al., 2008; Zafarani et al., 2008; Ghasemi et al., 2009; Sadeghi et al., 2010; Ghodrati Amiri et al., 2010; Bagheri et al., 2011; Saffari et al., 2012; Hamzehloo and Mahood, 2012; Soghrat et al., 2012; Zafarani and Soghrat, 2012; Kale et al., 2015) which may provide new tools for further hazard zone mapping in Iran. There are also some published spectral acceleration hazard maps (e.g. Hamzehloo et al., 2012). The future trend in hazard mapping seems to cover the intensity assessment, realistic acceleration and also the development of site specific hazard analysis for Iran based on the detailed integrated the site characteristics database. It is expected that the further studies to be focused on the new approaches as well as the developing of spectral zoning maps, a new focus on M_{max} assignments and incorporation of seismic historical data in hazardous region having rare instrumental seismicity data.

In addition, after some earthquake (such as the 1978 M_w7.4 Tabas earthquake, 1990 M_w7.3 Majil earthquake and 2003 M_w6.5 Bam earthquake), several questions were raised on the reliability of the seismic hazard zoning maps and on the comparison between the recorded and previously assessed ground motions. Such examples indicate the importance of the accuracy of the input dataset and the level of knowledge of the seismic source parameters in the study regions (fault geometry and mechanics, return periods of large and destructive earthquakes, etc..). Although there are fairly good recorded historic and instrumental data in Iran and good researches on some critical active faults of the Iranian Plateau (e.g. studies on paleoseismic, GPS and seismicity rate of North-Tehran, North Tabriz and Mosha faults by Ritz, 2012, Solaymani Azad et al., 2011 and Solaymani Azad et al., 2014), but more investigation such as paleoseismic investigation and evaluation of seismic capacity of other active faults as well as identification of blind faults are still a matter of concern. In addition, there are still ongoing challenges in hazard analysis such as the detailed evaluation of M_{max} and seismic potential of seismic source, determination of real border of seismic sources, seismicity rates, soil considerations, consistency of seismic gap models with the earthquake data, return periods of large earthquakes, patterns of aftershock sequences, near-filed effects and site effect considerations and etc; All these issues will be the challenges of the future seismic hazard maps. The future trend of such studies seems to cover the followings:

- Comparison and evaluation of the efficiency of the previous hazard maps based on earthquake occurrences;
- Preparation of time-dependent hazard maps;
- Quantifying the existing uncertainties in the data and calculations;
- Intensity assessments for rapid-response purposes;
- Smart updating of maps based on important earthquake occurrences;
- Development of site-specific hazard analysis for Iran based on integrated databases.

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